



WORKSHOP PROCEEDINGS REPORT
**GMOs FOR AFRICAN AGRICULTURE:
CHALLENGES AND OPPORTUNITIES**
JULY 2010



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About the Academy

The Academy of Science of South Africa (ASSAf) was inaugurated in May 1996 in the presence of then President Nelson Mandela, the patron of the launch of the Academy. 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*, 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.



WORKSHOP PROCEEDINGS REPORT
GMOs FOR AFRICAN AGRICULTURE: CHALLENGES AND OPPORTUNITIES

Foreword

This proceedings report is the product of a two-day workshop hosted by the Academy of Science of South Africa (ASSAf) from 17-18 September 2009. ASSAf, in partnership with the Union of the German Academies of Sciences and Humanities, the Network of African Science Academies (NASAC) and the Uganda National Academy of Sciences (UNAS) received funding from the InterAcademy Panel (IAP) to conduct a study on "Genetically Modified Organisms (GMOs): Opportunities and Challenges in Africa".

A planning committee comprising Dr Hennie Groenewald (Chair), Dr Antonio Llobell and Prof. Ed Rybicki from South Africa and Prof. Patrick Rubaihayo from Uganda was established. The committee held its first meeting in June 2009 and decided to focus on agricultural crops within the context of the African continent. The proposed structure for the follow-up scientific workshop was also formulated at this meeting.

The two-day September 2009 scientific workshop was titled "GMOs for African Agriculture: Opportunities and Challenges". Invited experts from seven different African countries (South Africa, Uganda, Kenya, Senegal, Cameroon, Zimbabwe and Mauritius), as well as an expert from the Union of the German Academies of Sciences and Humanities, attended the meeting to address issues concerning GMOs in agriculture.

Papers presented at the workshop included accounts of research being undertaken in Africa on GM technology, and highlighted the opportunities created by GM technology and the many challenges faced in applying this technology to African agriculture. It was noted that the capacity to develop GM technology and to evaluate risks was available. Scientists in African countries were ready to engage in scientific and funding partnerships to develop GM technology, and the basis on which regulatory systems can be developed already exists. However, it was recognised that there are numerous challenges that lie ahead, chief of which are those relating to the commercialisation of GM products and the applications of GM technology in the market place.

It was agreed unanimously by participants at the workshop that the conclusions of the workshop should be brought to the attention of policy-makers across Africa and that this should be done through the production of a concise, colourful and digestible policy-makers' document. The production of the workshop proceedings is the first step in this direction.

This study on GMOs was conducted by ASSAf as a forum study, in which invited experts were assembled to exchange views on a particular topic, and through the presentations and debates were able to draw some conclusions. This particular study was conducted under the umbrella of the ASSAf Committee on Science for Poverty Alleviation, underscoring the potential role of GMOs in food security on the African continent. It is sincerely hoped that this study will assist in the alleviation of poverty in Africa.

I would like to thank the IAP for funding this study and particularly wish to express my thanks to those who assisted in the planning of the workshop and all those who contributed the

papers that comprise this proceedings report. Finally, I wish to thank all the staff of ASSAf, particularly Ms Phakamile Mngadi, for the support given to the committee to enable them to complete this task.

Prof. Robin Crewe

President: Academy of Science of South Africa

Acknowledgements

The Committee on Science for Poverty Alleviation of the Academy of Science of South Africa (ASSAf) wishes to express its appreciation to all the presenters, as well as all the individuals who gave their valuable input. The workshop programme giving the names of all presenters is included as Appendix 2.

The valuable leadership and guidance provided by Dr Hennie Groenewald, Chair of the Committee, is gratefully acknowledged.

Prof. Roseanne Diab, Executive Officer, is thanked for her support.

Beverlie Davies (editor) and Profit Creative are also acknowledged for producing this publication.

The following ASSAf staff are also acknowledged: Mr Takalani Rambau, Liaison Manager, for proposing the project to the InterAcademy Panel (IAP) and securing the funding; Ms Phakamile Mngadi, Projects Officer/Study Director of this Forum and Dr Nthabiseng Taole, Projects Manager for their much-valued contributions during the course of the Forum process and the production of these proceedings.

The support offered by all ASSAf staff and others who contributed to the success of this Forum and the ASSAf publication team for the production of this report are also greatly appreciated.

Finally, the Committee acknowledges the financial support provided by the IAP, as well as that provided by the South African National Department of Science and Technology (DST).

Executive Summary

The production of genetically modified organisms (GMOs) in Africa has the potential to alleviate many problems on the continent – at present, millions of Africans are vulnerable to food insecurity and malnourishment. This is particularly evident in rural areas, where people depend primarily on agriculture for food and income. This report focuses on the potential of biotechnology, through GMOs, to provide solutions to such problems.

Biotechnology is defined as “any technique that uses living organisms or substances from these organisms, to make or modify a product, to improve plants or animals, or to develop microorganisms for specific uses” (Office of Technology Assessment of the United States Congress).

Modern biotechnology has been associated with genetic engineering or genetic modification (GM). Recombinant DNA, or genetic engineering, is a more precise form of biotechnology, allowing a breeder to transfer known, desirable genes into crops, instead of moving large groups of mostly unknown genes into crops, as in most traditional breeding. “genetically modified crops”, often known by the acronym “GM crops”, are usually received with varying emotions worldwide. Nonetheless, GM application, a component of biotechnology, is gradually finding its niche across the globe. Indeed, plant and crop breeders have been using biotechnology to modify the genetic make-up of crops for thousands of years.

African agriculture has for decades been faced by multiple challenges, ranging from low productivity to poor or non-existent markets and infrastructure. There has been a decline in the production of cereals over the past four years, which has been attributed to low-input (i.e. farming based on a reduction of fertilisers, herbicides and insecticides) usage, declining soil fertility, erratic climatic conditions and low government commitment to fund development efforts in the sector. Biotechnology offers a mechanism to increase crop productivity, and as such to contribute towards food security and poverty eradication in Africa.

A decade after GM crops were introduced into the world, their production has grown to about 125 million ha globally. Biotechnology first found its way into Africa through *Bt* maize, which was introduced into South Africa in 2003. Since its introduction, the technology has been found to reduce losses of maize incurred through damage by stem borers. However, there is still a large untapped potential in biotechnology that can be embraced to address Africa's challenges.

Although biotechnology is gradually being embraced across the globe, it nonetheless faces much opposition. Challenges to its adoption include:

- perceptions and attitudes
- access to and use of proprietary technology
- biotechnology policy
- the cost of biotechnology research.

In order to tap into the potential that biotechnology offers to agricultural productivity and food security, there is a need for greater dedication by African governments towards biotechnology development. This can be done by developing their capacity to negotiate access to intellectual property (IP) rights, and to enact and operationalise IP rights and biosafety policies and guidelines that foster technological innovations, delivery and trade.

In **Chapter 1**, the situation with respect to GM crop plants in Germany is investigated. German companies invest large sums of money in plant biotechnology, but much of the research and production is conducted outside Germany due to the hostility of the German public towards GM plants.

The licensing of GM crops for all 27 member states of the European Union (EU) is carried out by the European Council. To date, relatively few products from GM crops have been admitted in the EU for human consumption or fodder and all have to be labelled as GM. It is

noted that in Europe a large proportion of the public is opposed to plant gene technology and that politicians have been influenced by this sentiment.

The activities of the German science academies in conjunction with the InterAcademy Panel (IAP) to counteract the misleading campaigns by GM opponent organisations are explored in this chapter.

The ecological and economic aspects of the cultivation of GM insect-resistant varieties of maize, rice and cotton are summarised, and it is concluded that the growth of these crops by small-scale farmers in developing countries can be beneficial.

Chapter 2 focuses on the role of GMOs in food and nutrition security in Africa. In 2000, the UN adopted the Millennium Development Goals (MDGs), many of which have a direct connection with food security. By definition, food security is achieved when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. Clearly, in the light of this definition, food security poses a major problem for the developing countries of sub-Saharan Africa, where problems of food supply, hunger, under-nutrition and malnutrition exist.

GM technology presents an exciting opportunity to contribute towards the resolution of the African food and nutrition security problem, provided it is carried out within a framework of appropriate biotechnology policy with sufficient financing for human capital development, the construction and equipping of the necessary laboratories and the conducting of rigorously planned, results-oriented GM food research. Research results have shown the possibility of increasing crop yields, improving the storage potential of harvested crops, improving the protein content of starchy foods, biofortification of local foods, and improving the functional potential of local foods.

In **Chapter 3**, some of the opportunities and challenges in the use of GM technology are explored. The use of GM technology and its products is still in its infancy in Africa. South

Africa, which has biosafety regulations in place, is one of the three countries [with Egypt and Burkina Faso] on the continent that are producing commercial GM crops. The GM crops that are produced on a commercial basis have been limited to maize (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), soybean (*Glycine max* L.) and oilseed rape (*Brassica napus* L.). These four crops have been transformed for the two traits of insect resistance and herbicide tolerance. There is a need in Africa also to develop GM crops with other important traits.

One of the very few transgenic crops with virus resistance that has been commercialised is papaya (*Carica papaya* L.). Papaya with resistance to papaya ringspot virus (PRSV) is now grown on a commercial basis by farmers on the Hawaiian islands, where GM technology was used to save the local papaya industry from total collapse due to infection by PRSV. The Hawaiian papaya experience can be used as a model to address the many virus problems that have affected African farming communities for a long time.

Various laboratories across the continent are using GM technology to develop transgenic crops with virus resistance. The first all-African-produced modified plant in the form of transgenic maize with resistance to the maize streak virus (MSV) has been developed. This maize is at present being evaluated under containment. Other projects underway on the continent are also discussed.

As the number of scientists with training in molecular biology, tissue culture and virology increases, there is likely to be a concomitant increase in the number of projects aimed at developing transgenic crops with virus resistance. Against this background, it is concluded that the future for the development of GMOs in Africa looks promising. GM technology in the form of GMO plants with virus resistance could be the key to unlocking the potential of African agriculture by, among other things, addressing and solving the numerous viral disease problems that have hampered the economic production of Africa's major food and commercial crops.

Chapter 4 provides an evidence-based evaluation of the environmental effects of GM crops. Most concerns about GM crops can be categorised as follows: food safety and animal/human health concerns, environmental concerns, agricultural concerns and socio-economic issues.

Some of the studies that have been conducted on potential impacts of insect-resistant and herbicide-tolerant GM crops are highlighted. In order to effectively evaluate GM crops, an acknowledgment of their potential benefits must be made in addition to an evaluation of the potential damage to the environment and human and animal health.

With a large number of GM crops currently under development in Africa it is evident that regulatory authorities in the continent will continue receiving applications for GM trials and/or environmental releases. In order to be able to effectively evaluate these applications, it is imperative that they have access to relevant information and appropriate training.

The application of a multidisciplinary systems biology approach to the evaluation of GM crops is described in **Chapter 5**. The concept of "substantial equivalence" is used to compare GM plants and their non-GM counterparts in terms of changes in gene expression and associated protein and metabolite derivatives as a result of genetic modification. These key compounds have been determined by international standards to form the basis of substantial equivalence. The substantial equivalence approach was adopted by regulatory bodies to ensure that GM plants and foods are as safe and nutritious as their conventional counterparts.

A case study involving the genetic modification of a *Bt* maize cultivar grown in one location over three years (seasons) with its non-GM maize counterpart is presented.

Chapter 6 documents the lessons learned from the commercialisation of a GM potato in South Africa. It is concluded that only larger multi-institutional and multidisciplinary groups stand any chance of success in the commercialisation process and it is noted that the South African authorities appear to be becoming more conservative and less willing to

grant permits. If this is the trend, it may make it more difficult for other African countries to embrace this potentially beneficial technology.

GMOs are produced by one of three methods: recombinant DNA technology, chemical methods, or through nuclear techniques. **Chapter 7** focuses on the use of nuclear techniques in GMO production, noting that they are highly competitive in comparison with non-nuclear technologies, and that huge economic benefits have accrued in other regions through the use of radiation-induced mutations.

An opinion paper on sustainable GMO technologies for African agriculture is presented in **Chapter 8**. Agricultural sustainability usually refers to agronomic sustainability, including aspects such as agronomic practices, productivity and ecological diversity – all factors that should be considered during the risk assessment of a GM crop before it is released commercially. Most GM crops that have been commercialised to date were developed primarily for large-scale farming systems and would, arguably, not impart the same scale of benefits to small-scale and subsistence farmers, typical of developing countries.

Therefore, to allow developing countries to derive the full potential benefits of biotechnology crops, it is proposed that, in addition to the traditional biosafety aspects mentioned above, technology developers should also more carefully consider factors such as the relevance and accessibility of a particular technology to ensure sustainability. Risk assessment and risk management play a critical role in the successful commercialisation of GM crops and should therefore be considered as an integral part of any GM research and development programme. This chapter develops these concepts and presents a risk analysis framework which can be used in an R&D programme to identify, assess and mitigate potential biosafety and other deployment risks.

The sustainability of GMOs usually revolves around their sustainable use in agricultural systems, focusing predominantly on food/feed and environmental safety. Sustainability is therefore often equated with the post-release safety of the GMO, an aspect that is

regulated in all systems and is therefore carefully considered during the development and risk assessment processes. Potential socioeconomic impacts, by contrast, are currently either not regulated in many countries or are considered only at a very late stage of product development. The fact that most of the current commercial GM crops were designed around the needs of specific markets which differ considerably from those in the developing world, and that they were not developed based on locally established priorities and competencies, has resulted in GM products that are unable to deliver positive socioeconomic impacts to many farmers in developing countries.

The sustainable adoption and use of GM technology is also subject to many socioeconomic and practical constraints, which should be considered proactively in *ex ante* sustainability analyses. By integrating sustainability analyses, including biosafety and socioeconomic assessments, into a GMO research and development pipeline, the development of both safe and economically sustainable products could be ensured. Such an approach should also improve the overall efficiency of the innovation system because it will help to ensure the development of safe, relevant and accessible products that are truly sustainable.

The penultimate chapter, **Chapter 9**, recognises that Africa, home to over 900 million people and representing 14% of the world's population, is the only continent where food production *per capita* is decreasing and where hunger and malnutrition afflict at least one in three people. It is the continent that represents by far the biggest challenge in terms of adoption and acceptance of new technologies, and the chapter questions whether agricultural biotechnology can work in Africa.

It is noted that despite the Green Revolution, crop yields in sub-Saharan Africa have hardly changed over the past 40 years and cereal production *per capita* is steadily declining. It is estimated that with current yields, the projected shortfall of cereals will be 88.7 million tons by 2025.

Biotechnology offers considerable opportunity for addressing many of Africa's pressing challenges. Ongoing biotechnology research in Africa focuses largely on attempting to solve local problems associated with food production, health and the environment.

Biotechnology can play a role in increased global crop productivity to improve food, feed and fibre security in sustainable crop production systems that also conserve biodiversity. It can contribute to the alleviation of poverty and hunger, and the augmentation of traditional plant breeding, and can reduce the environmental footprint of agriculture, mitigate climate change, reduce greenhouse gas emissions and contribute to the cost-effective production of biofuel. Agricultural biotechnology is vital for addressing the chronic food shortages in sub-Saharan Africa.

GM technology is employed in only a few African countries, namely South Africa, Zimbabwe, Egypt, Kenya, Burkina Faso, Uganda and Malawi, and to a lesser extent in Mauritius. Of all these countries, only South Africa, Egypt and Burkina Faso have reached the commercialisation stage.

Most countries in Africa have ratified the Cartagena Protocol on Biosafety (CPB) and have received United Nations Environment Programme – Global Environment Facility (UNEP-GEF) assistance to formulate their biosafety frameworks, yet only a few have functioning biosafety legislation that allows field trials of GM products (South Africa, Zimbabwe, Malawi, Kenya, Uganda, Tanzania, Burkina Faso, Ghana, Nigeria, Egypt, Tunisia, Morocco and Mauritania).

With the commercialisation of biotechnology products in other parts of Africa, South Africa is no longer the sole producer of biotechnology products in Africa. However, the country remains the pioneer of the technology and is a role model for the rest of Africa. South Africa is seen as the hub of agricultural biotechnology for Africa as it is one of the few countries in Africa that has a well-developed regulatory system and the expertise to manage the technology. However, South Africa seems to be moving towards stricter legislation, contrary to available scientific evidence.

There is therefore a need in South Africa to ensure that decision-makers who develop policies and amend and enforce the existing legislation and regulations are continually educated and informed on biosafety and biotechnology.

Chapter 10 presents the experience of a technology developer in the regulation of GMO activities in South Africa and concludes with some recommendations.

Challenges are experienced at various levels: in the design of the legislative framework, in the operational procedures and in the authorisations granted. It is recommended that legislative frameworks should be functional, practical and operational, while providing protection of the developer's investment in terms of IP. Application forms should be activity-specific, easily accessible and science-based. Assessment of applications by regulators should be timely, transparent and focused on information that will assist in determining the safety of the proposed activity and product. Concerns, decisions and reasons for decisions should be communicated in a timely fashion and be clearly stated. Conditions should be activity-specific, based on agricultural practice and remain consistent to enable implementation, unless supported by scientific evidence that would necessitate any amendment to the conditions. Applications should be processed within the time periods described in legislative frameworks.

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List of Acronyms

AATF	African Agricultural Technology Foundation
ABNETA	Agricultural Biotechnology Network in Africa
ANOVA	Analysis of Variance
ARC	Agricultural Research Council
BAU	Business as Usual
BBTV	Banana bunchy top virus
BCMN	Bean common mosaic necrosis virus
BCMV	Bean common mosaic virus
Bt	<i>Bacillus thuringiensis</i>
CACGP	Commission on Atmospheric Chemistry and Global Pollution
CBSD	Cassava brown streak virus disease
CMD	Cassava mosaic virus disease
CMV	Cauliflower mosaic virus
CP	Coat protein
CPB	Cartagena Protocol on Biosafety
CRIG	Cocoa Research Institute of Ghana
CSIR	Council for Scientific and Industrial Research (South Africa)
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
CSSV	Cocoa swollen shoot virus
CTV	Citrus tristeza virus
DESA UN	Department of Economic and Social Affairs of the United Nations
DST	Department of Science and Technology (South Africa)
EC	European Commission

LIST OF ACRONYMS

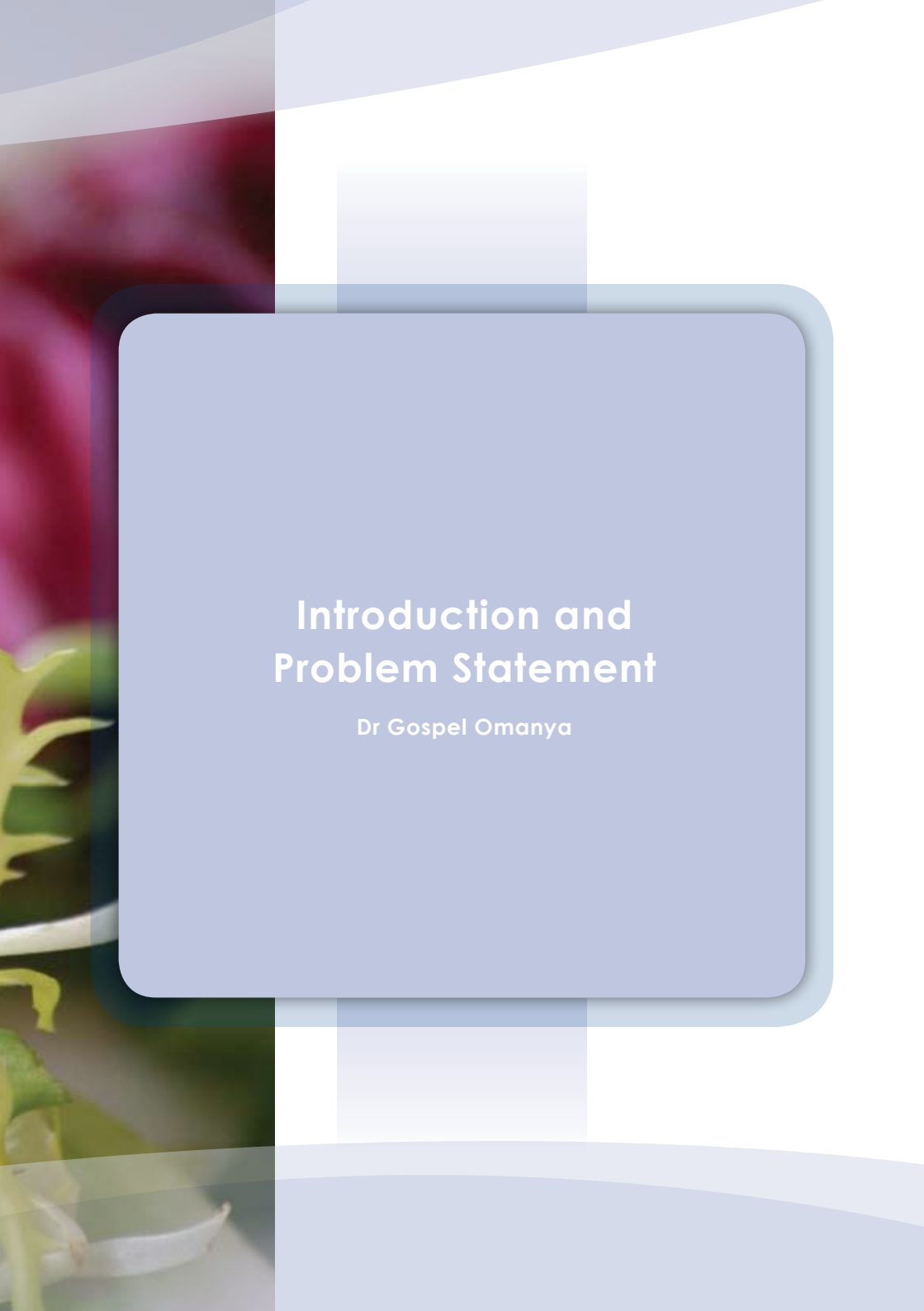
ENSAIC	National Advanced School of Agro-Industrial Sciences
EPA	Environmental Protection Agency (US)
EU	European Union
FAO	Food and Agricultural Organisation of the UN
GAEC	Ghana Atomic Energy Commission
GC-MS	Gas Chromatography–Mass Spectrometry
GM	Genetically modified
GMO	Genetically modified organism
GT	Glyphosate tolerant
HCN	Hydrocyanic acid
HPV	Human papillomaviruses
HT	Herbicide tolerant
IAEA	International Atomic Energy Agency
IAP	InterAcademy Panel
ICGEB	International Centre for Genetic Engineering and Biotechnology
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IEC	Information, Education, Communication
IFPR	International Food Policy Research Institute
IIDMM	Institute of Infectious Disease and Molecular Medicine
IMF	International Monetary Fund
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
IOC	International Ozone Commission
IP	Intellectual property
IPRs	Intellectual Property Rights

IR	Insect resistant
ISAAA	International Service for the Acquisition of Agri-Biotech Applications
KARI	Kenya Agricultural Research Institute
MAS	Marker-assisted selection
MDG	Millennium Development Goals
MSV	Maize streak virus
NARS	National Agricultural Research Services
NASAC	Network of African Science Academies
NMR	Nuclear Magnetic Resonance
OECD	Organisation for Economic Co-operation and Development
PCA	Principal component analysis
PDR	Pathogen-derived resistance
PLRV	Potato leafroll virus
PRSV	Papaya ringspot virus
PTM	Potato tuber moth

LIST OF ACRONYMS

PVX	Potato virus X
PVY	Potato virus Y
R,D&C	Research, development and commercialisation
RR	Roundup Ready
SANGONeT	Southern African NGO Network
SPCSV	Sweet potato chlorotic stunt virus
SPDV	Sweet potato disease virus
SPFMV	Sweet potato feathery mottle virus
TSWV	Tomato spotted wilt virus
UNAS	Uganda National Academy of Sciences
UNEP-GEF	United Nations Environment Programme – Global Environment Facility
WABNet	West African Bioscience Network
WHO	World Health Organisation
WTO	World Trade Organisation
ZYMV	Zucchini yellow mosaic virus



The cover features a light blue rounded rectangle with a subtle drop shadow, centered on a white background. To the left, a vertical strip shows a close-up of a pink flower and green foliage. The title 'Introduction and Problem Statement' is written in a bold, white, sans-serif font within the rectangle. Below the title, the author's name 'Dr Gospel Omanyia' is written in a smaller, white, sans-serif font.

Introduction and Problem Statement

Dr Gospel Omanyia

INTRODUCTION AND PROBLEM STATEMENT

DR GOSPEL OMANYA

African Agricultural Technology Foundation (AATF), Kenya

Introduction

Biotechnology: A Historical Perspective

Biotechnology is "any technique that uses living organisms or substances from these organisms, to make or modify a product, to improve plants or animals, or to develop microorganisms for specific uses" (Office of Technology Assessment of the United States Congress). In this broad sense, plant and crop breeders have been using biotechnology to modify the genetic make-up of crops for thousands of years (McHughen, 2008). In fact, no currently grown crop varieties are "natural", in that all arose from human intervention in moving genes around to create new genetic combinations. A new variety, whether developed using traditional or modern breeding methods, must carry a new combination of genes not present in nature. Modern biotechnology has been associated with genetic engineering or genetic modification (GM). Recombinant DNA, or genetic engineering, is a more precise form of biotechnology, allowing the breeder to transfer known, desirable genes into crops, instead of moving large groups of mostly unknown genes as in most traditional breeding. But the words "genetically modified crops", often known by the acronym "GM crops", are usually received with varying emotions worldwide. Nonetheless, GM application, a component of biotechnology, is gradually finding its niche across the globe.

Incidentally, biotechnology has been with us throughout history, since the domestication of plants around 8000 BC. For instance, brewing, fermentation, bread- and cheese-making and the production of dairy products were some of the earliest forms of applying biotechnology. Groundbreaking work by Mendel in the 1860s laid the foundation for classical plant breeding. This took advantage of natural genetic recombination within

species, an aspect that has been exploited by farmers over the centuries, resulting in superior harvests in successive generations. Later in 1901, it was discovered that the bacterium *Bacillus thuringiensis* (Bt) was able to produce toxins that are lethal to insects but harmless to humans. Furthermore, the discovery of *Agrobacterium tumefaciens* in 1907 offered a unique tool for transfer of the Bt genes to crops, ushering in a new era of gene transfer across plant species, a process that became clearer following Watson and Crick's unravelling of the DNA structure in the 1950s. Biotechnology thus provides a complementary approach to conventional breeding methods.

African agriculture and biotechnologies

African Agriculture: Challenges and Future Prospects

Millions of Africans are vulnerable to food insecurity and malnourishment. This is particularly evident in rural areas, where people primarily depend on agriculture for food and income. However, the agricultural sector on the continent has for decades been faced by myriad challenges, ranging from low productivity to poor or non-existent markets and infrastructure. As shown in Figure 0.1, the yields of cereals in sub-Saharan Africa have stagnated over the last four decades, despite the tremendous growth recorded in other regions of the world. This decline in productivity has been attributed to low-input usage, declining soil fertility, erratic climatic conditions and low government commitment to fund development efforts in the sector.

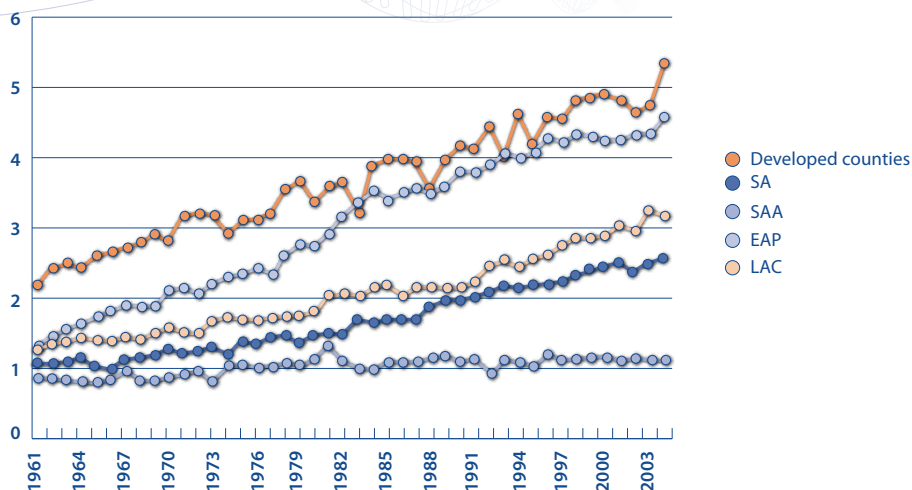


Figure 0.1: Global trends in the yield of cereals (1961–2003)

As a result of the incidence of poverty among small-scale farmers in Africa, it has been difficult for them to purchase adequate inputs, a predicament that further fuels the vicious cycle of poverty. Indeed, Chambers (1983) elaborates that poverty contributes to physical weakness through the lack of food, small physiques, malnutrition leading to a low immune response to infections, and the inability to reach or pay for health services. Furthermore, the climate change predicament is predicted to aggravate the situation considering that only 4% of crop land on the continent has access to irrigation and that 33% of the land is subject to moderate drought. The rise in global food prices has caused a dilemma since government has to spend huge sums of foreign exchange for food imports.

However, as noted by the World Bank (2008), agriculture can work in concert with other sectors to produce faster growth, reduce poverty and sustain the environment. This is because agriculture contributes to development as an economic activity, as a livelihood and as a provider of environmental services, making the sector a unique instrument for

development. However, to achieve this, there is a dire need for renewed efforts towards revitalising agriculture at local and global levels since agricultural productivity growth is synonymous with poverty alleviation. Agriculture can be a main pathway leading out of poverty by making small-scale farming more productive, profitable and sustainable through the establishment of policy instruments that embrace innovation and technology, market reforms and improved linkages between farmers and research.

Biotechnology and Agricultural Development

The debate on the linkage between rural development and biotechnology has been going on for some time. However, the important question has been: "What role can biotechnology play in solving the farm problem and make agriculture work for the poor?" As noted by USAID (2007), agricultural biotechnology offers an additional tool for increasing crop productivity, especially when conventional methods cannot deliver on breeding targets. This offers a great breakthrough in Africa towards advancing even faster towards food security and poverty eradication. A number of studies have been done to assess the impact of GM crops on farm productivity in developing countries (e.g. Huang *et al.*, 2005; Zilberman *et al.*, 2007). There is unanimous agreement that biotechnology is indeed an important tool for increasing farm productivity for the smallholder farm sector. A study by Subramanian and Qaim (2009) provides empirical evidence that production of Bt cotton has direct and spill-over positive socioeconomic effects on all types of rural households through improved yields and increased employment. These important findings point to the role that GM crops can play in solving poverty and development issues.

Status of Biotechnology in the Developing World

A decade after genetically modified crops were introduced into the world, their production has grown to about 125 million ha globally (GMO Compass, 2009). According to the annual report of the International Service for the Acquisition of Agri-Biotech Applications (ISAAA, 2008; Karembu *et al.*, 2009) on the global crop situation, a world total

of 13.3 million farmers used GM crops in 2008, 1.3 million more than in 2007. However, over 90% of these farmers are in developing countries, mainly China, India and the Philippines. Although the developed countries are leading in the production of GM crops, with the US alone accounting for close to 50% (62.5 million ha) of the global area under GM crops, production in the developing countries has also been growing gradually. In 2008, China, Paraguay and South Africa cultivated GM crops on an area of over one million ha, and in the same year, Bolivia, Egypt and Burkina Faso cultivated GM crops for the first time. So far, the Philippines has approved 21 transgenic varieties for food, feeds and processing. These include *Bt* maize, herbicide-tolerant maize, rice, soybean, canola, potato, cotton, sugar beet and alfalfa. India has also approved GM cotton which is at present being cultivated on about 1.5 million ha, with other crops (eggplant, rice, cauliflower, tomato, okra, potato and mustard) under trial for potential release. China has about 3.3 million ha under GM crop production – the Chinese government has committed vast resources (US\$1.4 billion) for development of agricultural biotechnology, and has established more than 100 biotechnology laboratories, signifying intent and commitment by the country to use biotechnology to address its food security challenge. Two Latin American countries, Argentina and Brazil, are following the global giant in GM crop production with 21.0 and 18.5 million ha respectively, mainly *Bt* maize and Roundup Ready soybean. Other countries producing GM crops (*Bt* cotton, *Bt* maize and Roundup Ready soybean) in the region are Paraguay, Bolivia and Uruguay.

However, despite the fact that Africa is the only continent whose *per capita* food production has been declining, biotechnology has been adopted on a very cautious basis. By 2007, only the Republic of South Africa had benefited from the commercialisation of GM crops. However, in 2008, two more countries, Egypt and Burkina Faso, joined South Africa. As Africa gradually embraces innovative techniques, the development and implementation of biosafety policies and laws will be key in guiding the commercialisation and use of biotech products.

Current Biotechnology Solutions in Africa

Biotechnology found its way into Africa through *Bt* maize introduced into South Africa in 2003. Since its introduction, the technology has been found to reduce losses of maize incurred through damage by stem borers (Wanyama *et al.*, 2004). James (2008) reports that GM maize in South Africa offers a grain yield advantage of 11% and increased revenue of US\$35 per ha. In Burkina Faso, *Bt* cotton was commercialised in 2008, making this the third African country to commercialise GM crops after South Africa and Egypt (Kerumbu *et al.*, 2009). It was reported that the technology has produced 15% higher yields and that insecticide sprays have been reduced by two thirds, hence reducing labour costs and environmental pollution. Vitale *et al.* (2008) further reports that 15 102 ha were planted for cotton seed production in 2008 and this could result in 163 265 ha of *Bt* cotton in 2009 in Burkina Faso. In North Africa, Egypt has several GM crops under field trials, including maize, melon, potato, wheat and sugar cane (Mansul, 2005). However, the country is yet to enact a biosafety law even though some of the tested crops (potato, squash, maize and cotton) are approaching commercialisation.

Potential Biotechnology Solutions in Africa

As mentioned earlier, a number of biotechnological successes such as *Bt* maize in South Africa and *Bt* cotton in Burkina Faso are beginning to benefit farmers in Africa. However, there is still a large untapped potential in biotechnology that can be embraced to address Africa's challenges. In recognition of these potentials, the African Agricultural Technology Foundation (AATF), an international not-for-profit organisation, is leading several public-private partnerships to access, develop and deliver various technologies and products to resource-poor farmers in Africa. These include herbicide-tolerant maize varieties for *Striga* weed control, cowpea varieties with resistance to Maruca pod borers, drought-tolerant maize varieties, banana varieties resistant to bacterial wilt, rice varieties with better productivity under saline and low soil nitrogen, and reduction of aflatoxin contamination in maize grains.

Challenges and future perspectives

Challenges to the Use of GM Crops in Africa

While biotechnology is gradually being embraced across continents, it nonetheless faces challenges to its adoption. Such challenges may be founded on perceptions and attitudes which vary depending on the level of information and knowledge of stakeholders.

Perceptions and attitudes

A number of perception and attitude issues have been raised about GM crops by several stakeholders, including environmental activists. These groups have raised concerns over the potential effects of GM crops on human health. Human health concerns have been raised over food safety aspects associated with allergenicity, toxicity, horizontal transfer, antibiotic resistance and changed nutrient levels. Concerns have also been raised over the effect of GM crop production on the environment, especially their impacts on non-targets, crop-to-weed gene flow and pest resistance build-up. It is important to note that biotech products actually undergo intense safety tests to minimise any negative effects, if any.

Access and use of proprietary technology

New technologies, particularly biotechnology, are increasingly coming with intellectual property protection. This may promote private sector research and development, but it may also impose higher royalty fees that could spill over into product prices that outpace the particularly resource-poor farmers in Africa. Fortunately, institutions such as the AATF have the prime mission of negotiating for royalty-free access to proprietary technology such that end-products are affordable to small-scale farmers in Africa. In delivering its products, the AATF facilitates stewardship to ensure responsible and sustainable use for long-term benefits.

Biotechnology policy

Although there have been success stories about biosafety legislation in Africa, progress has been a bit slow, with only seven countries (Burkina Faso, Mali, Mauritius, South Africa, Sudan, Zimbabwe, Kenya) having developed functional national biosafety frameworks. A further 13 countries (Ethiopia, Ghana, Madagascar, Malawi, Mozambique, Namibia, Nigeria, Rwanda, Senegal, Uganda, Tanzania, Zambia, and Egypt) are at various stages in the development of biosafety policies and laws. Apparently the raging debate on GM crops has sent mixed signals, hence influencing decision-making at policy level and slowing progress.

The cost of biotechnology research

The cost of biotechnology research has been prohibitive and this has been a major challenge in African countries, considering that most of them have minimal budget allocations for agricultural research and development. According to Kalaitzandonakes *et al.* (2007), the cost of regulatory compliance for *Bt* maize ranges between US\$7 million and US\$15 million over and above the development cost. Therefore this requirement for huge investments has been a key drawback in the progress towards breakthroughs in biotechnology research and development.

Policy implications and future perspectives

From the foregoing discussion, it is apparent that the adoption of new agricultural technologies, including biotechnologies, will play an important role in closing the current harvest gap in African agriculture and in helping African farmers to cope with the impact of climate change. GM also offers an opportunity to move faster in addressing food security and poverty challenges among Africa's households. Meanwhile, the increasing trend of Intellectual Property Rights (IPRs) in agricultural research will most likely continue.

To tap into the potential that biotechnology offers to agricultural productivity and food security, there is a need for renewed dedication by African governments towards

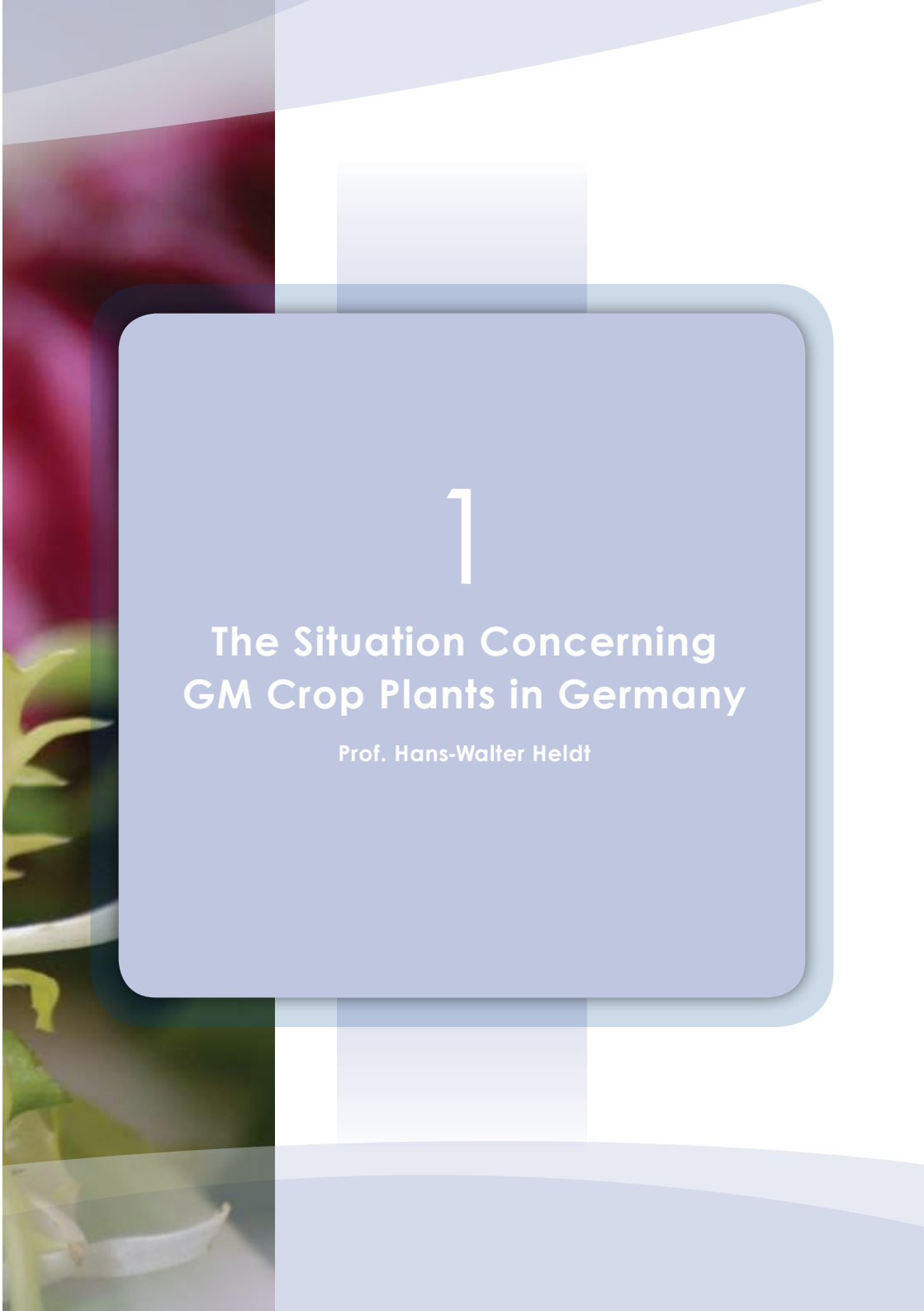
biotechnology development. This can be done by developing their capacity to negotiate access to IP, enact and operationalise IP and biosafety policies and guidelines that foster technological innovations, delivery and trade. It is essential for African countries to understand the importance of minimising the cost of regulations in order to maximise the benefits from biotechnology because positions taken by other regions may not necessarily be suited to Africa. Furthermore, there is need for sound stewardship that will ensure responsible and sustainable use of biotechnologies while minimising any risks.

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1

The Situation Concerning GM Crop Plants in Germany

Prof. Hans-Walter Heldt

THE SITUATION CONCERNING GM CROP PLANTS IN GERMANY

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1 Plant research in Germany

In Germany, experimental plant research has a long tradition. The first publication on a transgenic plant was by Jeff Schell's group at the Max Planck Institute for Plant Breeding Research in Cologne together with the group of Marc van Montagu in Gent, Belgium (De Block *et al.*, 1984). At present, a large number of institutions in Germany are engaged in experimental plant research, examples of which are given below. This list, which is far from complete, includes large research institutes with up to several hundred staff members and research groups at universities. The research institutes, as well as universities, carry out primarily basic research, which is in many cases related to biotechnical applications.

1.1 The Max Planck Society

The Max Planck Society for the Advancement of Science is an independent, non-profit organisation that promotes basic research. With about 80 institutes, it supports promising research activities in life sciences, natural sciences and humanities that require personnel and equipment expenditures that universities cannot afford.

- (a) **Max Planck Institute for Molecular Plant Physiology**, Potsdam-Golm (Prof. Ralph Bock, Prof. Mark Stitt, Prof. Lothar Willmitzer). From genome structure to genome function, network analyses, genetic diversity, phenotyping, data mining and biomodelling and biotechnology.
- (b) **Max Planck Institute for Plant Breeding Research**, Cologne (Prof. George Coupland, Prof. Maarten Koorneef, Prof. Paul Schulze-Leffert). Plant developmental biology, plant breeding and genetics, plant microbe interactions.

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- (c) **Max Planck Institute for Chemical Ecology**, Jena (Prof. Ian T. Baldwin, Prof. Wilhelm Boland, Prof. Jonathan Gershenzon). Molecular ecology, plant defense mechanisms, metabolism of secondary plant compounds.

1.2 The Leibniz Association

The Leibniz Association is the umbrella organisation for 86 institutions conducting research or providing scientific infrastructure. They conduct strategic theme-based research with an interdisciplinary approach.

- (a) **Leibniz-Institute of Plant Genetics and Crop Plant Research (IPK)**, Gatersleben (Prof. Andreas Graner, Dr Winfried Weschke, Dr Helmut Baeumlein, Dr Udo Conrad, Dr Lothar Altschmied, Prof. Falk Schreiber, Dr Mario Gils, Prof. Nicolaus van Wieren, Dr Michael Melzer).

Gene bank with 148 000 accessions from 3 049 plant species and 801 genera, and herbarium with 390 000 samples. Seed development, gene regulation, phyto-antibodies, expression mapping, plant bioinformatics, hybrid wheat, molecular engineering, molecular farming, elucidation of genes regulated by biotic and abiotic stress, structural cell biology.

- (b) **Leibniz-Institute of Plant Biochemistry**, Halle (Prof. Steffen Abel, Prof. Dierk Scheel, Prof. Ludger Wesjohann). Molecular signal processing, stress and developmental biology, bioorganic chemistry of natural products from plants and fungi.
- (c) **Institute for Biosafety of Genetically Modified Plants**, Quedlinburg and Brunswick (Prof. Joachim Schiemann). Risk assessment and monitoring of GM organisms and co-existence of cultivation systems with and without GM plants, investigation of possible effects of GM plants on nature and sustainable agriculture. The institute gives advice to the government on the safety aspects of gene technology.

1.3 University of Bielefeld

- (a) **Department of Genetics** (Prof. Alfred Puehler). Research to indentify genes from plants and microorganisms responsible for relevant biological phenomena, e.g. symbiotic nitrogen fixation. Biological safety research analyses of the potential and probabilities of a putative horizontal gene transfer in natural habitats.
- (b) **Department of Biochemistry and Physiology of Plants** (Prof. Karl-Josef Dietz). Analysis of protein structure and function (peroxiredoxins, V-ATPase), salt adaption and tolerance, heavy metal tolerance.

1.4 University of Cologne

Botanical Institute II (Prof. Ulf Ingo Flügge). Molecular plant physiology (chloroplast translocators). Plant membrane database, improved antioxidant content for food applications, European Arabidopsis stock centre (Tamara).

1.5 University of Düsseldorf

- (a) **Department of Developmental and Molecular Biology of Plants** (Prof. Peter Westhoff). Genetic analysis of chloroplast differentiation, molecular basis and evolution of C4 photosynthesis.
- (b) **Department of Plant Biochemistry** (Prof. Andreas Paul Weber, Prof. Peter Jahns). Systems biology and biochemistry of intracellular transport processes in plants, photo-oxidative stress in plants.

1.6 University of Erlangen

- (a) **Department of Molecular Plant Physiology** (Prof. Norbert Sauer). Multiple aspects of transport through plasmodesmata, long-distance assimilate allocation between tissues and organs, and cell-to-cell signalling in plants.

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- (b) **Department of Biochemistry** (Prof. Uwe Sonnewald). Molecular plant biochemistry and physiology (photosynthetic carbon fixation and its use for primary and secondary metabolites). Plant biotechnology (plant-made vaccines and antibodies, improved food and feed sources with reduced allergenic potential and increased nutritional value).

1.7 University of Freiburg

Department of Plant Biotechnology (Prof. Ralf Reski). Production of pharmaceutically relevant proteins by transgenic *Physcomitrella* grown in bioreactors.

1.8 University of Göttingen

- (a) **Department of International Food Economics and Rural Development** (Prof. Matin Qaim). Role of agricultural biotechnology for rural development, e.g. poverty and welfare in India, socioeconomic impacts of banana tissue cultures in East Africa.
- (b) **Department of Tropical Plant Cultivation** (Prof. H. Thiessen). Biogeochemical determinants of land-cover change and land use in savanna cultivation grazing systems.
- (c) **Department of Molecular Phytopathology and Mycotoxin Research** (Prof. Petr. Karlovsky). Role of secondary metabolites in biotic interactions between plants and fungi.
- (d) **Department of Biochemistry** (Prof. Ivo Feussner). Role of oxilipins in plant development and stress response, production of unusual fatty acids in crop plants for industrial purposes.
- (e) **Department of Plant Molecular Biology and Physiology** (Prof. Christiane Gatz). Regulation of gene expression in response to xenobiotic stress.

1.9 University of Heidelberg

- (a) **Department of Plant Cell Biology** (Prof. David G. Robinson). Intracellular protein transfer in plant cells (e.g. vesicle-mediated).
- (b) **Department of Plant Molecular Physiology** (Prof. Thomas Rausch). Molecular mechanisms by which crop plants counter the effects of abiotic and biotic stress exposure, development of genetic markers for breeding stress-resistant crop plants.

1.10 University Hohenheim

Department of Plant Production and Agro Ecology in the Tropics and Subtropics (Prof. Joachim Sauerborn, Prof. Folkard Asch, Prof. Georg Cadisch). Plant production in the tropics and subtropics, crop water stress management, development of sustainable agricultural production systems, generation of fungal disease-resistant crops.

1.11 University of Potsdam

- (a) **Department of Molecular Biology** (Prof. Bernd Mueller-Roeber). Plant genome research, biomolecular technologies.
- (b) **Department of Plant Physiology** (Prof. Martin Steup). Various aspects of starch metabolism.

1.12 University of Rostock

- (a) **Department of Biochemistry** (Prof. Birgit Piechulla). Floral scent synthesis and emission, molecular basis of chronobiology of plants.
- (b) **Department of Plant Physiology** (Prof. Hermann Bauwe). Investigation of the process of photorespiration at the molecular level.

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German companies invest large sums in plant biotechnology. BASF Plant, among other projects, carries out research on the development of drought-tolerant crops, protection of plants against the fungus *Phytophthora*, generation of canola traits with healthy long-chain omega-3 fatty acids and starch for industrial use in potato (AMFLORA). Bayer Crop Science is working on the generation of genetically modified rice, cotton, maize, canola and soybean. KWS Saat AG has developed herbicide-resistant sugar beet, and is involved in the generation of large-size maize plants for biogas production. Unfortunately much of the research and production of the above companies is being done outside Germany due to the hostility of the public in Germany towards GM plants.

2 Licensing of GM crops in Europe for human consumption and fodder and for cultivation

The licensing for all countries of the European Union is carried out by the European Council. After an assessment of the safety of the environment and consumption by the European Food Safety Authority, the assessment has to be approved by a qualified majority vote of the European Council for Agriculture and Fisheries. The different European Councils each represent 27 member countries. The bigger the country's population, the more votes it has, but the number is weighted in favour of the less populous countries. A qualified majority is reached if a majority of member states approves, and there is a minimum of 74% of the votes and the votes in favour represent at least 62% of the total population of the European Union.

Obviously, the hurdle for any agreement is very high. This explains how until now only relatively few products from GM crops have been admitted in the European Union for *human consumption or fodder* as listed below. It should be noted that this licensing does not include cultivation in Europe.

3 GM crop products admitted in Europe

- **Maize:** 11 traits, herbicide and insect resistance (Syngenta, Monsanto, Pioneer)
- **Canola:** 4 traits, herbicide resistance, male sterility (Bayer Crop Science, Monsanto)
- **Soybeans:** 2 traits, herbicide resistance (Bayer Crop Science, Monsanto)
- **Sugar beet:** 1 trait, herbicide resistance (KWS Saat, Monsanto)
- **Cotton:** 6 traits, herbicide and insect resistance (Monsanto, Bayer Crop Science)
- **Carnation flowers:** 4 traits, altered colour of flowers, durability (Florigene Ltd)

In Europe the rule is that products from GM crops have to be labelled. If food or fodder contains more than 0.9% of a GM product, or if 0.9% of a product derived from GM material was involved in producing it, then the label must say so. This applies to food in the supermarket as well as food served in restaurants. It has the effect that GM products are not used in restaurants as they would have to be marked on the menu card. The products are practically unsaleable in supermarkets. If labelled products were to appear on the shelves, activists from Greenpeace and other GM opponents would turn up and make such a fuss that the shopkeepers would not put up with it. Thus, in reality the consumer has no choice.

When licensed GM products are used as fodder, the resulting animal products do not have to be labelled according to the European rules. Since animal farmers are largely dependent on imported soybean and maize as fodder, GM products are frequently fed to the animals. This has raised protests of GM opponents in Germany with the result that in Germany the label "Without Gene Technology" has been recently created for animal products not containing GM fodder. It remains to be seen to what extent this label will actually appear on products on the shelves of supermarkets.

In several European countries, due to misinformation campaigns of GM opponents such as Greenpeace, large parts of the public are against plant gene technology, and as

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the leading politicians of these countries follow this sentiment, it is often very difficult to obtain a qualified majority for the admission of a GM trait in the European Council. To give an example: the safety of maize MON 88017 as food or fodder was approved by the European Food Safety Authority, but it failed a qualified majority for its licensing in the European Council of Agriculture. This had severe consequences: shiploads of shredded soybean had to be returned since they contained traces far below 0.1% of the maize MON 88017 as contaminant. Since the Council has until now not agreed on threshold values for permissible contaminations, due to the sensitivities of modern analysis techniques, even traces of dust from unlicensed GM traits are enough for a rejection. This creates great difficulties in the fodder industry.

Licensing for the *cultivation* of GM crops is extremely difficult. In 2003, BASF generated, in cooperation with the Max Planck Institute in Potsdam, a potato with uniform starch (amylopectin) for industrial use (AMFLORA). Numerous studies gave convincing evidence that growing of AMFLORA was safe for the environment and it was approved by the European Food Safety Authority as safe for human consumption in case these potatoes were eaten by mistake. The commercial cultivation of the potato was planned for 2007. Until now the European Commission has still not given its approval. So far only a single GM trait, namely the maize MON 810 containing a *Bt* protein for protection against the corn borer, has been admitted in Europe, and for about ten years has been grown successfully in Spain and also in a very few places in Germany. There is a provision that member governments are allowed to ban the cultivation of a GM crop licensed in Europe if there is an immediate danger. For the sake of popularity, governments of some member states, including Germany, used this provision to ban the cultivation of MON 810 based on dubious publications which have been debunked by experts.

In a country such as Germany, the problem with GM products is that the consumer derives no benefit from consuming them, since food prices are low anyway. Also there is no pressing need for the large majority of German farmers to cultivate the insect- and

herbicide-resistant crop plants currently available. On the other hand, people are very conscious about the quality of their food, and many are willing to pay much higher prices for food if it is labelled "organic" despite the fact that it has never been proved that "organic" food is healthier than conventional food. Organisations of GM opponents exploit this sentiment to seek donations by worrying the public with unfounded allegations that the consumption of GM food is a health hazard. Professionally organised campaigns, in particular by Greenpeace, have been very successful in convincing the majority of the public of this, and the politicians, when making decisions, just follow this sentiment.

4 Activities of German Academies in conjunction with the InterAcademy Panel (IAP) to counteract the misleading campaigns by GM opponent organisations

The Union of German Academies of Sciences and Humanities adopted a programme funded by the IAP on the prospects of GM crops for sustaining the food supply for the growing populations of developing countries (IAP GMO Initiative on Genetically Modified Plants). The programme aimed at counteracting the false arguments of environmental activists against Green Biotechnology by forming a panel of experts to collect scientifically based arguments. Texts were to be produced and presented in a simple manner in order to attract the attention of decision-makers and the media. A Commission of Green Biotechnology of the Union of German Academies produced two draft reports and a statement which were the basis for extensive discussions at an International Workshop on GM Crops held in Berlin in May 2006. The panel of international experts at this workshop (the participant from South Africa was Prof. Jocelyn Webster from AfricaBIO) passed, by subsequent correspondence, the reports *Are there hazards for the consumer from eating GM food?* and *GM insect-resistant crops with regard to developing countries*, which were both adopted as official documents of the IAP. Moreover, a statement on GM crops in developing countries was passed. A summary of the findings of these documents, being relevant to the present workshop, is therefore given below.

4.1 Commission of Green Biotechnology of the Union of German Academies and an International Workshop on GM Crops held in Berlin in May 2006

(a) Are there health hazards for the consumer from eating genetically modified food?

Based on the published scientific literature, this report examines the potential hazards and risks of consuming genetically modified (GM) plant products. Toxicity, carcinogenicity and food allergenicity, and the possible effects of consuming foreign DNA (including antibiotic-resistant genes) are all taken into account. The report concludes that food derived from GM plants approved by the EU and the US poses no risks greater than those from the corresponding "conventional" food. On the contrary, in some cases food from GM plants appears to be superior with respect to health.

Probably no discovery in plant sciences has had, in so short a time, such far-reaching consequences on agriculture as the method reported in 1983 for the genetic modification of plants using gene technology. In 2005, such genetically modified varieties comprised 60% of global soybean cultivation, 14% of maize, 28% of cotton and 18% of rape seed; between 2003 and 2005 the overall increase of the area worldwide given over to GM crops was 33%. This clearly demonstrates that the application of gene technology in agriculture has been economically very successful.

Genetic modifications to crop plants have so far focused primarily on the production of herbicide-tolerant varieties for minimising harvest losses due to weeds, and the generation of insect-resistant varieties to decrease losses from insect damage. More recent developments are directed at protection against viral and fungal infections, the enhancement of tolerance towards drought and salinity, the formation of male sterile plants for the generation of productive hybrids, and the improvement of the

nutritional quality of crop plants, for example by modifying the fatty acid composition in oil seeds.

The campaigns of opponents of agricultural biotechnology have deliberately provoked widespread public anxiety by asserting that food from GMOs is a health hazard. "Organic" products are advertised as free from GMOs, thus claiming that they are especially healthy. The slightest trace of GMOs in "organic" products as a result of cross-pollination is termed "genetic pollution"; in some countries it may justify a claim for damages.

(b) Does the consumption of food from GM plants really involve a health hazard for the consumer?

This report bases its findings on reliable and attributed data. Thus, in marked contrast to the claims made by opponents of these foods, all the information used is derived from publications in peer-reviewed scientific journals in which contributions are reviewed anonymously by experts in the field. The interests of the consumer are protected by very rigorous licensing procedures based on scientifically robust protocols as laid down by national and international organisations, including the Food and Agricultural Organisation of the United Nations (FAO), the Organisation for Economic Co-operation and Development (OECD) and the EU. These regulations are much stricter than those required for conventionally grown food *which normally receive no formal testing whatsoever from a health perspective*. Moreover, in the EU it is now obligatory that all food ingredients from GM plants are so labelled if they exceed a threshold content of 0.9% for each ingredient.

In principle, no absolute guarantee can ever be offered for the safety of any food, whether produced conventionally or from GM plants. It is common knowledge that conventionally produced food can be the cause of allergies in predisposed persons; nuts (and particularly peanuts), strawberries, shellfish and wheat are

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all familiar examples. Foods of plant origin often contain toxic or carcinogenic substances; nature has provided plants with a large arsenal of defensive substances as protection against damage from feeding insects or from bacterial and fungal infections. Moreover, plant products may be contaminated by fungal toxins, a number of which are strongly carcinogenic; *Fusaria* toxins, which often pollute wheat and maize (even when grown "organically"), are examples. It has been estimated that in industrial countries most of the carcinogenic substances ingested derive from "natural" plant food.

Since absolute safety is never possible, the basis for approving GM food products is the failure – after extensive prescribed testing – to find any adverse indicators. Such tests show that these foods are at least as safe and nutritious as the corresponding products from conventionally produced crops.

This paper addresses in more detail some conceivable risks of consuming GMOs or products containing them. Note has been taken in particular of the very detailed GM Science Review of the Royal Society (First Report 2003, Second Report 2004), compiled by a panel of 28 distinguished scientists from various disciplines, a report from the Food Standard Agency (UK) and the Symposium of Green Biotechnology of the Union of the German Academies (2002).

- (c) Is it possible that some or all GM foods are more toxic or carcinogenic than conventionally grown food, either directly because of the new gene product itself or from unexpected effects of the new inserted gene(s) causing damage to one or more existing genes?**

It must be stressed that in conventional breeding seeds have for long been treated with mutagenic chemicals or high-energy radiation (Y-rays from a cobalt radiation source) to promote random mutations in the hope that some of them may be beneficial. The potential dangers from such mutations, as well as from the natural

mutations which occur continually in all living organisms, are very much higher than those from transgenic plants. Yet no formal testing of their safety as human and animal food is required.

The situation is very different for GM products. It takes at least ten years to develop a new GM trait, during which time a very detailed investigation is undertaken in both laboratory and field trials of the equivalence of the GM plant to its conventional counterpart: they are compared with respect to phenotype, growth and nutritional properties, and chemical composition. Toxicity and carcinogenicity are tested in feeding trials with livestock and rats before the product can be approved for the market. Trials with thousands of animals have shown GM products to be harmless: no scientifically substantiated reports have suggested that the health or productivity of animals is impaired after being fed GM fodder in comparison with the conventional equivalent. Moreover, for some ten years GM food products have been part of the human diet in the US and some other countries. It is estimated that 60–70% of processed foods on US supermarket shelves contain GM components – and they are not labelled. Accordingly, trillions of GM meals have been eaten without any scientifically based report indicating a single health hazard – not one. Furthermore, in spite of a number attempts to do so, there has been no successful consumer claim in any court anywhere for compensation for damage supposedly incurred from the consumption of GM products. This constitutes yet more evidence for the efficacy of the testing procedures and for the safety of the products themselves.

On the other hand, the well-known health risk to consumers from the presence in maize of contaminating fungal toxins is decreased in GM insect-resistant varieties. Conventional maize cobs are often infected with the fungus *Fusarium moniliforme*, resulting in production of the fungal toxin fumonisin. For more than a century, “mouldy corn disease” has been recognised as a hazard for horses, pigs and other livestock, with entire herds dying after being fed corn infected with *Fusaria*.

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Sixteen years ago, fumonisin was identified as the cause of the disease. It is known to induce liver cancer in rats. Fumonisin is thus a serious problem; it is so stable that it survives processing and can sometimes be found in cornflakes. In the UK in September 2003, the analysis of 30 samples of maize products in supermarkets led to the removal of ten of them because of excessively high levels of fumonisin content. The contaminated samples with the highest fumonisin contents were those labelled "organic".

Several studies have found contamination with fumonisin to be greatly decreased in insect-resistant (Bt) GM maize, whereas in conventional maize plants the fungi proliferate in cobs injured by insects. In GM maize there is much less insect damage and hence less fumonisin. ***These findings indicate that food from GM maize is more healthy for humans than that from conventionally grown maize.***

(d) Is there a higher risk of food allergy from eating food derived from GM plants than from conventional food?

Estimates suggest that 5–8% of children and of 1–2% adults are allergic to certain conventionally produced foods. Peanuts, for instance, are known to contain 12 allergenic proteins.

While there is no legal requirement for the testing of foods from conventional varieties, strict allergy tests are mandatory for GMO products. The World Health Organisation (WHO) has introduced a protocol for detailed GMO allergenicity tests, both for the plant products concerned and also for their pollen. This protocol is being constantly improved. Tests of this sort on one occasion alerted scientists to the fact that the introduction of a gene from Brazil nut into soybean, in the hope that it would improve quality, would be allergenic for certain people. As a result, further development of that GMO was abandoned by the company involved prior to any commercialisation, demonstrating that the safety regulation system functions well.

Our collective experience to date shows the strict allergenicity tests of GM products to have been very successful: not one allergenic GM product has been introduced onto the market. In conventional breeding, in which genes are altered at random by experimentally-caused mutations or unexpected gene combinations generated by crossings, such tests are not legally required. ***For this reason the risk of GM plants causing allergies can be regarded as substantially lower than that of products from conventional breeding.*** Furthermore, intensive gene technology research is already underway with a view to removing allergens from peanuts, wheat and rice.

- (e) **Has the consumption of transgenic DNA adverse effects on health? Might transgenic DNA survive the digestive tract and become incorporated into human cells, thus altering their genetic information? Does transgenic DNA affect the intestinal microflora and might this constitute a health risk?**

Every day, people on average consume 0.1–1 g DNA in their food. In food from GM plants, transgenic DNA would amount to about 1/100 000–1/1 000 000 parts of this. Scientists are in agreement that digestion of transgenic DNA in no way differs from that of DNA from conventional food. The “new” genes in GM plants derive mostly from other organisms already present in conventional food: viruses and soil bacteria are present in vegetables.

All DNA, transgenic or not, is degraded in the digestive tract although this process may not always be complete. Experiments with animals have shown that very limited quantities of DNA fragments from food may be taken up into blood and body cells, which probably applies equally to humans. Nevertheless, this would have no effect on the genetic composition of human cells: the stable integration of plant DNA into animal genomes has never been observed, with natural barriers apparently in place to prevent any such horizontal gene transfer.

To provide a promoter (gene switch) for the synthesis of the foreign protein in GM plants, a promoter from the cauliflower mosaic virus (CMV) is often used. There

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has been speculation that the DNA sequence of this virus promoter might be incorporated from undigested plant material into the genome of human cells, there to provoke the development of tumours. No evidence has been provided for this theory which ignores the fact that the viral promoter has the properties of a plant DNA with its uptake into the human genome prevented by the natural barriers mentioned above.

However, there is another significant detail negating this speculation: for centuries, cabbage and cauliflower have been part of the human diet. Half of all cauliflower and 10% of cabbage are infected with the virus, so people have been eating cauliflower mosaic virus for centuries or perhaps for millennia. There have never been adverse health reports from the consumption of these naturally "contaminated" vegetables.

Experimental research has demonstrated that natural barriers make the horizontal gene transfer of plant DNA extremely unlikely, whether from the roots of plants into soil bacteria or from an animal digestive tract into intestinal bacteria. This argues strongly against unsupported assertions that recombinant DNA from a transgenic plant might be spread by bacteria.

The situation is different in the case of recombinant DNA originally derived from a bacterial source. Those DNA sequences can indeed be inserted into bacterial genomes by homologous recombination. A number of approved GM plants do contain bacterial genes conferring resistance to antibiotics; they are used as selection markers in the procedure of gene transfer. The possibility exists of these resistance genes being transferred to intestinal bacteria. In most cases, the gene employed confers resistance to the antibiotics kanamycin and neomycin. Because of their high toxicity, these antibiotics are very seldom used in human medicine, and then exclusively for external applications only. Moreover, the resistance genes to these two antibiotics are already present in large amounts in an average soil sample.

Occasionally, bacterial ampicillin-resistant genes have been used as selection markers for the generation of GM plants. Since ampicillin is used medically for severe infections such as meningitis, there has been speculation that the consumption of products from the corresponding GM plants may lead to a loss of therapeutic effectiveness due to the spread of ampicillin resistance via intestinal bacteria. Plausible though this scenario at first sight appears to be, in normal healthy persons up to 27% of the *Escherichia coli* bacteria in the intestine *already contain this ampicillin-resistant gene*. The practice of adding antibiotics to cattle fodder means that the droppings of 75% of cattle and pigs in Germany were found to contain *Escherichia coli* bearing the ampicillin resistance gene. In New Zealand, some 20% of soil bacteria were found to contain the ampicillin marker even though GM plants had never been grown there. ***This clearly shows that the presence of these antibiotic resistance markers in GM plants, even if they were able to survive passage through the digestive tract, represent no risk to human health.*** However, since it seems to be impossible to convey to the general public the difference between various antibiotics and the corresponding resistance genes, they are no longer used as selection markers or are later excised and so not present in GM plants.

In summary, the evidence suggests it to be most unlikely that the consumption of the well-characterised transgenic DNA from approved GMO food presents any recognisable health risk.

5 Conclusion

This paper noted at the outset that the consumption of any foodstuff present various degrees of risks to health. Estimating the importance of risks specifically related to GM food products can be made only by comparison with the corresponding conventional products. The former offer the advantage of having been exceptionally thoroughly tested with respect to health risks, but the latter have not been tested at all. In estimating the health risks, it is also relevant to remember that, since 1996, hundreds of millions of people in

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the Americas and elsewhere have regularly been consuming GM products as part of their normal diets without any proven evidence of adverse health effects. It might be argued that this is only evidence for the absence of strong and easily observed adverse effects, and that milder or long-term damage cannot be excluded. While long-term effects are not expected, which is equally true for all food; *how many of our ailments in later life derive from decades of eating particular foods?* For the most part, we do not know.

The present regulations for the approval of GM plants and their product have established a framework which:

- affords an effective safety evaluation on the basis of scientific data before marketing
- requires GM products to be labelled by law, so offering the consumer informed choice
- specifies monitoring procedures which will reveal unexpected effects after the introduction of GM products onto the market
- permits the regulatory authorities to evaluate these data at any time.

This report shows that, because of the rigour with which they must be tested and the controls to which they are subject, it is extremely unlikely that GMO products approved for market in the European Union and other countries present a greater health risk than the corresponding products from conventional sources.

6 Genetically modified insect-resistant crops with regard to developing countries

Using existing literature, this report summarises ecological and economical aspects of the cultivation of genetically modified insect-resistant varieties of maize, rice and cotton. It shows that the growth of these crops by smallholder farmers in developing countries can be beneficial for their earnings, their health and also for the ecosystem.

Agriculture in general leads to ecological disturbances as wild plant communities are replaced by monocultures of crop plants. In order to obtain sufficiently high yields, fertilisers are used and weeds combated by herbicides and tilling. Insect attack and fungal infections have to be minimised. These are both achieved conventionally by the application of pesticides which have adverse effects on the agricultural ecosystems. An alternative approach is to use genetically modified (GM) crops resistant to pests. It is just over ten years since the first GM crops were introduced, yet they are very popular with farmers. In 2005 it was estimated that approved GM crops were grown globally on 90 million ha, about 5% of all arable land; the increase between 2003 and 2005 alone was 33%. Some 90% of those benefiting were resource-poor farmers from developing countries whose increased incomes from biotech crops contributed to the alleviation of their poverty. The Nuffield Council of Bioethics stated in 1999 that "GM crops had a considerable potential to improve food security and the effectiveness for the agriculture in developing countries".

Whether the growth of GM crops is more economically rewarding and less damaging to the environment than the cultivation of their conventional counterparts with conventional protection by agrochemicals needs to be considered on a case-by-case basis. The present report deals with three important crops grown in developing countries: maize, rice and cotton, all with genetically engineered resistance against feeding insects. This has been achieved by the expression within the crop plants of proteins (*Bt* proteins) derived from the bacterium *Bacillus thuringiensis*. Over 200 different *Bt* proteins toxic to selected insects have been identified in various strains of this bacterium. For 40 years *Bt* proteins have had a safe history as biopesticide preparations and are approved for organic farming. Rats fed with very high doses of *Bt* proteins showed no detectable toxic effects, whereas synthetic pesticides, such as organophosphates and chlorinated biphenyls, are toxic. The high price of *Bt* preparations, however, makes them expensive for use on commodity crops and they represent less than 2% of pesticides sold worldwide. Synthetic pesticides kill a very broad spectrum of insects, i.e. the target pests, as well as beneficial insects, whereas *Bt* crops kill primarily those insects attacking the crops.

Seeds incorporating Bt technology are particularly suitable for smallholder farmers, because they do not require the equipment and knowledge necessary for pesticide applications, and reduce farmers' exposure to insecticides, particularly for those using hand sprayers.

6.1 Maize

Worldwide, maize is the leading staple in terms of tonnage, with two-thirds of the global hectareage grown in developing countries. It is noteworthy that the yields of maize harvested per hectare in the Corn Belt of the US can be 20-fold higher than that of resource-poor subsistence farmers in developing countries. Although most maize is used as animal feed, it is a staple food in many countries, particularly in sub-Saharan Africa and South Asia. For example, the consumption of maize in Kenya has been reported to be 400 g per person per day. In such countries it is imperative for food security that maize harvest yields are improved. Decreasing the harvest losses caused by insect pests is a major factor in yield improvement and stability.

On a global basis, the most important insect pests of maize are the larvae of various moths (corn borers). In temperate areas of America, and also more recently in Europe, rootworm larvae which damage roots have emerged as serious maize pests, with the yield losses in fields infested with rootworms as high as 50%. While rootworms can be combated by spraying organophosphates onto the soil, stem borers are difficult to control by pesticide spraying as the caterpillars penetrate into the plant. The application of pesticides must thus target the caterpillars during the very short time between their emerging from the egg and entering the maize plant. *Bt* maize, by contrast, has the advantage of the caterpillars being targeted when they feed on the plant and are so prevented from entering the stem. Although combating some pests will increase the population of others, the global deployment of *Bt* genes to control maize pests has been estimated to have the potential of eliminating 40–50% of the insecticides currently in use.

During the past ten years, hundreds of million people have consumed products from GM maize and it has been widely used as animal feed. Yet, as discussed in an earlier report

of our commission ("Are there health hazards for the consumer from eating genetically modified food?"), there is no evidence of the consumption of GM maize or its products being harmful to health. Moreover, there is clear evidence that GM maize offers the advantage of being much less subject to contamination by mycotoxins such as fumonisin and aflatoxin, toxins produced by fungi that infest maize cobs and cause serious illnesses in man and animals. The invading fungi are opportunistic, primarily infecting kernels damaged by caterpillars. Contamination by these powerful toxins can be so high that harvest products have to be withdrawn from the market. For subsistence farmers, e.g. in parts of Africa, the toxins cause serious health problems, particularly for children. The significantly lower mycotoxin contamination of GM maize is due to the fact that the cobs have fewer injuries. Thus, *Bt* maize offers a critically important advantage for consumers concerned about food safety.

So far, *Bt* maize seeds have been distributed as hybrid varieties giving high yields, but the harvested grains cannot be used as farmer-saved seed. Critics of biotechnology often offer this as a reason why, in developing countries, *Bt* seeds are not suitable for smallholder farmers who mostly use farmer-saved seeds. However, hybrids are the predominant seed types in many developing countries. In China, the largest producer of maize after the US, where maize is grown by 105 million farmers with an average holding of 0.23 ha per farm, 84% have adopted hybrid seeds since they offer a higher return. For areas such as Central America and West Central Africa, where most of the maize is grown by subsistence farmers with farmer-saved seeds, non-profit organisations are called upon to introduce *Bt* genes into local varieties so that these farmers may also profit from *Bt* technology.

6.2 Rice

Worldwide, rice is the principal food for nearly two billion people, with the main producers being China, India and Indonesia. In these countries, rice is mostly grown by about 250 million smallholder farmers. Again, major insect pests are caterpillars such as stem borers and leaf-folders. At present, the productivity of rice plantations depends heavily on

chemical inputs. The introduction of conventional pesticides about 30 years ago had a devastating impact on insect diversity, drastically reducing the populations of fish and crabs in the rice fields. Many companies and institutions in the world, e.g. in Iran and China, are developing genetically modified insect-resistant rice. *Bt* rice cultivars have already been field-tested in Iran, China and Costa Rica, to be fully commercialised in due course. Field studies indicate that the introduction of *Bt* rice has the potential for decreasing the amount of pesticides sprayed on the fields by more than 50% together with considerable increases in harvest yield.

6.3 Cotton

Cotton is grown in developing countries, mainly by smallholder farmers. The harvest is particularly threatened by insect pests such as the cotton bollworm and caterpillars feeding within the fruit where the cotton fibres are produced. Without treatment, these pests can destroy most of the harvest. Conventionally, they are combated by spraying organophosphate or pyrethroid pesticides. More pesticides are applied per hectare of cotton than to any other crop with the number of sprayings necessary per season varying from 2 to 12, but sometimes as high as 30. Despite major expenditure on pesticides, cotton cultivation has totally collapsed in various regions of the world because of extremely high infestation levels.

For the past nine years, genetically modified cultivars containing a *Bt* protein toxic to the cotton bollworm have been available. Their commercial introduction has been very successful: by 2005, *Bt* cotton was grown on 28% of the global hectareage of cotton, with an increase of 33% in the last year. Whereas the *Bt* cotton technology was originally commercialised by a single company in the US, it is now also distributed by a range of companies and institutions in China, India and elsewhere. In China in 2005, about 65% of the cotton was *Bt* cultivars, and in South Africa as much as 85%.

7 Ecological aspects

Experience with traditional crops shows that, through hybridisation, they can give rise to weeds requiring special agricultural practices for their elimination. It is well established that gene flow occurs between both GM cultivars and non-GM crops and their wild relatives. Cultivars of maize, rice and cotton sown as crops do not have sufficient biological fitness to survive in natural habitats; in most cases the incorporation of a few additional genes is unlikely to alter the fitness of a cultivar in a natural ecosystem. Maize has wild relatives only in Mexico and Central America, whereas the wild relatives of cotton and rice are more widespread. So far, no transgenes have been observed to escape from maize or cotton to a wild relative, there permanently to initiate a selective advantage. In the wild, insect resistance could offer such a selective advantage, but insect resistance mediated by a single gene is unlikely to persist. In the case of *Bt* rice, particularly with modern rice cultivars designed for dry-land agriculture, special attention must be paid to the question of the possibility of gene flow to weedy wild rice relatives. It is surely relevant for such scenarios that, for more than 30 years, a very large number of rice cultivars have been grown into which single genes conferring resistance to certain insects have been introduced by conventional breeding. There are no known cases in which wild or weedy rice populations have become more competitive as a result of hybridisation with these cultivars.

Some years ago it was reported in a laboratory experiment that feeding pollen to *Bt* maize caused considerable toxicity to Monarch butterflies and that survival of the species was threatened by this GM crop. The report provoked so much public anxiety that the EU placed a moratorium lasting several years on the approval of GM crops. Extensive field studies, subsequently carried out by numerous investigators, clearly demonstrated that the cultivation of *Bt* maize has no measurable impact on Monarch butterflies. A large number of studies on *Bt* maize, rice and cotton, performed in several countries, have all shown that the populations of many non-target insects are higher in fields of *Bt* cultivars than in fields of conventional crops regularly receiving applications of broad-spectrum pesticide.

There has been concern that *Bt* proteins from the litter of plants and root exudates persist in the soil and have an impact on its fauna. Taking into account that agricultural soils are in any case highly modified by conventional cultivation, and particularly by tilling and the application of fertilisers and pesticides, the impact of *Bt* crops on the fauna in the soil has been shown in extensive studies, including bioassays, to be negligible.

As mentioned earlier, *Bt* proteins are toxic only to selective insect pests. Combating those pests that are insensitive to the *Bt* toxin means that in many cases the cultivation of *Bt* cultivars still requires the application of pesticides, although the number of pesticide sprays required is mostly much lower than with conventional cultivars. Decreases in pesticide applications are beneficial not only to the environment but also to farm labourers. Spraying chemical pesticides is a considerable health hazard, especially if hand sprayers are used. A survey in China revealed there were formerly on average 54 000 poisoning incidents annually, including 490 deaths due to the use of pesticides, and that the introduction of *Bt* cotton cultivars reduced this health risk substantially. ***These facts provide overwhelming support for the beneficial effect of *Bt* crop cultivation, both for the environment and for the health of farm labourers.***

8 Economic aspects

Since the seeds of *Bt* cultivars are more expensive than their conventional counterparts, a farmer will have to decide whether infestation by pests is high enough to make the purchase of GM seeds profitable. Although the returns for using *Bt* technology can result in reduced labour and pesticide costs, as well as increased harvest yields, there remain situations in which the cost of *Bt* seeds is not justified.

The fact that in 2003 30% of maize and 46% of cotton in the US were planted as *Bt* cultivars clearly demonstrates that *Bt* technology can indeed be profitable for farmers. The fact also that only 30% and 46% was planted suggests that there are circumstances in which the additional cost of the seeds is not justified. The decision of whether or not to use such seeds was made by individual American farmers on commercial grounds.

This also applies to many developing countries. In China, where cotton is grown by about 11 million farmers with an average holding of 0.4 ha, about two-thirds of these farmers have already adopted *Bt* cotton. *Bt* technology is reported as being profitable because it leads in many cases both to a substantial decrease in pesticide use and to a yield increase.

In India, where cotton contributes 30% of the national agricultural gross domestic production and is grown mainly by smallholder farmers, the infestation of cotton fields by insect pests is very high and the average yield per area is only about half of the world average. In India, only three years after the commercial release of *Bt* cotton, about one million farmers have decided to grow it. As reported, most, although not all of the farmers, made substantial profits as a result. Future success depends on the introduction of locally adapted varieties. In both China and India the distribution of *Bt* technology is no longer restricted to multinational companies but increasingly involves national companies and institutions, resulting in more competitive pricing.

These examples show clearly that Bt technology can indeed be valuable in economic terms to smallholder farmers with relatively small fields in developing countries, as well as to the large farms in developed countries.

There is, however, the possibility that pests may become resistant to *Bt* toxins as has happened in the past with the extensive use of organophosphates and pyrethroids. Although the evolution of resistant pests will not cause major ecological problems, it might seriously affect the economy of farmers and seed companies. In order to prevent such resistance, countries, such as the US, have adopted insect-resistant management programmes which include providing refuges of non-GM crops or other hosts. This ensures that susceptible insects are available in sufficient numbers to mate with any resistant survivors from *Bt* fields, so preventing the build-up of resistant insect populations. Thus far this system has worked well; almost all farmers obey the rules and several recent studies have failed to find any resistance. Smallholder farmers do not have such problems, because they usually have several small fields with diverse crops.

World agriculture must continue to fulfil the food and fibre needs of the growing human population, as well as rectify the existing widespread malnutrition. *To achieve this aim, pest control will have to rely on integrated pest-management practices which include crop rotation, biological control, Bt technology and the sparing use of pesticides. Bt technology has shown itself to be a valuable contribution to knowledge-based agriculture.*

9 Statement on genetically modified crops

Molecular engineering of crops has brought revolutionary advances in agriculture. In 2005, just ten years from their introduction, many GM crop varieties have been grown on about 5% of all global arable crop land in 21 countries by 8.5 million farmers, 90% of whom are resource poor. Some developing countries have used GM varieties and benefited from them for several years and are now in a position to affirm their need and their will to develop more GM farming. We of the academies of sciences worldwide wish to state the following:

Foods from GM crops are more extensively tested than any other. They have been shown to be as safe as, or even sometimes safer, than foods derived from the corresponding conventional plants. Ten years of human consumption and extensive nutritional testing amply support this conclusion (see the report of the IAP GMO initiative: *Are there health hazards for the consumer from eating genetically modified food?*).

Any food, GM or not, may certainly involve some risk – known or not, indexed or not – for human health. There is at present not the least scientific or medical evidence that possible risks posed by GM food are higher than risks posed by non-GM food.

The environmental impact of GM crops is no greater than that of traditional crops. In some cases GM crops have decreased the negative effects of current agricultural practices: for example, insect-resistant cotton requires mostly substantially decreased applications of chemical pesticides, and herbicide-tolerant crops allow no-till practices, cutting energy use and promoting healthy soils. Seed-incorporated technology is particularly suitable for small farmers in developing countries. GM crops resistant to insects, viruses or fungi reduce

farmers' exposure to chemical pesticides, particularly when pesticides are applied with hand sprays. The successful cultivation of GM cotton in China and South Africa shows how former subsistence farmers have significantly increased their income and dramatically improved their quality of life.

In both developed and some developing countries, organic farmers already operate in an environment in which they are subject to influences from neighbouring activities. With proper separation safeguards the presence of genes encoding GM traits in organic products is negligible. Nothing in GM agriculture prevents organic farmers from pursuing their normal practices. Although the rules of organic farming currently exclude the use of GM crops, there is no evidence-based justification for that position.

GM crops can make a major global contribution to the quantity and quality of food. In developing countries, farmers suffer major crop losses caused by insects and diseases. GM technology has already shown that such losses can be significantly reduced, leading directly to improvements in food quality and safety (e.g. insect-resistant maize has appreciably lower levels of highly carcinogenic fungal toxins).

Just as each consumer ought to have the right to accept or reject GM food, so farmers in developing countries and elsewhere should be able to decide for themselves whether to plant conventional, organic or GM crops. They should have the freedom to decide whether it is profitable for them to use the more costly GM seeds instead of conventional seeds. For there to be choice, appropriate regulations including labelling of GM products must be in place, regulations that are proportionate and not excessive. For developing countries to have access to crop biotechnology for their own agriculture, international and non-profit organisations must help governments to formulate appropriate regulations and assist with the training of personnel to administer them.

We wish to debunk the unsupported arguments against genetically modified (GM) crops. On the basis of a wealth of experimental evidence on GM crops – evidence that has accumulated in the past decade from many studies – we affirm that:

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- Foods from legally approved GM crops are no less safe for humans and animals as conventional crops.
- In the country concerned, legally approved GM crops do not pose greater environmental hazards than conventional crops.
- Small-scale farmers, not just large farms and multinational corporations, can profit from the adoption of GM crops, which in turn could contribute to the alleviation of poverty and hunger in the developing world.
- GM crops pose no unresolvable conflict with either non-GM crops or organic farming.
- GM crops can make major contributions to the quantity and quality of food worldwide.
- Freedom of choice should apply to all farmers and consumers, not just to some of them.
- Decisions about the cultivation of GM crops and the consumption of GM foods must be based on the best available scientific evidence, not on ideological or political beliefs. We should be able to call on governments and non-government environmental organisations to end any unjustified campaigns against GM crops.

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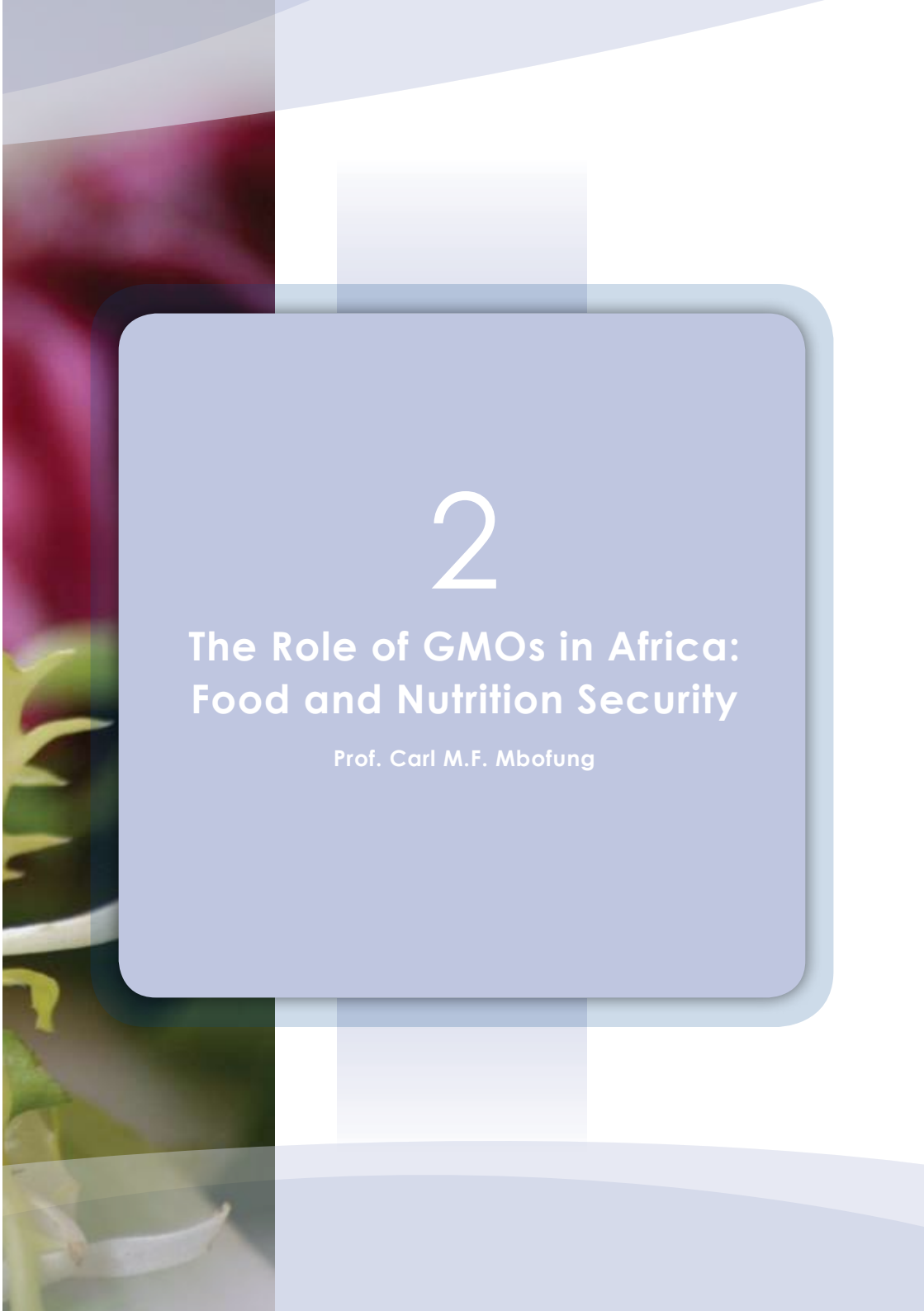
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2

The Role of GMOs in Africa: Food and Nutrition Security

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THE ROLE OF GMOS IN AFRICA: FOOD AND NUTRITION SECURITY

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Developing countries, especially those in sub-Saharan Africa, have for decades been faced with numerous problems which impede their overall growth process. As a consequence, the human development index of these countries has, in most cases, remained at quite a disappointingly low level. Within the community of multilateral organisations and the United Nations, this situation and others have for long been a matter of concern and debate on how to ameliorate these countries' development processes. It was in the course of one of their meetings that the UN, at the end of the 1990s (2001), adopted the Millennium Development Goals (MDG) consisting of eight points that were to serve as indicators of the progress being made towards development in these countries by 2015. Halfway through September 2007, the MDG African Steering Group, consisting of the Secretary-General of the UN, the top executives of the African Development Bank, the European Union (EU), the International Monetary Fund (IMF), the African Union and of the World Bank, met to identify the practical steps needed to achieve the MDG in Africa. At the end of the meeting the following recommendations, aimed at spurring on progress for the attainment of the MDG in African countries by 2015, were adopted:

- (a) The doubling of agricultural production with the objective of reducing poverty, hunger and malnutrition.
- (b) The progressive introduction of commercial farming aimed at accelerating economic growth.
- (c) The improvement of child nutrition and the systematic introduction of school meal programmes.

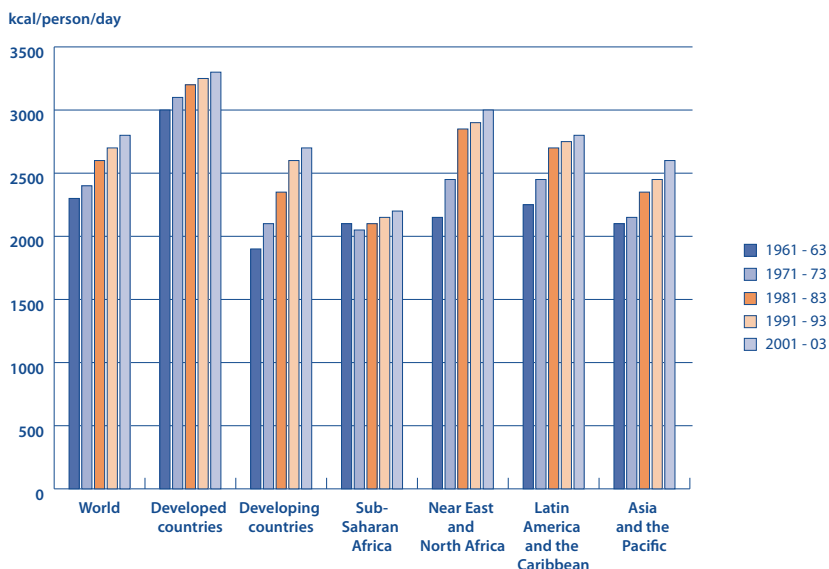
- (d) Micronutrient supplementation to vulnerable groups, especially to children under the age of two, accompanied by systematic deparasitation programmes.

These recommendations all have a direct connection with the issue of food security. By definition, food security is achieved when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. In the light of this definition food security is a major problem for the developing countries of sub-Saharan Africa. This is more so when one considers the factors that influence food production. In almost all cases low food production has constantly been ascribed to such factors as climate (drought or inadequate rainfall), soil fertility, soil erosion and desertification; poor farming practices; crop losses due to weed and insect attack; inappropriate post-harvest technology; poor farm inputs and natural disasters. In addition to these factors, the situation is increasingly being made worse by the global warming phenomenon, the decrease in farm labour due to rapid rural urban migration, widespread poverty and conflicts. The recent world food crises, together with the HIV/AIDS pandemic, only aggravate the situation, and the attainment of the MDG related to food and nutrition by 2015 is looking more like a myth for most African countries.

In situations of food insecurity, problems of food supply, hunger, undernutrition and eventually malnutrition tend to exist in varying proportions. Available statistics on hunger, undernutrition and malnutrition in developing countries in general and in Africa in particular, are not only alarming but are disturbing indicators of the poor state of the food and nutrition situation. These indicators reveal the magnitude of the challenges that the governments of these countries have to overcome to improve human life.

Food supply situation: *Per capita* food consumption figures for sub-Saharan Africa (Figure 2.1) have not only been the lowest in the world but have remained relatively stagnant for more than four decades (1961–2003), suggesting a very poor food security situation. Based on the International Model for Policy Analysis of Agricultural Commodities and Trade

(IMPACT) for food supply, demand, net trade and malnutrition under the Business as Usual (BAU) scenario, projected crop production data indicate that annual cereal production rates in sub-Saharan Africa will decrease from the average rate of 3.6% achieved between 1982–1997 to 2.7% between 1997–2025 (Rosegrant *et al.*, 2004). Equally, a decrease from 4.3% to 2.7% for the same periods will be experienced in the case of root and tuber production.



Source: FAO (2007)

Figure 2.1: Per capita food consumption between 1961 and 2003

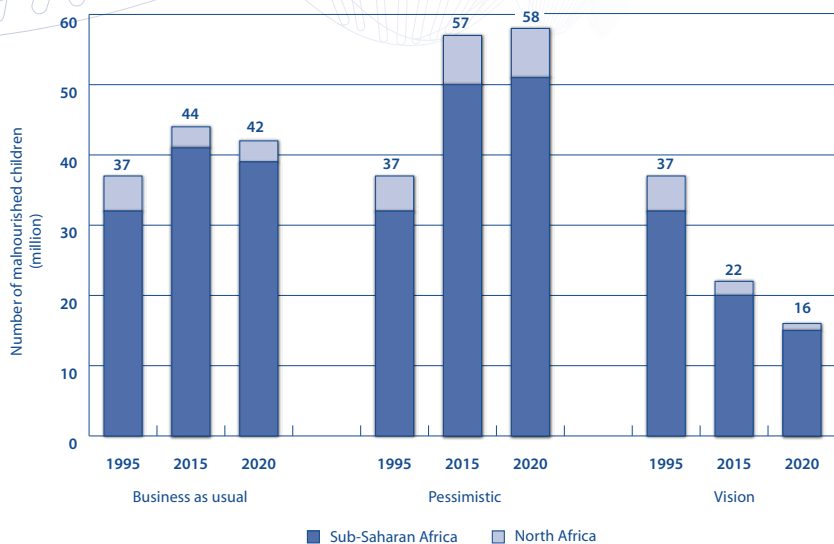
In this scenario, the incidence of hunger and the high prevalence of undernutrition and malnutrition are bound to be common. At the global level, estimates for the 1999–2001 period put hunger and malnutrition as affecting 842 million people, with 798 million living in developing countries. Sub-Saharan Africa alone accounted for 198 million.

Recent global statistics for malnutrition show that 60% of the almost 11 million deaths occurring in children under the age of five in developing countries are associated with nutritional problems (UNICEF, 2007). In Africa, the prevalence of malnutrition varies from

5% to 34%. About one in every three children under the age of five experiences chronic growth retardation with the attendant consequences of poor brain development and poor health. These figures, which reflect the degree of food insecurity on the continent, are in some cases exacerbated by widespread poverty and the occurrence of HIV/AIDS. Also common is the occurrence of micronutrient deficiencies. Of particular concern in this case is the high incidence of iron deficiency anaemia (30–50% in pregnant and lactating women; 20–30% in children under the age of five) and vitamin A and iodine deficiency with their attendant effects on metabolism and growth. At country level, to use Cameroon as an example, the prevalence of these micronutrient deficiencies show that:

- (a) Pregnant and lactating women and children under the age of five are the main groups at risk of vitamin A deficiency. Earlier studies have shown the prevalence of this avitaminosis to be around 40% for under-five-year-olds, with the northern parts of the country registering the highest (62.5%) rates.
- (b) Anaemia due to iron and other vitamin deficiencies is equally very widespread among the vulnerable groups, and the prevalence, which varies according to ecological zones, is as high as 53% for pregnant women and 75% for children.
- (c) Iodine deficiency is also common although relatively low in intensity. The prevalence ranges from 5.3% for children to 7% for women. Over 424 000 new-born babies suffer from mental retardation because of iodine deficiency during the intrauterine period.

This malnutrition is projected to worsen in time if deliberate and appropriate action is not taken. According to the International Food Policy Research Institute (IFPRI, 2004), the malnutrition figures of 37 million African children will increase by 13.5% to a whopping 42 million by 2020 (Figure 2.2). If current efforts are not improved upon, the figures will even be as high as 58 million. These trends equally predict that sub-Saharan Africa will be far from attaining the MDG for undernutrition in 2015 (21.1% as against 17.9%) as shown in Table 2.1.



Source: IFPRI IMPACT simulations

Figure 2.2: Malnutrition trends for African children between 1995 and 2002

Table 2.1: Projected undernutrition figures

Region	Undernourished population (millions)			Prevalence of undernutrition (% of population)		
	1990-1992	2015	WFS Objectives	1990-1992	2015	MDG Objectives
Developing countries	823	582	412	20.3	10.1	10.2
Sub-Saharan Africa	170	179	85	35.7	21.1	17.9
Middle East and N. Africa	24	36	12	7.6	7.0	3.9
Latin America & Caribbean	60	41	30	13.4	6.6	6.7
South Asia	291	203	146	25.9	12.1	13.0
East Asia	277	123	139	16.5	5.8	8.3

The seriousness of this problem lies in the fact that, if unattended to, its consequences will be carried over from parent to offspring in a vicious cycle (Figure 2.3) with the magnitude of the problem growing with each passing cycle. The overall impact will be a reduction in the biological potential of children and in the development process of the country.

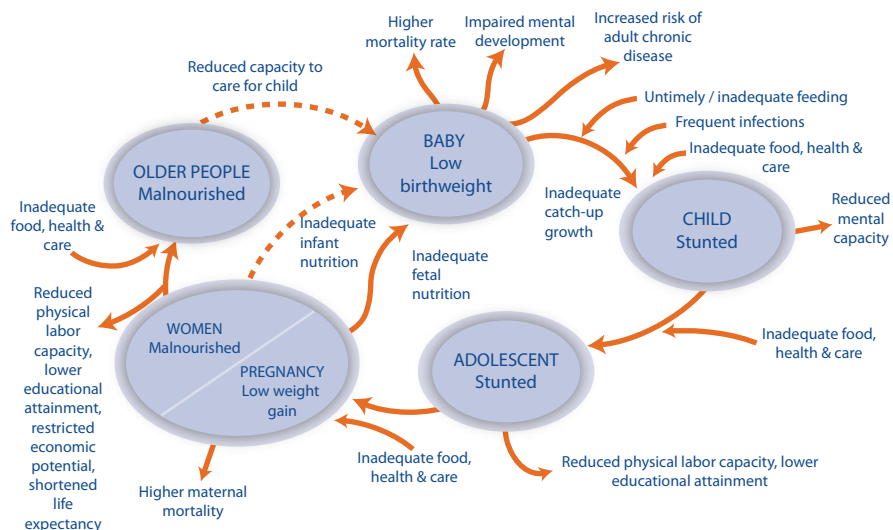


Figure 2.3: Vicious cycle of the burden of malnutrition

Source: Benson, 2004.

The food and nutrition picture of sub-Saharan Africa in Figure 2.3 calls for reflections on and suggestions for a way forward to contribute to the solution to these problems. Generally, although nutritional status is attributed not only to food security (Figure 2.4), it does play a predominant role. Given the several constraining factors that are known to influence food production in Africa, the present paper takes a look at the role that recent genetically modified organism (GMO) technology can play in contributing to the enhancement of the food and nutritional status of African countries.