The Open Forum on Agricultural Biotechnology in Africa (OFAB) Uganda Chapter

Summary of 2009 OFAB Proceedings

UGANDA NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY
AFRICAN AGRICULTURAL TECHNOLOGY FOUNDATION
PROGRAM FOR BIOSAFETY SYSTEMS
Citation:


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Reviewers

The OFAB summary report was reviewed in draft form by reviewers chosen for their diverse technical expertise in accordance with the procedures approved by the Uganda National Council for Science and Technology (UNCST) on behalf of the collaborating partners. The UNCST thanks the following individuals for their participation in the review process:

- Mbabazi-Tugume R., Uganda National Council for Science and Technology, Uganda
- Wamboga-Mugirya P., Science Foundation for Livelihoods and Development, Uganda
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<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AATF</td>
<td>African Agricultural Technology Foundation</td>
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<tr>
<td>ABSP</td>
<td>Agricultural Biotechnology Support Project</td>
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<tr>
<td>ASARECA</td>
<td>Association for Strengthening Agricultural Research in East and Central Africa</td>
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<tr>
<td>DNA</td>
<td>Deoxyribonucleic acid</td>
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<td>FAO</td>
<td>Food and Agricultural Organisation of the United Nations</td>
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<td>GMO</td>
<td>Genetically Modified Organism</td>
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<tr>
<td>IFPRI</td>
<td>International Food Policy Research Institute</td>
</tr>
<tr>
<td>ISAAA</td>
<td>International Service for the Acquisition of Agri-biotech Applications</td>
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<tr>
<td>LMO</td>
<td>Living Modified Organism</td>
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<tr>
<td>MAAIF</td>
<td>Ministry of Agriculture, Animal Industry and Fisheries</td>
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<tr>
<td>NaCRRI</td>
<td>National Crops Resources Research Institute</td>
</tr>
<tr>
<td>NARL</td>
<td>National Agricultural Research Laboratories</td>
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<tr>
<td>NARO</td>
<td>National Agricultural Research Organisation</td>
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<tr>
<td>NaSARRI</td>
<td>National Semi-Arid Resources Research Institute</td>
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<td>NBC</td>
<td>National Biosafety Committee</td>
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<td>OFAB</td>
<td>Open Forum on Agricultural Biotechnology in Africa</td>
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<tr>
<td>PBS</td>
<td>Program for Biosafety Systems</td>
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<tr>
<td>Scifode</td>
<td>Science Foundation for Livelihoods and Development</td>
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<tr>
<td>UNAS</td>
<td>Uganda National Academy of Sciences</td>
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<td>UNCST</td>
<td>Uganda National Council for Science and Technology</td>
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<tr>
<td>UNFFE</td>
<td>Uganda National Farmers Federation</td>
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<tr>
<td>WHO</td>
<td>World Health Organisation of the United Nations</td>
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<td>CONSENT</td>
<td>Consumer Education Trust of Uganda</td>
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Foreword

Modern biotechnology tools have in the recent past provided immense opportunities to boost agricultural productivity, improved incomes as well as enhanced nutrition in developed and developing countries. Similar tools have also been used in industry and medicine, providing novel and sustainable methods of product development. The uses of such tools, especially genetic modification, however require adequate safety considerations and regulation because of the perceived risks and the possible misuse that could lead to unanticipated negative effects to human health and environment. Establishing regulatory systems for biotechnology necessitates sufficient capacity building within countries using or intending to use these tools. Communication and information systems also have to be developed so that policymakers and government regulatory agencies are abreast with the most recent knowledge and information about the technology. Users of biotech tools and products also require access to reliable information for decision making. One of the approaches to communicating biotech information in Uganda is the Open Forum on Agricultural Biotechnology in Africa.

The Open Forum on Agricultural Biotechnology in Africa (OFAB) is a platform that enables various stakeholders involved in agricultural biotechnology to share information on key national and international advances in biotechnology. OFAB is an initiative by several stakeholders and is organised in Uganda by the Uganda National Council for Science and Technology (UNCST) in partnership with African Agricultural Technology Foundation (AATF) and the Program for Biosafety Systems (PBS). The Uganda Chapter of OFAB was launched in December 2007 and over 14 sessions had been held by the end of 2009. OFAB Uganda Chapter celebrated one year in December 2008 with a farmers’ biotechnology advocacy workshop where farmers from all parts of the country interacted with biotech scientists, policymakers and entrepreneurs. Farmers indeed demanded for biotech products, calling on the government to immediately develop necessary systems for the safe harness of modern biotechnology.

The forum has further updated stakeholders and the general public on the progress with biotechnology and biosafety research for development initiatives within the country. OFAB in Uganda is managed by a Programming Committee comprised of various stakeholders including biosafety experts, biotech researchers, consumer experts, and civil society. On behalf of AATF, UNCST, and PBS, the Programming Committee thanks all partners, scientists, and all persons/institutions who have contributed to the success of OFAB in Uganda. We urge you to continue this support for as long as necessary. Recent studies have indicated that OFAB is a major biotech and biosafety information source to policy makers, media and the general public.

This book is a compilation of OFAB proceedings and includes where available, full papers from key topics presented during the year ending December 2009. Where verbatim is presented, attempts were made to assure accuracy in meaning of comments from participants.

Wishing you interesting reading and look forward to your support to OFAB.

Theresa Sengooba
Coordinator, Program for Biosafety Systems & Member, OFAB Uganda Programming Committee
Background to OFAB

1.1 Introduction

Modern biotechnology has for decades offered mankind with solutions to various problems in health, agriculture, environment and industry. In agriculture, modern biotechnology involving recombinant DNA techniques have led to development and use of various crop varieties that address a number of production and consumer constraints. The major crops targeted have included maize, cotton, soybean but efforts have now led to the development of staple crop varieties with specific desirable traits in attempts to reduce hunger and poverty in developing countries. In Africa, these crops include sorghum, potato, cassava, and banana among others. In the health sector, several medicines have been made using genetically modified plants and microbes to relieve humans/livestock the burden of disease. Insulin is a clear example of how modern biotechnology involving transgenesis has produced medication used by millions of people around the world.

The World Health Organization observes that ‘Modern methods of biotechnology enable the accelerated development of food products with recombined or improved traits with an increased specificity compared with conventional techniques’. These new agricultural biotechnologies promise much to the countries willing to adopt the new varieties. Moreover, the gains from farm-productivity enhancing GM varieties could be multiplied many fold if biofortified GM varieties such as golden rice were also to be embraced (Anderson and Jackson, 2006). Biofortification of staple crops will significantly reduce nutrient-deficiency-associated conditions such as anaemia, blindness, and stunting.

Uganda is making significant strides in developing modern biotechnology based products that will address the specific needs of the country’s farmers and populace. Banana, cotton, cassava and maize are the main crops under research to produce transgenic varieties with better protection against drought, pests and diseases as well as with enhanced nutritive potential. Legal instruments will however be needed to have these products safely delivered to the public. UNCST with partners is working to ensure the safety of such technologies through laws and guidelines/regulations.

It has been recognised that creating cooperation across the different countries in all aspects of biotechnology is paramount noting the porosity of country borders. In other words, a GMO released in one country could easily seep into the neighbouring territory through formal or traditional seed exchange systems. There is general consensus that this is a right time to support awareness campaigns for biotechnology and biosafety to enable scientists, decision makers, institutional stakeholders and the general public to access facts on biotechnology development.

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In recognition of the foregoing, the Uganda National Council for Science and Technology in collaboration with the Program for Biosafety Systems (PBS) and the African Agricultural Technology Foundation (AATF) initiated the open forum on agricultural biotechnology (OFAB) in Uganda. Currently, the program is in five countries, (mainly supported by AATF), they include Kenya, Uganda, Tanzania, Egypt and Nigeria. OFAB is designed to facilitate the flow of information among the scientific community, policy makers and the general public while providing an opportunity for key stakeholders to know one another, share knowledge and experiences, make new contacts and explore new avenues of bringing the benefits of biotechnology to the African agricultural sector.

1.2 OFAB Objectives

The main objective of OFAB thus, is to create a platform for scientists and other stakeholders to meet and discuss various issues related to biotechnology and biosafety and their relationship to agricultural development in Africa.

The specific objectives of OFAB in Uganda were to:

1. Enhance participants’ awareness on biotechnology and biosafety,
2. Share information and experience on biotechnology and biosafety activities in the region,
3. Identify and/or recommend common areas of biotechnology and biosafety to maximise utilisation of available capacity at national and regional level.

1.3 Approach

The Forum takes the form of a monthly lunch-hour meeting comprising of participants from various stakeholder groups including parliamentarians from relevant sectoral committees i.e. Committees for Environment, Agriculture, Health, Science and Technology, farmer representatives, civil society, NGOs, the media, and government institutions concerned with training, regulation and research in agriculture, environment, forestry, fishery, and biotechnology. The Open Forum provides an opportunity to make formal presentations and discussions focussing on the relationships between science, technology, innovation, environmental protection, policy, trade, social benefits sharing and their impact on economic development.

1.4 OFAB Programming Committee Members

1. Dr Peter Ndemere   UNCST (Chairperson)
2. Dr. Dennis Kyetere   NARO
3. Ms Grace Wachoro   AATF
4. Mr. Kimera Henry Richard   CONSENT
5. Prof. Dr. Opuda-Asibo   Kyambogo University
6. Dr. C.F Mugoya   ASARECA
7. Mr Okasaai Opolot   MAAIF
8. Dr. Theresa Sengooba   PBS
9. Ms Ruth Mbabazi-Tugume   UNCST (Coordination)
10. Mr Herbert Oloka   PBS
Joint farmers’ advocacy workshop on biotechnology tools and innovations and first OFAB anniversary event

2.1 Opening Ceremony

The session was chaired by Dr. Theresa Sengooba, the Regional Coordinator for the Program for Biosafety Systems. The moderator for the session, Mr. Rwakakamba Morrison, welcomed participants and requested them to introduce themselves. He then invited the session Chairperson to brief the participants. Dr. Sengooba took the opportunity to again welcome the participants before briefing them about the history and objectives of OFAB. OFAB Uganda-Chapter, she said, has achieved tremendous strides since its launch in December 2007, and was now a year old in Uganda. She added that the day’s meeting was an opportunity for farmers to interact with biotechnology scientists as well as policy makers on issues regarding biotechnology. Tissue culture applications, already in use by many farmers in Uganda, were the focus of the day. She then invited Dr. Peter Ndemere to make the opening remarks.

2.1.1 Opening Remarks, by Dr. Peter Ndemere, Executive secretary UNCST

Dr. Peter Ndemere in his remarks noted that biotechnological tools have greatly improved innovations through increased efficiency and less cumbersome operations. He pointed out that without good tools, one cannot work effectively and efficiently and that, innovation implies doing a new thing to increase efficiency and improve or to change tools and methods for better results. He described UNCST as the institution responsible for identifying the gaps (and problems) in all sectors of the economy, then prioritising the problems depending on the resources, assessing their competitive advantage and how feasible they are, determine knowledge and skills needed to solve the problems and devise ways of addressing them using science.

Dr. Ndemere mentioned that a key strategy is to use already existing technology through technology transfer and adoption, or technology upgrading in collaboration with Uganda Industrial Research Institute. He further noted that many technologies have been developed but are not in use in Uganda. Thus the need to promote technology incubation for marketing to industrialists in order to support scientists. This calls for a good policy environment, critical mass of people and infrastructure, and investment budget from the government if Uganda is to achieve development in science and technology.

On Africa’s development challenges, Dr. Ndemere noted that the continent may face increased pressure on food and other resources in future as a result of increased population (projections indicate a doubled population by 2050). He added that Africa lagged behind in the green revolution but should not miss the biotechnology revolution. He said that biotechnology can help solve some of the problems in agriculture and industry by providing practical solutions to some of these challenges. He congratulated Kenya Government for passing their Biosafety Bill.

He emphasised that the aim of UNCST, AATF and PBS collaboration was to implement OFAB-Uganda, designed to facilitate interactions between scientists, policy makers, farmers, media
and other stakeholders and that the meeting was to celebrate one year of OFAB implementation in Uganda. In conclusion, the UNCST Executive Secretary thanked participants and donors for their support and urged them to work together to build a vibrant agricultural sector, he then declared the meeting open.

### 2.1.2 Welcome Remarks, by Hon. Frank Tumwebaze, President of UNFFE

Hon. Frank Tumwebaze welcomed participants to the meeting and recognised the presence of Hon. Olive Wonekha, the Chairperson of the Parliamentary Committee on Agriculture and other committee members present. He thanked UNCST for the collaboration with UNFFE, adding that innovations will no longer start and end in laboratories and government offices since farmers are now actively participating in discussions involving science and technology. However, he noted that there were questions that still needed clarification such as: whether there are Genetically Modified Organisms (GMO) in Uganda and Clarification on the Biosafety/Biotechnology programs and activities in Uganda.

He called on researchers to simplify research findings and integrate their results with local knowledge that the farmers know, and encouraged farmers to seek knowledge on banana tissue culture from scientists and AGT to allay their fears. Hon Tumwebaze thanked UNCST, AATF and PBS for their collaboration and suggested the decentralization of such fora to other regions of the country. Explaining that it is through farmers’ understanding of the basics of plant breeding such as “What is improved seed?” that agriculture can be enhanced.

In his concluding remarks, Hon Tumwebaze thanked the organisers for making the forum a reality and requested researchers to come up with innovations that reduce the costs of inputs. He called on the integration of stakeholders’ roles in dissemination of research findings with the farmers as the ultimate beneficiaries.

### 2.1.3 Key note address: Biotechnology Developments: Global, Regional and National Perspectives by Dr. Geoffrey Arinaitwe, NARL.

Dr Arinaitwe welcomed all participants to the meeting and congratulated the people of Kenya upon the successful passing of their Biosafety Bill. He went on to defined biotechnology as “the application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services”. Adding that Plant biotechnology is a precise process in which scientific techniques are used to develop useful and beneficial plants.

He described the different biotechnology applications in human health (diagnostics, therapeutics, drug delivery, genomics and molecular modelling, gene therapy); agriculture (tissue culture, embryogenesis, genetic engineering, genetic markers, diagnostics, transplantation, transplantation, fuels); food processing (Bio-processing, nutraceuticals, and functional foods); environment (biofiltration, bioremediation, and phytoremediation of soil, air and water); and natural resources (industrial bioprocessing, biopesticides, biodesulphurization). He then stressed
here that tissue cultured plants are not genetically modified but rather clones from a particular plant. Pointing out that unless the mother plant is genetically modified, the plantlets can not be genetically modified.

Dr Arinaitwe mentioned that over 50 biotechnology products have been approved for commercial use in the USA, including crops like canola, soybean, maize, cotton, tomato, potato, and squash. USA, Canada, China and Argentina he said are the major countries involved in the biotechnology of crops. He further stated that more products are in the pipeline including those designed to deliver vaccines to humans and those with enhanced nutritional content.

Dr Arinaitwe noted that Africa’s population is rising at high rate and stressed the need for food to feed this population. He stated that the main approaches to increasing food production are: developing plant varieties with specific properties for survival in their localities; developing environmentally sustainable higher yielding and less expensive varieties; and developing varieties that have more nutritious constituents than the wild type species.

He asserted that the key success factors for biotechnology in Africa include: an enabling legal framework, a state of the art infrastructure, skilled human manpower, and efficient management functions. He further described the nutritional needs of Uganda and efforts put in place to improve nutritional quality of crops through biotechnology. He then concluded by emphasising that biotechnology applications have the potential to boost food security and incomes in Uganda and Africa as a whole. He added that everyone needs to participate in order to develop biotechnology.

**2.1.4 Reactions to the presentations**

Hon. Frank Tumwebaze in his reactions inquired on how to get biotechnology concerns out of the way sighting an example of the concerns about GMOs.

Hon Victoria K. Sebagereka in her comments noted that there is no proper labelling of products in Uganda. What are the effects of these? She added.

“What are we doing to communicate biotechnology information?” asked Hon Olive Wonekha. She then added that in the COMESA region, Uganda has a comparative advantage in producing staple crops, what is being done to promote this? She asked.

A participating farmer sought for clarification on the allegations that there was GM maize variety in Kenya that caused sterility in rats feeding on it.

David Wanzara a participating farmers’ representative from Masindi observed that there was scarce information on GMOs and that most of the information given was scaring. He then pointed out that there was need to transfer this information to farmers so that it can be applied in improving productivity.
Chebet Maikut, from UNFFE, noted that there was need to focus on biotechnology. He emphasised the need for the Ministry of Science and Technology. He then asked “How can we use biotechnology safely to avoid negative concerns?”

2.1.5 Responses to the reactions

Dr. Ndemere the Executive Secretary of UNCST in his response said that there may be GM products (in form of cooking oil, cereals) in Uganda. However, he noted that there was need for a Biosafety law, regulations and guidelines to guide the detection of GMOs in products.

The government, he added, is developing an intellectual property law to protect innovations, and the Science and Technology Policy under formulation provides for protection of intellectual property.

He also pointed out that no scientists are working to get hazardous products onto the market, saying that there are regulations to assess for toxicity in the products. On communication of biotechnology information he said that all stakeholders are ambassadors of information, adding that all interested parties should endeavour to seek information from the relevant sources.

Dr. Arinaitwe in his response said that Biotechnology products are highly regulated and undergo several tests to ensure their safety. On the fear of ‘the terminator gene’, he said it is unfounded and that it is a theory that has not been used anywhere. He also added that there is no need to label products since many have readily available own labels.

On Genetically Modified Organisms (GMO), he said there are no GMOs in Uganda to warrant labelling. And added that Biotechnology is being used to manufacture products such as beer and antibiotics, he further informed the participants that the yeast used in brewing is genetically engineered.

He also retaliated that there is need for more information on the rats that became sterile after eating the maize in question. He then added that farmers need to be given information by the relevant agencies or people and refocusing needs to be done by all sectors, not only in biotechnology.

Hon. Frank Tumwebaze the president of UNFFE informed the participants in his response that UNFFE is currently working on the distribution of information to participating farmers through such fora. He also added that UNFFE is also aiming at linking scientists directly to farmers to address some questions that may arise. He further said that his fears are now reduced since he’s confident that scientists will produce and assess biotechnology products locally.

2.2 Session 2: Biotechnology for farmers

2.2.1 Biotechnology in Uganda: Plant Tissue Culture Development and Applications by Dr. Settumba Mukasa, Makerere University.

Dr. Mukasa the In Charge-Plant Tissue Culture Laboratory, Department of Crop Science, Makerere University, explained that biotechnology was broad with wide applications in environment,
medicine, industry and agriculture. He went on and defined plant cell and tissue culture as ‘the technique through which any plant part (other than storage organs) is cultured under a conducive sterile environment with the purpose of obtaining growth.’

He named the applications of tissue culture in plant breeding, industry (secondary metabolites), germplasm conservation, horticulture and forestry. He explained that tissue culture is used in production of disease free plants. He further elaborated the process of producing disease free plants that he said requires a plant tissue culture laboratory, seed certification and system, and trained personnel.

Dr. Mukasa presented a case study of tissue application in the production of disease free banana plantlets. He stated that bananas experience various disease challenges that are compounded by the vegetative propagation methods involving the use of suckers. Tissue culture techniques have been successfully applied in the rapid multiplication of desired banana clones free from diseases. He also noted that millions of quality plants can be produced at any given time and that the technology is very appropriate to other vegetatively propagated crops e.g. sugarcane, flowers, and coffee.

He mentioned that rapid clonal propagation is yet another important application of tissue culture. Over 400,000 plants can be derived from one plant within a year. He highlighted the innovations in packaging of tissue culture plantlets such as the use of small polythene bags to carry many banana plantlets and stated that many farmers have taken up tissue culture plantlets and are now reaping benefits.

Dr. Mukasa also stated the requirements for tissue culture development in Uganda as: optimizing protocols for rapid in vitro multiplication of farmers’ preferred cultivars; optimizing molecular techniques for indexing plants for viruses; good policies that allow and support investment in biotechnology; scaling up the sustainable production, and distribution system of clean tissue culture plantlets through public-private partnerships. He concluded by mentioning that the key players in Uganda’s tissue culture industry are Makerere University Plant Tissue Culture Laboratory, Agro-Genetic Technologies Ltd and the National Agricultural Research Organization.

### 2.2.2 Tissue Culture in Uganda as a business by Mr. Erostus Nsubuga, AGT

Mr. Nsubuga, the Chief Executive of Agro-Genetic Technologies Ltd (AGT) started his presentation by giving an overview of the company. He said that AGT started in 2002 and is currently the only company doing commercial tissue culture (TC) business in Uganda. Currently he said the company produces TC plantlets for banana, pineapple, coffee and aloe vera. Banana and pineapple constitutes 70% of AGT production (approx.1 million plantlets per year).

He then added that AGT has a product and sales distribution network consisting of 23 banana nurseries in four districts and has established demonstration gardens at these sites. These nurseries have helped farmers by providing easy access to any number of their desired planting materials. The establishment of local nurseries ensures farmer participation that has made the technology more acceptable.
Mr. Nsubuga said that the company has expanded and distributes planting materials to Rwanda as well. Transportation has been improved by developing methods that avoid soil since it facilitates transmission of diseases. Improved methods ensure that plants move from laboratories to farmer nurseries directly.

He said the major partners to AGT include; NARO, NAADS, MUK, UNICEF, President’s Office, IITA, APEP, Caritas, VEDCO, Farmers groups, and Africa 2000 Network among others. With help of these partners, AGT has made positive impacts in improving livelihoods of many farmers, especially women involved in the production of bananas. AGT has also created employment and has facilitated the career advancement of their employees.

Mr. Nsubuga outlined the constraints faced by AGT which include: limited awareness among many local politicians and farmers; lack of essential laboratory facilities and materials locally; high production costs, inadequate distribution centres, low capacity to provide local extension services.

### 2.2.3 Farmer experience with tissue culture; by Mr. Musoke Festo, Farmer

Mr. Musoke Festo a Farmer from Mukono District has been growing tissue cultured plantlets and in his presentation mentioned that Banana wilt is destroying bananas in Mukono and Kayunga districts and that NGOs together with NAADS have assisted the farmers by introducing tissue cultured plants that are disease free.

He was the first farmer to benefit from tissue culture technologies in Mukono. It was only after different demonstrations by AGT that people understood that the plantlets would grow into large plants. He appealed to AGT to establish a nursery in Mukono and was granted the opportunity to distribute banana plantlets which earns him about Ug. Shs. 3 million a year.

He said that many farmers have adopted tissue culture plants because they are disease free, they produce large bunches therefore fetching good prices. He noted that the major challenge is the high price of the planting materials, and that Government should subsidise this technology for the farmers. He finally emphasised the need for AGT improve its distribution network.

### 2.2.4 Reactions to the presentations

The session chair thanked the presenters and said the interaction was important as a scientist, an entrepreneur and a farmer all presented their sides of the story. She then invited questions and comments from the participants.

Hon. Olive Woneka began her comments by thanking Mr. Nsubuga for bringing out technology to farmers from scientists. She then asked “Where are the nurseries located?” And followed it up with another question on why AGT is doing big business with Rwanda, she added that “is it because Uganda doesn’t have an adequate market?” She ended her remarks by noting that farmers need motivation before they take up the nursery business.

Mr. Wanzara David, farmer from Masindi asked Makerere University to spread technologies across the country (nationwide).
One of the participating farmers began his remarks by commending Mr. Nsubuga for producing clean planting materials to fight the bacterial wilt. He then inquired to know the steps being taken by government in multiplying Robusta coffee varieties resistant to the coffee wilt.

The farmers’ representative from the West Nile region asked “where can one find tissue culture products in Arua?” and added that there is need for making the technology relevant in West Nile as well.

Another participating farmer inquired on the possibility of establishing a demonstration of the tissue culture technology and a nursery at the Jinja Agricultural show grounds. It was also added that there is need to follow up on the tissue culture products to ascertain if they are indeed disease free in the farmer’s fields.

Olive Nabukonde, the ISAAA representative in Uganda, suggested that UNFFE should start radio stations or programs in local areas to enable farmers acquire more information and knowledge.

The UNFFE Vice-President suggested that AGT should collaborate with UNFFE to liaise with District Farmers Associations to facilitate dissemination of this technology to other areas.

Dr. Arinatwe from NARO urged the farmers not to forget NARO’s role in agricultural research in Uganda.

Hon. V. Sebagareka requested for information on why crops get diseased during the dry season and look fine during the rainy season while it is vice versa in animals as is the case in Kayunga District.

2.2.5 Responses to the reactions

Dr. S. B. Mukasa in his response said that taking technology to the people was a broad task and required multi-stakeholder approaches among the different institutions involved. On managing the coffee wilt disease, he said there is need for the concerned authorities to step in and play their role. He concluded by giving an example of the inter play as NARO could give the materials, Makerere University develops a protocol for mass propagation, and the private sector multiplies and distributes it.
Mr. E. Nsubuga informed the participants that AGT was operating in only four districts in Uganda that include Mbale, Kampala, Wakiso and Mukono. He also added that AGT considered Rwanda largely because the market was organised (orders made in bulk) making it simpler for the company. In Uganda he said, AGT has not formalised any arrangements with NAADS that would facilitate bulk production for the company to enjoy economies of scale.

On the coffee wilt issue he said that NARO has developed wilt resistant lines but are yet to be multiplied. Tissue cultured plants he added should be followed up with good agricultural farming practices as the plants per se are not resistant to diseases but are rather disease free. Pointing out that plants that are not disease resistant before the technology is applied will remain so.

Mr. Tumushemereirwe, a Presidential on Science and Technology, in his remarks said that there was need to conduct research to understand the concerns from Kayunga. He then added that there was presidential commitment to promote biotechnology but parliament needs to fast track the law on biotechnology. He added that a regulatory framework will be developed depending on the law enacted by Parliament.

2.3 Session 3: Biotechnology and agribusiness in Uganda

2.3.1 Panel Discussion on the First Anniversary of OFAB in Uganda

Topic: What are the challenges to biotechnology? Where are the opportunities and what needs to be done to promote biotechnology for agribusiness development in Uganda?

Panellists: Prof. Kenya Eucharia, University of Nairobi
Mr. Henry Kimera, CEO, CONSENT
Dr. Josephine Namaganda, NARO
Hon. Gordon Sematiko, Vice Chair, Science and Technology Committee of Parliament
Peter Wamboga, SCIFODE; Session Chair

Mr. Wamboga introduced the panellists’ and briefed participants on OFAB and its collaborators, adding that OFAB brings scientists together with the public.

2.3.2 Biotechnology for Agribusiness: Prof. Kenya Eucharia

In her submission, Prof. Kenya Eucharia noted the use of biotechnology as a business. She mentioned that the crops being multiplied in Kenya by tissue culture include bananas, flowers, pyrethrum and sugarcane.

She further mentioned that there is need for more discussions with farmers on issues regarding biotechnology and a need for a Biosafety law to guide scientists in Uganda. Other crops that are under research for tissue culture propagation are sweet potato, cassava, maize, pumpkin, yams, aloe vera, and oil palm.

Prof. Eucharia noted that biotechnology has also been applied in clonal forestry for trees such as eucalyptus and jatropha. Other applications and potential for biotechnology include seed
technology, biofuels (not yet fully exploited in Africa), science and technology parks (already started in Kenya).

She said that the major challenges facing biotechnology development in Uganda include; the little or no political will to support research that is directly beneficial, and the slow adoption of new technologies. She added that the way forward relies on information sharing; improved support systems; increased emphasis on value addition; openness to new technologies; and the need to trust scientists in order to build lasting beneficial partnerships. East African scientists cannot be bought to serve non national agendas, as some circles tend to intimate, she said.

Mr. Wamboga, took the opportunity to tell participants that scientists in Uganda are adapting biotechnology to tackle our problems. He then invited Hon Gordon Sematiko to make his remarks.

2.3.3 Biotechnology for Agribusiness: Hon. Gordon Sematiko

In his presentation, Hon. Sematiko said there was political will in Kenya to promote science and technology and that is the reason they have managed to enact a law on Biosafety. He further mentioned that there is political will in Uganda to promote biotechnology but there is need for “practical will” as implementation of some policies remains a challenge. Political will should be measured in terms of the actions on the ground, not through enacting redundant policies.

He emphasised the need to promote agricultural biotechnology and it is not incumbent upon the promoters to explain the perceived negative effects of biotechnology to the public. In other words, the benefits of biotech products should be weighed against the potential risks (actual or perceived) before adoption of these products, he said.

Uganda has adopted the Biosafety policy but there is need for infrastructural development to promote biotechnology in the country. The current infrastructure does not support industrialisation of research products. Hon. Sematiko concluded by saying it is important to improve public awareness on new technologies.

2.3.4 Tissue culture: Challenges and opportunities; Dr. Josephine Namaganda

Dr. Josephine Namaganda in her presentation defined plant tissue culture as ‘the growing of plant parts (shoots, leaves, buds, flowers, seeds) on artificial nutrient medium and illustrated the common approaches used. The success of the propagation process, she said, depends on having the right media composition, aseptic conditions, optimum growth conditions (light, temperature, humidity).

She mentioned the importance of plant tissue culture in pest and disease elimination from planting material, rapid multiplication of planting material (especially vegetatively propagated plants), germplasm conservation, germplasm exchange, other applications in crop improvement (embryo rescue, pollen and anther culture, regeneration of genetically transformed plants).

She highlighted the challenges in the tissue culture industry in Uganda. Which she said include: high cost of production (expensive for farmers), acceptability, misconceptions (super variety,
GMO), availability (limited supply). She finally mentioned the opportunities in the tissue culture industry in Uganda such as banana and coffee success story, business opportunities (in commercial tissue culture laboratories, nursery operation, supplying tissue culture consumables, manufacturing tissue culture material and equipment).

2.3.5 Comments

Participants emphasized the need for strategic interventions in biotechnology development. Parliament is working on several sectoral Bills and hope to engage the line ministers on many of these bills. Mr. Rwakakamba then invited Dr. Sengooba to give highlights of OFAB.

2.3.6 Highlights of OFAB 2008: Dr. Theresa Sengooba

Dr. Theresa Sengooba gave the highlights of OFAB in the past year, she began her remarks by informing the participants that OFAB is designed to bring together scientists and other stakeholders in biotechnology. She also said that several issues had been clarified during the different OFAB meetings that were held in Uganda. OFAB, she said is to continue for several years as there is need for continued interaction between the scientists and the public.

2.3.7 Remarks from a Farmer

He emphasized that this forum is an opportunity for farmers to get information on biotechnology and thanked UNCST for the collaboration with UNFFE. He noted that farmers are the first researchers and should not be ignored and that there should be a good mechanism to distribute research information and products to farmers. Finally, he thanked the presenters for the deliberations.

2.4 Closing Remarks: Hon. Olive Wonekha

In her closing remarks, Hon. Olive Wonekha (Woman MP, Bududa) and Chairperson Parliamentary Committee on Agriculture, Animal Industry and Fisheries, thanked the organizers of the meeting including UNCST, PBS, and AATF. She further added that scientists have done tremendous work in communicating biotechnology information throughout the day. She then suggested that the next OFAB meeting should tackle issues on “How Uganda/Africa missed the green revolution”. She then added that there has been effective collaboration between the different stakeholders in biotechnology and this is a good sign for its development.

Hon. Olive Wonekha also mentioned that efforts in biotechnology (and general agriculture) should be linked to the current global issues such as the rising food prices (opportunity or peril?). Adding that there is need to relate efforts with trade and that the debate should be taken a little further, to handle issues such as climate change, biofuels etc. She then concluded her remarks by calling on farmers to do farming as a business so as to improve their livelihoods and incomes.
Eighth OFAB: Biotechnology research and development in fisheries

3.1 Background

Traditionally, plant and animal breeding has relied on crossing sexually compatible species to improve the genetic makeup of the target species. This approach encountered varying limitations in cases where a desired trait was not present within the primary gene pool of the target species. The advent of modern biotechnological tools such as genetic engineering has however, revolutionised the process of gene discovery and transfer in that genes from unrelated species could be identified and transferred to the target species. A number of crop and microbial products have been developed from genetic engineering and are in use in crop production, industrial processes and in environmental cleaning systems. Genetically modified (GM) crops, as they are popularly known, have been used in Asia, North America, South America, Europe and to a lesser extent, in Africa.

GM crops promise better resistance to biotic and abiotic stresses that can boost food and fibre production in Africa as well as improve the nutritive value of foodstuffs but their use has been restricted to one country in Africa (South Africa), although Burkina-Faso and Egypt have recently approved commercial cultivation of GM cotton and GM maize respectively\(^2\). The reason for this has been largely reluctance by many African countries to embrace the technology, mainly because of negative perceptions on the risks associated with these crops and technologies. Many policy makers in Africa, and indeed the general public, do not clearly understand the benefits and safety of GM crops owing to pessimistic publicity in various sections of the media. The full benefits of such technologies cannot be realised if countries do not make deliberate attempts to safely deploy biotechnology tools in agriculture, industry and environment.

Leading scientists in Africa have stated that modern biotechnology is needed in Africa now, and not in the future, and that the continent needs the technology more than any other continent since food shortages and adverse climatic conditions (drought, floods) greatly affect the continent\(^3\). To promote the adoption and safe use of modern biotechnology in Africa, there is need for the public and policy makers to clearly understand and appreciate the role the technology can play as well the potential risks (if any) posed on the environment and health. Such information can be obtained from scientists but these have limited interaction with the public.

The Open Forum on Agricultural Biotechnology in Africa (OFAB) provides an avenue for biotech scientists to directly interact with policy makers, media, civil society organisations, industrialists and the general public on issues regarding biotechnology. OFAB was initiated in Kenya in September 2006 while the Uganda chapter was launched in December 2007. A number of issues have been addressed in the forum in Uganda, including among others, the interface of

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biotechnology and crop seed systems. By the end of 2008, seven OFAB sessions had been held in Uganda, that included an anniversary session that was attended by several farmers from all over the country.

The eighth OFAB session was held in Kampala on February 27, 2009 and focussed on biotechnology application to the fisheries sector. Dr. Justus Rutaisire, the head of aquaculture research at the national Fisheries Resources Research Institute (NaFFIRI), presented a paper on Biotechnology research and development in fisheries. The fisheries sector world over has been using biotechnology tools in fish spawning programmes and it was therefore necessary to develop biotechnology in the fisheries sector.

3.2 Highlights of the eighth OFAB in Uganda

The 8th OFAB in Uganda was held on 27th February 2009 at the Imperial Royale Hotel in Kampala. The meeting started at 12:50pm and attracted 38 participants from within Uganda. Mr. Wamboga Peter, the OFAB Consultant, welcomed participants to lunch and played a BBC documentary on GMOs in South America, Europe, and Africa during the lunch period.

3.3 Welcome Remarks

Mr. Wamboga Peter, the moderator gave the welcome remarks in which he briefly explained the background to OFAB. He introduced the topic for the day that was focussed on biotechnology in fisheries. He then invited the Guest of Honour Dr. Maxwell Otim-Onapa, from UNCST to give the opening remarks.

3.4 Opening Remarks: Dr. Otim-Onapa

In his opening remarks, Dr. Otim-Onapa, gave a brief on OFAB and welcomed participants on behalf of UNCST, the host institution for OFAB. He mentioned that OFAB helps in enlightening the public on issues and advances in biotechnology and Biosafety. Through the forum, a number of Biosafety issues have been identified and are now being considered in the formulation of a Biosafety law. For example, Biosecurity has now been brought on board after various stakeholders expressed concern at its absence from the draft Biosafety bill.

He stressed that issues of biotechnology need to be discussed by experts in such fora from which the public can obtain information and that UNCST has developed and published the Biotechnology and Biosafety Policy to promote safe use of biotechnology in Uganda. He also noted that focus should now be geared towards how biotechnology can solve current issues in Uganda and beyond.

Dr. Otim-Onapa applauded Dr. Justus Rutaisire for coming to explain what biotechnology can do for the fisheries sector in Uganda and recognised support from AATF and PBS/IFPRI in organising the forum.

Mr. Wamboga thanked Dr. Otim-Onapa for the remarks and informed participants that biotechnology has been in use in many sectors prior to the advent modern biotechnology that evolved after the discovery of DNA structure. He introduced different participants from BIOEARN, PBS, the Media as well as the presenter for the day.
3.4 Key Presentation: Biotechnology research and development in fisheries: does it offer opportunities, for increased and sustainable fish production.

*Dr. Justus Rutaisire, NaFIRRI-NARO*

In his presentation, Dr. Rutaisire gave a background to the fisheries sector in Uganda, comprised of capture fisheries and aquaculture. Aquaculture involves farming aquatic organisms such as fish, mollusks, and algae among others. He noted the decline in fish production from capture fisheries due to increased demand that has led to over exploitation of the waters. This implies that fish consumption in Uganda, and indeed in sub-Saharan Africa, is very low as the majority depend on capture fisheries. The problem is further exacerbated by the current global food crisis.

He noted that real solutions to these problems must come from science through inter-disciplinary approaches involving both the natural sciences and the social sciences. He mentioned that aquaculture, just like any business must be predictable and profitable as well as answer questions related to environmental conservation. Globally, fish production from capture fisheries has been declining in the past 10 years while aquaculture has steadily risen to over 37% of global fish production.

Dr. Rutaisire highlighted several aspects of biotechnology applied in fish farming. These include: gamete production and storage; broodstock development and maturation; incubation and metamorphosis; early rearing, growth rate and feed conversion efficiency; transgenesis and cloning; and stock identification and marking among others. The main area where the technology has been applied is in the reliable production of high quality fish seed. This is enabled through hormone manipulation of fish reproduction through monitoring of fish hormonal plasma levels using biotechnological tool such as ELISA. Chromosomal manipulation has also been used to produce sterile fish.

He observed that sex manipulation (eg. Sex reversal) is yet another application of biotechnology in fish production. This is done to produce fish that either grow first or a single sex desired by the market. This can also aid in genetic improvement of particular fish species.

Dr. Rutaisire also stated that biotechnology is also used in long-term storage (cryopreservation) of gametes to enable use in the distant future. This aids in developing fish breeding programmes independent of maturation period and season. Transgenesis is also being developed to improve genetics of certain fish species for various traits such as resistance to disease and stress.

He then concluded by noting that biotechnology offers a great potential for increased fish production. The challenge however is to strike appropriate balance between realizing the potential for economic development while minimizing any risks to the environment and human health.

The moderator then informed participants that the USA was conducting research on biotechnology in fisheries but no transgenic fish had been developed yet.
3.5 Discussions

*Moses Talemwa, Weekly Observer:* Expressed shock at the similarities between fish and poultry production, especially as regards feed

*Sara Kisolo, RUDMEC:* Why haven’t Ugandans been encouraged to engage in fish farming technologies? What is holding government and scientists from promoting fish farming?

*Henry Bazire, Water Governance Institute:* What are the risks of manipulating fish on indigenous fish diversity? What is the relationship between fish meal fed to chicken and the fishy taste in some poultry products? What are scientists doing to promote fish farming in water stressed regions?

*Dr. Anne Wangai, BIOEARN:* What policy is there for fish biotechnology in Uganda and the region?

*Robert Anguzu, PRO, NARO:* Why are sexual reversals and changes common to fishes? On Biofiltering technologies, can a common man afford such an initiative?

*Henry Lutaya, Sunrise:* How can one get fish feed? I believe all fish feed is imported.

3.6 Responses from Dr. Rutaisire

Dr. Rutaisire stated that the tradition of capture fisheries has been delaying the adoption of aquaculture. Uganda has not had a focus on aquaculture, as has been the case in countries like Egypt that produce a lot of fish from aquaculture. He emphasised more danger in capture fisheries than in biotechnology. But aquaculture restricts these from going into the wild.

He said there is a natural sex change in certain species of fish and that environmental changes can affect this process. He noted that induced sex change is mainly done for commercial reasons. The biofilter is inexpensive since the raw materials are available locally.

He recommended that fish feed should float, and noted that this kind of feed is normally imported. Locally, Ugachic is soon commencing the production of floating fish feed. Climate change affects fish growth and reproduction, on aquaculture in water stressed environments, the problem is not lack of water but water management, he said.

3.7 Response from Mr. Henry Kimera, CONSENT

Mr. Kimera said that the current policy is comprehensive and covers fisheries, industrial development, agriculture etc. On fisheries research, there are policy frameworks that regulate research activities.
3.8 Closing Remarks

As a concluding remark, Mr. Wamboga thanked participants for attending the forum as well as Dr. Rutaisire for making time to share current research on fish biotechnology in the country. He further acknowledged the organisers of OFAB i.e. UNCST, AATF and PBS and the OFAB programming committee that proposed the topic for presentation.
Ninth OFAB: The role of biotechnology in forestry research, development and conservation

4.1 Background

World over, biotechnology has enabled tremendous development of various industries including agriculture, medicine, and food processing among others. Whereas biotechnology has a number of applications in environmental conservation and remediation, little efforts have been implemented in developing countries, where the technology is, perhaps, most needed. Biotechnology efforts in Uganda have been concentrated in agriculture and medicine. In the agriculture sector, modern biotechnologies, including recombinant DNA techniques, have been developed and are currently being tested for a few priority crops in Uganda.

As with all new technologies that are not well understood, there have been wrong perceptions among certain sections of society on the use and risks associated with such technologies. Recombinant DNA technologies, resulting in the production of genetically modified organisms (GMOs), have been used at commercial levels in agriculture for about 13 years. Main countries planting GM crops have been China, USA, Spain, Brazil, India, South Africa, and Argentina. To date, Bt cotton (containing a gene from the soil microbe Bacillus thuringiensis), and Herbicide Tolerant soybean are the most widely cultivated GM crops in the world.

The negative perceptions on GM crops and GM technologies have led to delayed adoption of GM technologies by many African countries. As a means to enlighten the public and other key stakeholders on modern biotechnology use in agriculture, the Uganda National Council for Science and Technology in partnership with the African Agricultural Technology Foundation (AATF) and the Program for Biosafety Systems (PBS) launched the Open Forum on Agricultural Biotechnology in Africa (OFAB) in December 2007. The forum, held monthly, enables direct interaction of scientists involved in biotechnology/Biosafety research with journalists, policy makers, civil society, farmers and other stakeholders. Since its launch, the forum has seen enhanced biotechnology knowledge among many sections of society, including the media, as scientists have given facts to the public. The forum has explained the potential of modern biotechnology, and indeed biotechnology, in improving livelihoods and economic development of Uganda. Many of the myths and potential risks associated with modern biotechnology have also been clearly articulated in OFAB.

The ninth OFAB session in Uganda focused on biotechnology application to the forestry sector. Uganda’s forest cover has been declining at alarming rates, at about 50,000 ha annually,
necessitating strategic interventions in the sector. Elsewhere, modern biotechnology has been applied to improve the productivity, as well as shorten the maturity period of selected tree species. China is the major country that has applied modern biotechnology to transform the Poplar tree that is grown on commercial basis in the country. Dr. Grace Nakabonge, from the Makerere University’s Faculty of Forestry and Nature Conservation, was the main discussant and presented a paper titled ‘The role of biotechnology in forest research, development and conservation’.

4.1 Highlights of the Ninth OFAB in Uganda

The ninth OFAB in Uganda was held on 27th March 2009 at Imperial Royale Hotel in Kampala. The session started at 12:40pm and attracted 53 participants (Appendix 1) that included legislators, academia, researchers and policy makers from the Ministry of Water and Environment. Mr. Wamboga Peter, the Moderator, welcomed participants to the meeting and invited them to lunch. A documentary on GM experiences in Europe, South America, North America and Africa was played during the lunch period.

4.2 Opening remarks

Mr. Wamboga Peter, from Scifode, welcomed participants and gave the opening remarks in which he explained the evolution of biotechnology from the first generation biotechnologies, such as bread baking to the current modern technologies involving transgenesis and gene silencing. He further explained the role of OFAB in Uganda and the need for the public to interact freely with scientists on issues regarding biotechnology. He then invited Dr. Grace Nakabonge to make the key presentation

4.3 Key Presentation: The role of biotechnology in forest research, development and conservation. Dr. Grace Nakabonge, Faculty of Forestry and Nature Conservation - Makerere University.

In her introduction, Dr. Nakabonge (pictured left) said the forestry cover is reducing in the country, and indeed, world over, yet over 90% of Uganda’s energy requirements are provided by Natural biomass such as forests. The main tasks in the forest sector are to conserve biological diversity in the forest ecosystems and production of timber and pulp and other non-timber products. She further noted that:

Biotech is needed in the domestication of native species and plantation forestry because it helps in rapid multiplication of seedlings, replanting of degraded natural forests, development of tree disease diagnostic tools, conservation based on population genetics, and in selection and breeding of new tree species.

Micro-propagation, for rapid multiplication is achieved through various approaches including somatic embryogenesis, cell culture, micro-cuttings, cryo-preservation, embryo rescue and others. Micro-propagation techniques have been tested in many tree species, notably Pinus, Picea, Eucalyptus, Acacia and Populus

Dr. Grace Nakabonge delivers the 9th OFAB key paper
among others. However, most of the activities have been conducted in North America, Asia, and South America, with limited application in Africa, let alone Uganda. Nonetheless, some efforts are underway in Uganda, especially as regards tissue culture based micro-propagation. In Uganda, farmers collect seeds for planting, a process that is cumbersome and greatly limits the number of trees that can be planted.

NFA and NARO also face challenges of getting seeds/seedlings and have relied on receiving clones from Australia, South America and other countries. The Faculty of Forestry and Nature Conservation at Makerere University is currently working with NFA and NARO to develop micro-propagation structures to enable steady supply of sufficient seedlings.

Biotechnology is also useful in characterization of genetic diversity, conservation and in forest health. Studies have been conducted on many tree species eg. Shear nut butter tree. DNA based molecular markers provide an important tool for studying population structure. Common markers used are RFLPs, RAPDs, AFLPs and microsatellites. These studies are mostly in Europe, North America, Asia, and Oceania and mainly involve the species *Pinus, Quercus, Acacia and Eucalyptus*.

On forestry Health (Pathology and entomology), Uganda faces many health challenges such as the Pine wilt disease that is currently affecting several plantations. Biotechnology has been used to study the pathogen and clearly identify it in order to develop appropriate control measures. Samples of the pathogen have been sent to South Africa for genetic analysis. Broadly, biotechnology can be used in pathogen identification, disease and pest monitoring, population biology, and in studying tree defence mechanisms.
Biotechnology is also being used in tree breeding efforts where molecular assisted selection (MAS) is employed in predicting presence of desired genes, such as the genes involved in lignin biosynthesis and water stress tolerance. Again, these efforts are concentrated in Europe, North America, and Asia. The main traits targeted are wood properties, abiotic resistance, genetic diversity, and growth rate among others.

She added that China is the main country planting genetically modified trees in the world. Genetic transformations are being conducted in North America, South America and Asia. Poplar is the most common GM tree under plantation.

Agrobacterium mediated transfer and bombardment are the most common methods used in genetic transformation of trees\(^7\). The traits considered for transgenesis include: faster growth, herbicide tolerance, sterility, reduced lignin biosynthesis, resistance to pests and diseases. Modification of lignin content is through blocking the biosynthesis pathway. Male sterility promotes growth and prevents gene escape from the modified plants, and has been applied in poplars. Main tree species under transgenic research are pine, poplar, birch, spruce and eucalyptus.

USA is the leading country with GM research activities; others are Australia, France, China, United Kingdom, Finland, etc. Avoiding gene escapes is prevented through sterility and use of juveniles. GM trees will be important in the future but there is need for appropriate planning to identify the traits and trees that will be of use for Uganda. Exotic trees can limit escape due to lack of compatible native relatives.

In conclusion, transgenic trees are mainly for improving plantation production with short rotation periods. Transgene escape is the most important concern, but this can circumvented through use of sterile trees. There is need for appropriate bio-policy to promote the judicious use of biotechnology in the country. In Uganda, there is need for research facilities, laboratories, and sufficient funds to achieve significant improvements in the forest sector.

Mr Wamboga recapped the presentation which he said was very informative. He then introduced various personalities in attendance including Hon. Charles Angiro, Mr. Richard Bakoja, Hon. Gordon Sematiko, Hon. Kityo Mutebi and Mr. Julius Ecuru. Mr Wamboga then invited the participants to give their comments and questions.

### 4.4 Comments

**Mr. Pathias Karekona, Environmental journalist, Tree grower:** He expressed concern about the wilt on pine plantations in Uganda. He further asked: Is there a concern by policy makers, civil societies and others on committing finances into tree growing?

**Hon. Charles Angiro:** He observed that native tree species are getting lost, and wondered whether exotic trees being planted are compatible with the local environment. He further mentioned

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\(^7\) See cover photo. Transformation of pine by bombardment followed by somatic embryogenesis. Photo Credit: Grace Nakabonge
that Parliament is not aware of the problems/challenges facing the forestry sector. What trees
would be recommended for quick maturity in Northern Uganda? He asked.

**Mr. Patrick Luganda, Journalist and Chair, Network for Climate Change:** He observed that there
is need for action to curb the decline in forest cover. It seems there is no coordinated effort in
the forestry sector. He further expressed concern on the lack of a needs assessment and focus
in the forestry sector. How much study has been undertaken to coordinate crop agriculture and
forestry, especially as regards disease/pest control? He asked. Monocropping is dangerous, for
instance the planting of too much pine and eucalyptus can cause serious problems in case of
pest and disease attack. There is need for coordination of activities, for example, information
should be availed from the various experts and research centres.

**Mr. Wamoto Nabendeh, WOSSO:** He noted that Mt. Elgon areas have lost forests and soils
through landslides. There is need to get concerned about the loss of biodiversity from Mt. Elgon
regions because this can cause several problems in Uganda, being the source of water for lake
Kyoga, Lake Victoria and many other rivers.

**Mr. Arthur Makara, Scifode:** He wanted to know how many forest pathologists, especially
molecular pathologists, do we have in Uganda? He further asked the policy makers present what
the government is doing to reduce brain drain. What is the technological capacity to handle
molecular biology in trees?

**Prof. E. N. Sabiiti:** He expressed delight with the OFAB forum, and said it was his first time to
attend. In response to a concern by Mr. Patrick Luganda that the scientists are not providing
information, Prof. Sabiiti said that Makerere University has a lot of information that journalists
can retrieve through a simple visit to the university. He then expressed concern that grasses
in certain areas of the country are being wiped out by exotic trees that restrict undergrowth
within their canopies. This, he added, has resulted into landslides in certain prone areas of the
country as the grass layer that usually offers protection against landslides is non-existent when
the exotic trees are finally felled. There is therefore, need to find trees that are compatible
with our ecosystems. Can available laboratories (e.g. Crop labs) be used for forestry research?
Biotechnology can be used to save our country but policies should be developed to ensure safety
and reduce ‘over commercialisation’ (patenting, that may lead to limited use of technologies).
He concluded by thanking the presenter for the very enlightening message.

**Ms. Susan Bingi, Ministry of Tourism, Trade and Industry:** She wanted to know whether Uganda’s
Acacias such as Gum Arabica are useful for further development and how we can offset carbon
from Acacia? (Directed to Prof. Sabiiti)

**Hon. Kityo Mutebi, Scifode:** He expressed concern about the lost forest cover in Uganda, and
believes the biggest culprits are the forest officers. The Local Council System is not good for
conservation as it deters the LC Chairpersons from enforcing developmental/conservation
measures on the local populace for fear of losing subsequent elections. There is need for an
executive decision to restore tree cover in the country. Uganda can learn from Rwanda that has
implemented successful tree planting programs that involve everybody. There is also need for
incentives in forestry, for example Carbon Trading.
Mr. Richard Bakoja, Bakoja Wood Country: He was worried about the drying of pine forests as a result of the wilt. Are we doing anything to conserve indigenous trees? What are the forestry authorities doing to preserve useful genes? It is important to conduct research on forests/farms to encourage learning and adoption.

Mr. Wamboga, the moderator, asked Mr Bakoja to ask the President of Uganda to lead the drive on reforestation.

4.5 Responses from Dr. Grace Nakabonge

Dr. Nakabonge pointed out that there is coordination of activities among the different stakeholders, for example, there are joint proposals for research & development with NaFFORI, NARO, NFA, and Makerere University among others.

Exotic trees are widely used because there has been thorough research on such trees, she noted. Micro-propagation is being developed for native tree species. Exotic species normally perform better in new environments because of limited natural enemies. For example, Eucalyptus does well in Uganda due limited pests and diseases.

On the issue of using agricultural laboratories for forestry research, Dr. Nakabonge said many of these labs and facilities are small and have limited capacity. Funding for research and practical training is very limited in Uganda. Donor funding is competitive with other fields such as agriculture and human health that often take priority over forestry research.

On forestry health, Dr. Nakabonge said collaboration is underway with a biotech centre in South Africa. The wilt causing organism has been sent to South Africa for analysis to determine the exact species. Efforts are underway to conserve native tree species. The Department of Community Forestry at the Faculty of Forestry, Makerere University, is currently in attempting to conduct forestry extension services.

Mr. Wamboga reiterated the concern of limited funding, but wondered how much money is needed, and how it should be channelled to achieve results.

Hon. Angiyo: The amount of money needed depends on the amount of forests required. The scientists should recommend policies to government on tree planting. Politicians should be more assertive in implementing policies. The government needs to take action to reduce brain drain, by encouraging incentives to local scientists.

Ms. Rachael Musoke, Commissioner, Ministry of Water and Environment. She said that she was happy with the forum, and thanked the presenter for the very informative paper. She further mentioned that she studied breeding in forestry, and therefore the paper was very timely. We need biotechnology now to develop the forestry sector.
The current status of forest management in Uganda is as follows: 15% under NFA, 15% under Uganda Wildlife Authority, 70% is under district forestry services with only 1% of this being under district management, the 69% is under community management. Limited funding restricts forest development at the districts.

She noted that forests are disappearing at alarming rates, about 50,000 hectares per year. The largest part of this loss is in the community. The limited staffing of forestry officers on the ground exacerbates the problem.

On concern about forestry officials contributing to forestry loss, she said limited resources affect conservation efforts even though the staffs are not necessarily without blame. Forestry research is being conducted by NFA and NARO.

Biotechnology has come in timely to quicken research efforts. However, there is limited biotech capacity in Uganda; eg. Labs are few, few breeders, few pathologists etc. There is need to train more officials for continuity of research. We could also invite foreigners to conduct gene mapping activities so as to develop and promote indigenous species/genes. Onfarm research is very important, she said. Tree planting initiatives are very important in the country eg. The use public holidays to plant trees. The Farm Income Enhancement Project is good but is targeting only a few sub-counties.

4.6 Closing Remarks

Mr. Wamboga thanked the presenter, the commissioner and the participants for attending the meeting and encouraged them to keep attending. He added that the next OFAB meeting would be in the last week of April. He announced the Biotechnology Conference that is due in March 2010.
Tenth OFAB: Impacts of banana and coffee wilt diseases on Uganda economy; biotechnology research and development interventions, legal and policy constraints

5.1 Highlights from tenth OFAB

The 10th edition of The Open Forum on Agricultural Biotechnology in Africa (OFAB)—Uganda took place on the 29th May, 2009 and was opened by Mr. Peter Wamboga-Mugirya—the Director of Communication and Partnerships at the Scifode, who warmly welcomed all participants to the forum, especially the Members of Parliament (MPs) present. In his remarks, Wamboga-Mugirya gave a brief and simple definition of Biotechnology as a science that deals with solving the problems that scientists and the public find affecting animals and plant lives. He explained that Bio refers to life, while technology is the tools or mechanisms that are used to safeguard or improve on plants’ performance in the case of agriculture, hence the term: Bio-technology.

He told participants, among them six MPs, senior civil servants, farmers’ representatives, the media, business executives and scientists, that OFAB was launched in Uganda in December 2007—making Uganda the second African country to host OFAB, after Kenya where OFAB was incepted and was first launched in Sept. 2007. He also informed the meeting that Nigeria and Tanzania were now the third and fourth African countries, respectively to launch OFAB chapters in 2009 after Kenya and Uganda [2007]. Other participants included representatives from civil society organizations, higher institutions of learning i.e., Makerere and Kyambogo Universities and Bukalasa Agricultural College; and senior biotechnology scientists from the National Biotechnology Centre (NBC) of NARO/NARL at Kawanda namely: Dr. Andrew Kiggundu (the day’s presenter); Dr. Geoffrey Arinaitwe; Dr. Josephine Namaganda and Dr. David Talengera, just to mention but a few.

Mr. Wamboga-Mugirya reported that so far this was the 10th OFAB—Uganda chapter programme since its launch by Hon. Eng. Hillary Onek, the then Minister of Agriculture, Animal Industry and Fisheries (MAAIF). One of the major objectives of OFAB, Mr. Wamboga-Mugirya said, is to help improve public understanding and appreciation of the science of biotechnology particularly in agriculture, which scientists are applying, especially the use of branch/tools of modern biotechnology, known as genetic engineering/modification, to improve agro-output and productivity in Africa. He said alongside Biotechnology, concerned authorities apply what is known as Biosafety which is the assurance that biotechnology is applied safely, without harm to human health and the environment, adding that today the world is concerned about emerging challenges of Bio-terrorism—the abuse/misuse of biotechnology. But, he said, scientists have introduced measures termed as Bio-security with which to manage Bio-terrorism.
5.2 Key presentation: Impacts of the Banana and Coffee wilt diseases on Uganda: Biotechnology Research and Development Interventions.

Andrew Kiggundu1, Wilberforce Tushemereirwe1,2, Geoffrey Arinaitwe1, David Talengera1, Charles M. Changa1, Yona Baguma2 and Africano Kangire2

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2National Crops Resources Research Institute, Namulonge (NaCRRI), P. O. Box 7084, Kampala, Uganda.

Introduction
Uganda has a population of 25 million people with an annual growth rate of 3% living on a land area of just under 200,000 sq kms. This makes it one of the most densely populated countries in Africa. More than 80% of the Ugandan workforce is involved in subsistence agriculture, earning less than a dollar per day. Increasing crop and animal productivity, improved human and animal health, industrialisation and environmental protection are important for improving food security, poverty eradication and national development. Investment in modern biotechnology (new engine of economic transformation) is one of the options that can significantly contribute to national development. The choice biotechnologies include agricultural biotechnology, medical biotechnology, environmental biotechnology, industrial biotechnology, biosafety and biopolicy.

Biotechnology research for development in Uganda
At Makerere University the oldest university in Uganda, the departments of Crop Science, Biochemistry, Veterinary Parasitology and Microbiology, Medical Microbiology and the institute of Environment and Natural Resources, have fully operational laboratories undertaking various research projects with different types and levels of biotechnology application. Most of these are molecular biology and tissue culture for crop improvement, diagnostics, understanding genetic resources and their ecology, bio-prospecting and product or process development.

The National Agricultural Research Organisation (NARO) is a major biotechnology developer in Uganda. The National Agricultural Research Laboratories at Kawanda has a busy biotechnology centre where work on marker assisted breeding of beans and bananas; tissue culture of banana and coffee; and genetic engineering of banana. Other NARO institutes with capacity in biotechnology work are the National Crops Resources Research Institute, Namulonge, doing molecular biology of cassava and potato; tissue culture of cassava and sweet potato and genetic engineering of cassava is in its initial stages. At Kachwekano Zonal Agricultural Research and Development Institute (KAZARDI), tissue culture and virus indexing of Irish potato is fully developed. The National livestock Resources Research Institute, in Tororo uses molecular tools for animal disease diagnostics for epidemiological studies.

Two national medical research institutions, the Uganda Virus Research Institute and the Joint Clinical Research Centre are employing biotechnology techniques for human disease identification, diagnostics and drug development. Recently the Uganda Industrial Research Institute (UIRI) started production of kits for livestock disease diagnostics and vaccines.

Two privately owned companies are involved in biotechnology related activities, Agro Genetics Laboratories Ltd, at Buloba, in Wakiso district undertakes provision of tissue culture derived planting materials of banana, coffee, pineapple and other horticultural crops. While Med Biotech Laboratories (MBL), in Kampala is a medical research private entity working on new options for...
malaria and TB control in Uganda.

Uganda National Council for Science and Technology, the Ministry of Agriculture Animal Industry and Fisheries, Uganda National bureau of Standard as well the National Environment Management Authority are the competent authorizes for the regulation of biotechnology research, development and commercial use in Uganda.

**Why Agricultural Biotechnology**

Most of the agricultural production in Uganda is characteristically subsistence in nature. The bulk of farmers are home growers mainly for food and then sale. Meanwhile a multitude of pest and disease constraints are being experienced by these farmers and these largely reduce production in some cases leading to devastating crop losses and food security risk. But subsistence farmers lack the money to invest in chemical control and even have very little knowledge on how to use them safely. This leads to the need for constant provision of new varieties, with resistance to the pests and diseases; therefore, at NARO crop breeding is central to the research agenda and is considered a central pillar in integrated pest management systems for agricultural protection.

However the subsistence cropping system especially in the central south western regions of Uganda is characterised by large production of vegetatively propagated staple starch crops such as cassava, banana and potato (sweet and Irish). These crops have very difficult genetic backgrounds such as polyploidy (multiple copies of the genome, in some cases different genomes), They have long generation time especially cassava and banana but also they are highly sterile and conventional crossbreeding relies on unpredictable chance selections, which can take a long time to generate a farmers acceptable new variety. Finally due to vegetative production, the same varieties are grown over and over again, leading to very low genetic diversity and there is a general lack of sources of resistance for an effective breeding programme.

Biotechnology comes in to rescue the situation where by the new scientific understanding of how genes function has led scientists to be able to directly insert genes controlling desired traits such as disease resistance without having to alter any of the other values such as taste and other farmer preference attributes. Biotechnology also offers time and cost effective development of resistant varieties with other productivity and health attributes that were never thought possible before, such as delayed ripening of fruit produce, shortened maturity periods, and increased micronutrient content such as vitamin-A, iron and zinc.

**Banana and the banana bacterial wilt disease**

Banana is the most important food crop and second most important cash crop in Uganda it is a key economic resource that serves as both a food and cash crop, accounting for 8-22% of national rural revenue. It is a high yielding staple food reaching up to 60 tons per hectare per year and no other crop can reach this yield potential. It is least disturbed by season imperfectability and because it grows and produces all year round it provides continued food supply and income for families. It also has a high industrial potential and under the Presidential Initiative for Banana Industrial Development, various value added food and fiber products are being explored for industrial development. Because of these values banana has remained a very important national crop and its cultivation has recently been seen moving into nontraditional growing areas of north western Uganda. However despite increased production, productivity has generally been on the decline. This is attributed mainly to a host of pest and disease constraints, including the banana weevil stem boar, root parasitic nematodes, black sigatoka fungal disease, fusarium wilt and the recent outbreak of the dreaded banana bacterial wilt (BBW).
BBW is caused by a bacterial pathogen, Xanthomonas campestris pv. Musacearum and screening studies have found all banana cultivars to be susceptible to the disease. It destroys up to 90% of a plantation and has been reported to cause a national GDP loss estimated at $360 million p.a (i.e., 90% of Banana contribution to GDP). It is spread mechanically by flying insects visiting flowers and farmer’s tools from infected plants to un-infected plants. The symptoms include wilting of the plant, yellowing leaves, premature and uneven ripening of the fruit and eventual death of the plants. On cutting through the stem or the fruits of an infected plant, bacterial ooze (similar to puss) can be seen. A national task force was mobilized to spread field sanitation control strategies to prevent spread of the disease. In the last two years, the spread of the disease has been stopped and the disease is nearly under complete control. However farmer sensitization needs to continue.

**Biotechnology for BBW**

Meanwhile at NARO, the Banana programme is undertaking the development of resistant varieties using genetic engineering. Two genes have been inserted in to Matooke varieties, and preliminary laboratory and greenhouse testing is underway at Kawanda. This work which is a collaboration between NARO, the International Institute of Tropical Agriculture (IITA) and the African Agricultural Technology Transfer Foundation (AATF) was started after the realization that there were no banana varieties with resistance to banana bacterial wilt. The genes being used were isolated from pepper by Academia Sinica biotech startup of the University of Taiwan who out-licensed the gene technology to AATF to be used for the development of bacterial wilt resistant bananas for Africa.

**Coffee and Coffee wilt disease**

Uganda is one of the five leading coffee growers and producers in the world. Mainly two types of coffee are grown; Arabica in the highlands and Robusta in the lowlands. Coffee supports the livelihoods of about 5 million people in Uganda involved in its cultivation, processing, marketing, and export. It contributes 20 - 30% of the foreign exchange earnings and is produced mainly by the 500,000 smallholder farmers, with less than 0.5 to 2.5 hectares.

Almost all the coffee trees in Uganda were planted over 50 years ago and have surpassed their biological optimum potential and therefore are not economically productive. The old trees coupled with poorly managed and leached soils have led to very low yields per unit area, (low productivity) and hence lower quality. The low input system used by most farmers is less profitable especially during this era where there is scarcity of land. Farmers have not put to optimum use the land and labour available to them in order to make profits. Consequently, low volumes of coffee exports, (oscillating between 2 to 3 million 60 kg bags per year), have been realized over the years;

To put more nails in the coffee coffin, the out break in 1993 of the dreaded the Coffee Wilt Disease, (CWD) had by 2002 reduced the Robusta coffee tree plantings by an estimated 50 percent (slightly over 150 million trees) of the overall tree population has been infected by the disease and died. The disease therefore has resulted in serious impact on the Ugandan population depended on coffee through reduced incomes.

CWD attacks all stages of growth of the plants and symptoms include wilting, defoliation, and streaks in the wood leading to plant death, berries ripen prematurely and dry up. It spreads with infected plant material (reuse of infected plants for firewood, seedlings), contaminated soil
or tools, wind, water, and other mechanical means. The Coffee Development Authority (CDA), NARO and the MAAIF have been instrumental in advising farmers on how best to prevent spread of the diseases to new areas such as; prevention of wounding of plants during field operations like slashing and digging, provide coffee trees with adequate nutrition through application of fertilizers and manure, mulch to conserve moisture and soil nutrients as well as other field sanitation measures like quarantine timely uprooting and burning of newly infected coffee trees, avoid the re-use of infected trees such as for fencing, use of clean planting materials derived mainly from tissue culture, avoiding use of coffee husks as mulch, avoiding and adhering to strictly no movement of coffee materials across districts, Coffee improvement and biotechnology applications.

The development of varieties with higher levels of CWD resistance appear to be the most promising approach and at NARO molecular diagnostic techniques have been developed for detection and screening of varieties with resistance to CWD and coffee lines with resistance to CWD have been identified from a wide range of local and introduced germplasm. Twenty 24 lines of Catimor arabica (dwarf coffee) commonly referred to as Tuzza varieties have been selected for country wide trial to test their resistance in different environments but also other agronomic benefits such as resistance to drought and productivity in the low lands where only Robusta coffee is grown.

The new national strategy for coffee improvement combined selection of new improved varieties with high productivity attributes to be used to undertake a massive replanting exercise to replace the old, diseased coffee trees with new, genetically pure and high yielding coffee varieties at a rate of 2-5% per annum, targeting to reach 200 million plants by 2015. Coffee tissue culture currently being undertaken at Kawanda is seen as the engine behind this massive replanting exercise, because it can be used to produce hundreds of pathogen free genetically identical plantlets from small tissues in a short time. Already the selected varieties are being micro-propagated at Kawanda where the propagation cycle has been reduced from 9 to 6 months.

In future NARO would like to initiate molecular and biochemical analysis to predict coffee taste quality in breeding lines to assist reduce breeding period of coffee from 2 – 3 years. Other future breeding strategies will target climate change. It is expected that if Uganda’s temperature raises by 3°C this will adversely affect Uganda’s coffee production by 80% and restricting it to the cooler highlands. Genetic engineering tools may need to be employed to archive drought and high temperature resistance.

**Challenges to Agricultural Biotechnology R4D in Uganda**

- Complete set of human capacity to create the critical mass needed to move biotechnology forward in all spheres. Medium and higher institutions of learning need to recognise biotechnology and develope curriculum that highlight its importance.
- Utilities, such as irregular electricity supply affect bioscience laboratories with temperature sensitive biological materials
- Procurement problems, the new public procurement and disposal regulations do not easily facilitate the specialised procurement of bioscience supplies. Lack of specialised supply and support companies located in Uganda
- Public awareness in biotechnology is largely poor in Uganda, most people are misinformed about biotechnology in general and have obtained the little information from misinformed
media, community leaders and NGO’s with an anti biotechnology agenda.

• Lack of adequate funding, Biotechnology research and development is expensive and more funding is needed to continue its development.
• Despite a very good government policy toward biotechnology and financial support research in the area, the law governing and regulating the technology is still not in place. This will hinder the commercial deployment of the technologies.

The way forward

• Advocate quick enactment of the enabling law on biotechnology
• Continued capacity building and building partnerships with all public and private stakeholders
• Invest in demand-driven and impact oriented research both for agricultural production and value addition for industrial development
• Strengthen Public and Private Biotechnology linkages to fully exploit biotechnology
• Integrate use of biotech tools into broader research and training
• Promote and strengthen partnerships with the donor, research communities and regional networks e.g. USAID, RF, B&MGF, NEPAD, ASARECA, BECA
• Establish biosafety competence for the safe commercial utilization of biotechnology
• Continued public awareness and education
• Networking amongst institutions involved in biotechnology

5.3 Remarks

In his remarks, Hon. Kigyagi said: “I’m surprised that up to now the national biosafety bill is still in draft form and not anywhere near the floor of parliament!! I hereby advise the sponsors of OFAB, to arrange similar meetings (OFAB) for Cabinet Ministers with Dr Kiggundu’s presentation to enlighten them on the science of biotechnology and its immense benefits. This would help cabinet to ask their colleague—the Minister of Finance, Planning and Economic Development—to bring the draft bill to cabinet for debate. In W. Africa, I have noticed two blocks of tug-of-war between Francophone and Anglophone countries over biotechnology which is slightly modern and more developed than ours. Is there a similar kind of rivalry in Uganda at the institutional level, hence the delay in enactment of the law?”

Hon. Kigyagi thanked by Dr Kiggundu for a well thought presentation; it has highlighted possible solutions to the devastating pests and diseases in bananas and coffee. He said that drought regions like Karamoja need genetically-modified crops that withstand droughts and have better yields. Even information about bananas being able to grow up to 60 metric tones per hectare annually is impressive. When will you grow bananas in northern Uganda?

Kyambogo Student: Why is it that Genetically Modified Food is not being allowed freely for human/consumption and yet broiler chicken is allowed to be consumed?

Ms. Rosemary Anyait Deputy (Principal of Bakalasa Agricultural College in Wobulenzi-Luwero): Why can’t Biotechnology program/course be extended to our college? Our students only visit Kawanda Research Laboratory Institute doing field work and so they gain very little yet given the great potential/attached to Biotechnology, they would really benefit a lot and as frontline extension workers, they would use biotechnology to solve farmers’ problems.
Another Kyambogo University Student: Students admitted on government sponsorship on Biological courses, argue that a majority of them tend to change to other courses, and they end up as private students yet if there was an arrangement to have them sensitized about the benefits of Biotechnology, most of them would retain their courses. They promised to campaign for Biotechnology studies at Kyambogo should there be support from the National Biotechnology Centre (NARO/NARL), Kawanda.

Kyambogo University Student: How can the grass-root people who are the banana farmers and victims of diseases and pests that destroy bananas and coffee benefit from Biotechnology?

Hon. Beatrice Anywar: I’m highly concerned about the increasing levels of brain-drain of our scientists to developed countries, after knowledge has been acquired from NARO and other areas of scientific research. These recipient countries grant citizenship to those they have taken and motivate them with high pay. One example is this scientist who renamed Xanthomonas Campestris Musacearum (BBW). He is here in The Science Times magazine! What mechanisms has the Government put in place to guard against this brain drain?

In response to some of the issues raised by Dr Kiggundu and participants, the moderator Mr. Peter Wamboga-Mugirya first of all challenged legislators to prove him wrong when he said most political leaders in Uganda spend most of their vital time politicking at the expense of matters related to food production, agriculture, science and technology.

On matters of industrialization, he argued that despite the fact that bananas have very high industrial potential through the existence of Biotechnology in Uganda, Investment is still hard why? to this the solution lies primarily on the formulation of legal framework by parliament who have the mandate to make enabling laws. On the question why Biotechnology is being left behind in Uganda? It brings us to the same issue of enabling law. Acquisition of new technology is possible according to NARO/NARL and UNCST. However, it is difficult to implement it in Uganda, why?

5.4 Response

Dr. Andrew Kiggundu argues that all is possible if there is availability of funds. The economy of Uganda is based on agriculture, with more than 90% of exports being agricultural products. Despite continuous price fluctuations in world coffee markets coffee cultivation has remained viable means of livelihood for the people of Uganda. Coffee provides employment for over 2.5 million people involved in cultivation, processing and trading. An estimated 270,000 hectares of Uganda’s farmland were dedicated to Robusta coffee production prior to the appearance of the wilt disease in the early 1990’s, said Hon. Beatrice Anywar.

5.5 Closing remarks: Hon. Beatrice Atim

In her closing remarks, first of all - thanked the organizers of OFAB for choosing her to officiate at the closing ceremony. I am most honored, she said, to partner with the great scientists of this country and I hope we shall network to cause change especially in Uganda’s agricultural sector. Hon. Beatrice Atim – Shadow Minister for Water &Environment in her closing remarks, first of all thanked the organizers of OFAB for choosing her to officiate at the closing Ceremony at the first time of attending OFAB to which she was highly privileged. She said the economy of Uganda
Coffee is vital to the economy of East Africa, providing a major source of foreign exchange earnings and as a cash crop, supporting the livelihoods of millions involved in cultivation, processing, marketing and export. But coffee wilt has spread to all Robusta coffee growing districts in Uganda, killing an estimated 14 million trees. Currently, the only methods of control are improved crop management strategies together with sanitary measures. However, these methods do not offer effective disease control and are expensive and impractical to implement.

Scientists also say that Uganda is losing billions of dollars to banana wilt disease that is destroying banana plants in the mainly banana producing regions of Uganda. It is estimated that the overall economic loss to the banana wilt disease is between $2 billion to 8 billion in the last 10 years while the production loss is estimated at about 53% in cooking bananas in the next 10 years if the disease is left unchecked.

According to a study, food security for about 100 million people and income to millions of farmers in the Great Lakes region of East and Central Africa face great threat from the deadly disease. An overall economic loss of over $2 billion was noted in the last 10 years of the disease. If BXW is not controlled, Uganda stands to lose an estimated 295 million dollars worth of banana output valued at farmgate prices, and income per household.

In this case genetic modification offers a low-cost and timely solution to the farmers, who are reluctant to use labour-intensive control measures. Awareness campaigns, advocacy and support from policy makers and the donor community are critical to help mitigate its impact on affected farmers and their households. The strategy to achieve this goal will be based on the use of cumulative power of current methods of molecular ecology, soil biodiversity studies, phylogenetic analyses and the progress in the area of biological control. Once the potentially active isolates for biological control are obtained it will be possible to introduce in the agriculture, easy to handle and multiply, cheaper for large scale use, safe for application by farmers of different levels, once applied it will maintain there for longer time and no need of reapplying. In general, this will be farmers driven technology and the most important thing is environmentally friendly.

5.6 Conclusion

This is the time that as a country, Uganda should take improving agriculture as a priority to ease poverty, secure food and earning a living for our people. Legislators ensure that the necessary laws and policies are in place to enable scientists guide us on the way to go, Biotechnology and Biosafety. Governments must be forced to take what matters to Ugandans i.e. Agriculture as a priority by allocating enough funds. Scientists, create a Forum of Biotechnology in Parliament as a linkage with legislators.
Eleventh OFAB: Biotechnology research and development in Uganda’s livestock sector.

6.1 Background

Uganda’s economy is heavily pivoted on agriculture that employs over 70% of the populace. The agriculture sector is constituted from crops, fisheries, forestry and livestock that are each practiced at both commercial and subsistence levels. All these sub-sectors require sufficient investment in research and product development as a number of challenges face the farmers, who are needless to say, mostly resource limited. Technologies have been developed and advanced to fight some of the challenges such as pest and disease burden as well as low genetic potential.

The livestock sub-sector is particularly constrained by array of disease and pest problems, many of which have no readily available treatment. The common diseases on livestock in Uganda include Foot and Mouth Disease (FMD), Rinderpest, East Coast Fever (ECF), Trypanosomiasis, Newcastle disease, swine fever, and worm infestation. The problems are compounded by the low genetic potential of Uganda’s local livestock breeds. The challenge therefore, is to reduce disease burden (effective control measures) as well as improve the farmers’ local breed of livestock. Biotechnology provides several opportunities to address these constraints through use of efficient methods for disease diagnostics, vaccine development, and genetic improvement. Efforts are underway at Makerere University and NARO to; develop vaccines for some of the neglected diseases, develop diagnostic/epidemiological tools for ECF, use indigenous cattle breeds to enhance resistance to ECF. Transgenic approaches have also been directly used in producing an anti-disease vaccine against trypanosomiasis from tobacco.

Despite the clear role of biotechnology in complementing efforts in agriculture, little knowledge among farmers and policy makers has limited the wide adoption of already developed biotech products. In addition, there are few, or no supporting laws for biotech research and development in Uganda. There is need for communication channels through which scientists can interact with

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the public, including policy makers and farmers, on matters pertaining to new developments in biotechnology that promise clear solutions to many a farmer’s concern. The Open Forum on Agricultural Biotechnology in Africa (OFAB) – Uganda Chapter is one such avenue for information exchange among scientists, policy makers and farmers on issues pertaining to agricultural biotechnology. This will aid decision making among policy makers as well as the general public, as facts presented by scientists will demystify any concerns harboured by the public.

Since its inception in December 2007, ten (10) OFAB meetings have been held in Uganda, each touching a different topic and audience. The 11th OFAB in Uganda was held on June 29 2009 with the theme ‘Biotechnology research and development in Uganda’s livestock sector’. Prof. George William Lubega from Makerere University’s Veterinary Faculty was the key presenter.

6.2 Excerpts from 11th OFAB in Uganda

The 11th OFAB meeting in Uganda was held at Shanghai Restaurant in Kampala, which was also the location at which OFAB Uganda was launched nearly two years earlier. The meeting started at 1:45pm, when the moderator, Mr. Peter Wamboga welcomed participants. A total of twenty three participants were present and this included six members of parliament from several sector committees.

6.3 Welcome remarks

Mr. Wamboga Peter, the moderator for the day gave the welcome remarks in which he provided an introduction to biotechnology in Uganda. He mentioned the status of biotechnology research and development in Uganda, including confined field trials of transgenic banana, cotton and cassava. Today’s OFAB, he added, will highlight efforts in livestock biotechnology research and development. The safety of biotechnology is ensured through appropriate Biosafety measures.

6.4 Key Presentation: Biotechnology research and development in Uganda’s livestock sector: economic implications, opportunities and benefits.

Prof. George Lubega, Department of Veterinary Parasitology and Microbiology, Makerere University Kampala, Uganda

Prof. George Lubega, in his presentation noted that; Biotechnology is part of agricultural modernization but requires research for proper development. Research can be basic or applied. Basic scientific research is mainly conducted by academic institutions to discover new science. Research for development implies application of existing science to produce new products.

Several issues in Uganda’s livestock sector require research and development; these include: poverty/subsistence production, poor breeds, diseases and low rate of technology adoption. Biotechnology implies use of living organisms to solve problems or make products for the benefit of mankind. The technology has been revamped with advances in DNA technology and information technology.

ICT, through bioinformatics, has boosted biotech development by enabling efficient gene identification and mapping. DNA technology involves the cutting, transferring and rejoining
genetic material from different sources. The process is easier with plants compared to animals, although a few success stories have been recorded in certain animals. For instance, mammary gland bioreactors have been developed in some animals to produce useful products.

He noted that many of the research efforts on livestock biotechnology in Uganda is funded largely by donors. In Uganda, a few efforts are underway to utilize biotechnology for livestock research and development. These are:

- Development of trypanosome vaccine using tobacco. Mice treated with the vaccine showed promising results.
- Diagnosis of trypanosomiasis using the Dip Stick Method.
- DNA based diagnosis for Taenia spp.
- Reverse line blot for diagnosis of East Coast Fever and other parasites.
- Improving local stock.
- Development of resistance markers for improving the existing vaccine regime.

Mr. Wamboga: Thanked the presenter and said the information is useful to the public and the policy makers present. He defined some of the terms used in Prof. Lubega's presentation and also noted that additional funding for biotech research in Uganda comes from ASARECA and the Bill and Melinda Gates foundation. There are other biotech initiatives in Uganda, such as: the Water Efficient Maize for Africa project; biotechnology in fisheries; and biotech projects in crops. There is however need for an enabling law to allow biotech products to be availed to the public.

6.5 Discussions

Dale Mutabiirwa, Africa for Peace: Biotechnology is very relevant to the country but there is need for a legal framework that supports the research. I support and applaud the efforts in biotechnology in Uganda. There is need for a special session of members of parliament on biotechnology. There is also need for lobbying in this regard.

Should the population be involved at early stages of process development? For example, should knowledge on biotechnology be extended to people through extension agents at sub-county level? The curriculum development institute of the Ministry of Education should be invited so that the agriculture syllabus can have a section on biotechnology so that understanding is developed early. How is ASARECA's information database useful to Uganda?

Peter Wamboga, Scifode: ASARECA has a Regional Agricultural Information Network (RAIN) that provides an avenue for agricultural information gathering, exchange, packaging, dissemination and utilization for economic growth. There is indeed need to have presentations made to parliament.

Hon. Lastus Serunjogi: There is need for linkages between researchers and industry, through for example nucleus seed or prototypes. Prof. Lubega, are you linking your research with National Animal Gene Bank? Why isn’t bioterrorism included in the Biotech Safety Bill?

Hon. Gordon Sematiko: The Faculty of Veterinary Medicine at Makerere is doing a great job, farmers should consult them. Are there any relationships with NARO on disease control and
research? About timing of information flow to farmers, in Uganda, farmers are interested in the final product rather than the process of developing that product. Are there any linkages with UIRI, they seem to be working on releasing a vaccine? There are several attempts underway to sensitize MPs, for example the PBS/NARO/UNCST meeting with legislators held at Kawanda in May 2009. There is however need to package information properly, to ensure simplicity in understanding. What causes several deaths of pigs in the country, farmers are abandoning pig production?

6.6 Responses from Prof. Lubega

He said that information is sometimes available at the start of a research project, but only models can be used to encourage industry. On involving the public early, this really depends on conditions at play. For instance, the subsistence nature of farmers makes it difficult to inform them early enough since they expect products immediately and sometimes expect it free of charge.

Countries like Malaysia deliberately created the private sector, Uganda could borrow a leaf as our private sector may need a push. Funds limit communication/awareness campaigns in schools and other educational institutions. Linkages are sometimes difficult to follow-up. NARO and Makerere work together on many initiatives.

On pigs dying, he said there are many limitations on research into such situations because funding is mostly donor driven and the donors or private companies shun away from solving such problems because they are largely an African problem.

6.7 Remarks

Hon Dombo: Are you doing any research on human cells?
Prof. Lubega: No, the faculty of veterinary medicine is not conducting any GE research with human cells
Peter Wamboga: The biotech bill formulation started a long time ago, before issues of bioterrorism came up.
Robert Kasozi, Journalist: We cannot separate aspects of regulating bioterrorism from the biosafety bill.
Hon. Dombo: How can we incorporate a specific section on bioterrorism on the biotech safety bill? We shall present biotech issues in parliament this week as the state of the nation address is being debated
Peter Wamboga: Bioterrorism is broad and needs a separate law.
Prof Lubega: There is need for more funds for science development, MPs could help with this.
Twelveth OFAB: Biotechnology and bioremediation of polluted environments; research and development in Uganda

7.1 Background

The rapid urbanisation in Uganda and parallel industrialisation within cities and towns has dramatically increased waste production. The wastes include wastewater from domestic use, wastewater from industrial processes, solid wastes, agricultural chemicals and chemical wastes from several industries. The country has established policies to protect the environment but overall, the management of these wastes has been, to a large extent, lacklustre. Only a few industries have established systems to effectively manage their wastes, the rest dump their wastes into streams, wetlands or land fills.

The challenge in industrial and domestic waste management is a global issue that has attracted significant research into more efficient methods to mitigate effects of waste in the environment. Synthetic polymers, plastics and heavy metals are key pollutants because of limited or no natural biodegradation capacities. Uganda, for instance, has abolished the use polythene bags due to concerns of pollution and persistence in the environment. Research efforts worldwide are now geared towards development of microorganisms with ability (or increased ability) to degrade such toxic wastes. Such methods, collectively termed bioremediation, are gaining grounds because of several advantages they possess over ‘quick fix’ methods. Bioremediation is often less expensive than alternatives, can be done onsite, and is environmentally benign. Plants are also being genetically engineered for increased uptake of heavy metals such that contaminated lands/wetlands can be cleaned.

Increasingly, biotechnology approaches have been (are being) developed to manage wastes from industrial, domestic and agricultural activities. Advances in biotechnology have made bioremediation the most rapidly growing field of environmental restoration. Microorganisms have been used to detoxify environments off plastics, industrial solvents, metals, petroleum hydrocarbons, and pesticides among others. Some of the microbes have been isolated from polluted environments while others have been genetically modified to alter or create metabolic pathways than can effectively degrade specific pollutants.

Plants capable of accumulating high concentrations of heavy metal have also been identified and used to detoxify polluted soils (phytoremediation). New methods involving plant growth promoting rhizobacteria (PGPR) have been developed since such bacteria increase absorption

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of particular nutrients from the soil. PGPR have been genetically engineered to degrade and mineralise organic pollutants as well as metal pollutants in combination with selected plants\textsuperscript{15,16}.

In Uganda, several applications of microorganisms are feasible in bioremediation projects\textsuperscript{17,18}. Research is on-going to use selected microorganisms in treating wastewater from abattoirs. The potential of biotechnology for remediation of polluted sites and treatment of waste can only be realised if the technology is fully embraced and safely applied. The Open Forum on Agricultural Biotechnology in Africa (OFAB) was created to link biotechnology scientists directly to policy makers, general public and the media so more informed decisions are made by the different stakeholders. OFAB Uganda-Chapter is organised by Uganda National Council for Science and Technology in collaboration with the African Agricultural Technology Foundation and the Program for Biosafety Systems. OFAB is held monthly and 12 meetings have been held since inauguration of OFAB in Uganda.

The 12th OFAB meeting in Uganda was held on July 31 2009 with the theme ‘Biotechnology and Bioremediation’ and the presentation was made by Dr. Joseph Kyambadde from Makerere University’s Department of Biochemistry.

### 7.2 Excerpts from 12th OFAB in Uganda

The meetings was held at Shanghai Restaurant in Kampala and started at 1:00pm. A total 30 participants attended the 12th OFAB meeting that was graced with members from the Parliamentary Committee on Science and Technology.

### 7.3 Biotechnology and Bioremediation of Polluted Environments: Research and Development in Uganda. Dr. Joseph Kyambadde, Department of Biochemistry - Makerere University (Appendix I)

Dr. Kyambadde gave a background on the evolution of environmental biotechnology in Uganda, including polices and laws in place to govern wastes and the environment. He further noted that; Europe, USA and other developed countries are more advanced in environmental biotechnology systems.

He said that donors fund the bulk of environmental biotechnology activities in Uganda. Environmental pollution is exacerbated by increased human population, urbanization and

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\textsuperscript{15} Zhuang et al., 2007. New advances in plant growth-promoting rhizobacteria for bioremediation. Environment International 33:406–413

\textsuperscript{16} Aken, B.V. 2008. Transgenic plants for phytoremediation: helping nature to clean up environmental pollution. Trends in Biotechnology 26:225-227

\textsuperscript{17} Byarugaba, D. K. 2004. Harnessing microbial resources for increased agricultural productivity and improved livelihoods. Uganda Journal of Agricultural Sciences 9:227-234

intensive agriculture. All these activities result into huge amounts of waste. Wastes include domestic solid waste and waste water, surface run-off containing agricultural chemicals, organic compounds, heavy metals from industrial processes etc.

Other wastes come from abattoirs, meat processors, breweries, tanneries, etc. Treatment options employed include:

- activated sludge
- Rotating biological contactors
- Trickling filters
- Immersed carriers
- Natural and constructed wetlands

Several synthetic and natural pollutants are released in the environment, bioremediation involves use of microbes to clean the environment. Several countries already using bioremediation and this was prompted by excessive contamination and pollution of several sites that would require huge funds to clean up. However bioremediation is limited because it takes several years to complete and may stall in case of toxic breakdown. Bioremediation is nonetheless advantageous in that it is a natural process that can be self sustaining, and can be applied with minimal disturbance of surrounding environment

In Uganda, bioremediation technologies are expensive to install but a few companies have systems. eg. East African Breweries Ltd, Kasese Cobalt Company, etc. Over 90% of waste water generated in Uganda is untreated.

In Uganda, several pipeline bioremediation research efforts are underway. These are:

- Phyto-remediation that involves use of wetland plants to clean the environment. Aquatic macrophytes are being tested for their potential in removing nutrients, pollutants and metals from municipal and mine wastewaters
- Microbial bioremediation using agents capable of degrading proteins, cellulose, etc. Wastewater from abattoirs in the city is not treated. Research is ongoing on the use of these agents to mitigate pollution due to effluent from city abattoirs. A prototype treatment has been developed and is currently being scaled up for use in the main city abattoir and for commercialization
- Research is also underway in bioremediation of municipal waste using a consortium of micro-organisms. Specifically, attempts are being made to reduce methane release into the environment by producing biogas for use in energy generation as well as producing compost.

He concluded that there is need for a well established research and development in bioremediation technologies in Uganda. The government also needs to improve funding for environmental biotechnology research efforts and dissemination

7.5 Discussion and comments

Mr. Wamboga thanked the presenter and introduced the Honourable MPs present including Hon. Kavuma Nvumenta, and other participants. He noted that various research efforts are underway in environmental management and agriculture but will require a law to be utilized
safely. The MPs can help push for necessary laws to handle biotechnology.

Dickson Biryomumaisho (FEDN): There is need to define the terms used in the presentation. Universities conduct research and release products that are not taken up by industry, what’s wrong? There is need for Environmental Impact Assessment for every project that will affect the environment.

Hon. Nvumentta Kavuma Ruth (Kalangala District): In order to commercialise innovations in bioremediation, there is need to demonstrate use of waste after the treatment. This will encourage industry to adopt such technologies

Hon. Nayiga Sekabira (Kayunga District): How do we ensure that we don’t lose the useful bacteria used in abattoir wastewater treatment? How long does the bacteria take to work on wastewater from the abattoir?

Hon. Charles Ngabirano: MPs have visited the Nakivubo channel and discovered that the situation is very bad. There is limited linkage between scientists and industry. Parliament is securing funds to help in waste treatment in Uganda (Over US $ 58m). Scientists are encouraged to interact with politicians. Laws on biotechnology and IPR are being followed up by parliament.

Hon. Nayiga Sekabira (Kayunga District): Are we thinking about polythene? How can we employ biotechnology to degrade polythene?

Grace Musimenta (Farmers Voice Newspaper): How can we help students at tertiary institutions develop waste into useful materials that can be commercialised? This would create employment and enhance innovations among students.

Halima Abdallah (The East African): The private sector can come up to address pollution if something negative comes up about their waste compounds. Is the water we get from NWSC clean? Why are we told to boil it?

Peter Wamboga: The cost of cleaning water has gone up four fold because of costs of chemicals and dirtier water in the lake. Several challenges affect water treatment.

Participant: NWSC has increased costs of water because of increased costs of treatment. MPs should advise on how to use the information presented to mitigate pollution. The presenter should also indicate costs of such innovations.

Participant: We need to address the challenges from below. Investors should not be allowed before passing EIAs.

Lucy Pali (Consent): There is need to simplify such information for public awareness.
7.6 Responses from Dr. Kyambadde

He said that research has been conducted on solid waste management and results are promising, for example microbes with important degradation qualities have been isolated from land fills in the country. Microbial suspensions are also being developed for use in solid waste management. Research projects are being conducted with students on waste management. Students are also being trained on industrial biotechnology.

The wetlands at Nakivubo channel have greatly been affected since the 90’s due to increased pollution from industrial waste and domestic waste water. Government policies need to be improved e.g. allocation of land in wetlands to individuals should not be accepted.

He also noted that lack of IPR laws is prohibiting some technology innovations in Uganda. Linkages between scientists, industry and policy makers are still weak but some efforts are underway.

The system of degradation developed for the abattoir allows for maintenance of microbial density in reactors. Degradation can take several hours to months and the information can indeed be simplified. Water treatment does not remove all components, for example heavy metals are not removed from the treated water!

7.7 Closing remarks: Hon. Nayiga Sekabira (MP, Kayunga District)

Hon. Nayiga Sekabira thanked the presenter and participants for gracing the forum. She said that the MPs are working on fast-tracking a bill in biotechnology and Biosafety so that research and commercialisation programs can be conducted safely. She promised to take the presentation and share with other parliamentarians.
Thirteenth OFAB: The green revolution and agro-biotechnologies – their interplay in Africa

8.1 Background

Africa’s agriculture has for decades been largely rudimentary with limited use capital inputs. Fertilizers, improved seed, irrigation, and mechanization have been minimally employed in farming systems in the continent\textsuperscript{19}. In sub-Saharan Africa, Uganda is by far the lowest user of mineral fertilizers. This is despite the obvious loss of fertility in several farming ecologies in the country. Pesticide use has been limited to cash crops such as cotton, tomatoes and a variety of horticultural crops. A national policy, the ‘Plan for Modernisation of Agriculture’ was conceived in the last decade but even then, farming practices have hardly changed for the 10 years of PMA implementation, and the country is already developing another strategy ‘the National Development Plan’ that it hopes will improve food and fibre production and transform the economy\textsuperscript{20,21}.

In the middle of the last century, a number of developing countries – notable Mexico, India, the Philippines, Pakistan – began implementing rigorous measures aimed at increasing agricultural productivity (and ultimately production) to feed their high (and increasing) populations\textsuperscript{22}. This ‘Green Revolution’, as it later termed, was promoted by Nobel Laureate Norman Borlaug with funding from various sources and commitment from the governments. Africa, unfortunately, did not benefit from the technological innovations of the revolution that enhanced food production in adopting countries. Africa’s reluctance to use such technologies has been attributed to unwillingness of many African countries to invest in agriculture and possibly, because the populations in Africa could still feed themselves under those practices. A few countries in Africa such as Republic of South Africa and Egypt have to a large extent practiced modern farming methods involving use of irrigation, improved seeds, chemical fertilisers and pesticides. In Uganda improved seed use is still very limited and only a small fraction of the cultivated land is irrigated\textsuperscript{23}. The Green Revolution was criticised in certain sections because farmers relied on corporate institutions for inputs that did not favour small scale farmers. Environmental degradation was yet another concern raised against the green revolution. The revolution was however credited with ending famine in countries such as Pakistan, India and China.

\textsuperscript{23} Uganda Seed Trade Association, (December 2002).cited in “Seed Market Survey” Investment in Developing Export Agriculture (IDEA Project) Chemonics International Inc. Kampala, Uganda and Washington, D.C.
The population boom in Africa in addition to political instability and changes in climatic factors has culminated in insufficient food supply in the continent. Hundreds of millions of people in the continent face starvation. Institutions are promoting green revolution in Africa, with the hope that long term food security can be achieved under small holder farming systems. Irrigation, fertilisers, and use of improved crop varieties were the key characteristics of the Green Revolution. The former two of course, were optimised for the different ecological zones but crop improvement is a continuous process, as new disease and stress challenges come up. The hybrids used in the green revolution were developed through conventional breeding methods but the later quarter of the past century saw the advent of modern biotechnological tools such as recombinant DNA technology that could be further used to improve crop varieties. These tools enhanced the realms of plant breeding, enabling the transfer of useful traits even from unrelated species. A classic example is the use of a gene from the soil bacterium Bacillus thuringiensis to confer pest resistance in cotton, maize, and more recently, eggplants. The first modern biotech varieties were commercialised in 1995, after rigorous testing.

Similar to the Green Revolution, modern biotechnology has been criticised by certain sections of society who argue that the technology may pause certain risks to human health and environment. Scientifically, some of the perceived risks are theoretically possible while others are not. The use of modern biotech has therefore been regulated in all countries where it is used, to assure safety to human health and environment. In Africa, only three countries have commercialised the use of modern biotech derived products, such as Bt cotton. Other countries in the continent are conducting field trials involving biotech crops, Uganda being one of these. Uganda is currently conducting confined field trials of genetically modified cotton, banana and cassava for resistance to biotic stresses. Such trials are expected to result into commercially viable products that could boost food and fibre production in Uganda, as well as improve incomes of small scale farmers. The use of such technology will however require sufficient public awareness and policy to be effectively harnessed. Moreover policy makers receive contradictory messages regarding biotechnology from different sources. There is therefore a need for public stakeholder and policymaker engagement in matters and issues related to modern biotechnology.

The Uganda National Council for Science and Technology (UNCST), the African Agricultural technology Foundation and the Program for Biosafety Systems initiated a platform, the Open Forum on Agricultural Biotechnology in Africa (OFAB), where scientists in the agricultural, environmental and biotechnology fields could directly interact with policymakers, farmers, environmentalists, the media and other stakeholders and deliberate any issues or concerns raised. OFAB Uganda chapter was launched in December 2007 and involve monthly lunch sessions where invited stakeholders listen to presentations from leading scientists and then deliberate on any issues. Similar meetings are held in Kenya, Tanzania, Egypt and Nigeria (by 2010).

8.2 Highlights from the 13th OFAB

The thirteenth edition of OFAB - Uganda was held on November 06 2009 at Shanghai Restaurant in Kampala. The guest speaker was Emeritus Professor Patrick Rubaihayo, a distinguished plant breeder and biotechnologist. The theme for the day was “Agricultural productivity and global food prospects”. The meeting attracted 22 participants that included journalists, farmer representatives, policymakers environmentalists, and scientists.

8.3 Contribution of Green Revolution and Agro Biotechnology to Food Security and Sustainable Agriculture. (Appendix II)

by Prof Rubaihayo, Dept. of Crop Science, Makerere University

Prof. Rubaihayo, in his presentation noted that; Africa is a huge continent that is much larger than all developed countries combined. Africa’s agriculture is highly undeveloped; and is characterized by limited use of fertilizers and irrigation.

The Green revolution was a notable increase in cereal grain yield in several countries, and involved the use of shot stemmed, high yielding hybrid varieties, fertilizers, pesticides and irrigation. The main challenges of green revolutions were: concerns over wholesale transfer of technologies to the developing world; use of persistent pesticides; use of chemical fertilizers. The adoption of green revolution technologies by countries was aided by political stability and availability of developed infrastructure that permitted the diffusion of seeds and other technologies. The green revolution was not observed in Africa due to many factors that included: unstable governments; poor infrastructure; governments were unwilling to invest in agriculture; Africa was able to feed itself at the time; there were few enlightened farmers. The green revolution is credited with averting famine in India and Pakistan as well as ensures that food production keeps up with population growth.

Modern biotechnological tools are now being used to improve crop productivity and production; the main tools used are tissue culture, finger printing, and genetic engineering (GE). GE involves the transfer of DNA from different species to another species to produce a GMO. GE technology has suffered bias and faces challenges similar to those of green revolution; Advocates of sustainable agriculture are the main opponents to GE technologies. The technology has been used to develop herbicide tolerant crops, drought tolerant crops, insect and disease resistant crops, and crops with enhanced nutritive value. These traits are especially useful where the desired genes are not available in the species population among related species.

He noted that certain sections of society however still express concerns over the use of GE; the main perceived risks include - creation of new allergens, antibiotic resistance, gene flow, loss of desirable genes from landraces. Africa needs to build a critical mass of knowledge in biotechnology for it to effectively harness biotech tools for agricultural development. Knowledge is the main ingredient of biotechnology, and any society that can generate knowledge is better placed to overcome the constraints to sustainable wealth creation.

In 2007, African countries committed themselves to promote safe and sustainable use of modern biotechnology, but to date, only a few have made strides in the development and deployment of modern biotechnologies in agriculture. The only African countries commercially producing GM
crops are South Africa, Egypt and Burkina Faso. There are however a number of countries at
different stages of GM development, include research at confined field trial stage and laboratory
research. He emphasised the need for African scientists to try and have commercial rights to all
genes they test, as this would ease potential commercialization of such genes.

He noted that several institutions in Africa are involved in modern biotech related activities.
These are AATF, BECANET, ABPS II, ISAAA, PBS etc. About 12 African countries have functional
biosafety frameworks; others are at various stages of developing biosafety frameworks. The
use of GM crops has had several benefits to the environment and incomes of adopting farmers.
There is comprehensive body of knowledge to address GM products, and African countries need
to work together in developing biotechnology. Adequate capacity is however needed to deal
with novel products.

Peter Wamboga: Peter gave a brief biography of Prof. Rubaihayo, who is and has been involved
in several biotechnology initiatives in Uganda and the region.

8.4 Discussions

Prof. Osiru (Dept. of Crop Science, Makerere Univ.): The green revolution succeeded in Mexico,
the Philippines etc because there was a permitting environment, what happened to Africa? Did
the scientists who initiated the green revolution overlook Africa or other reasons prevented
the continent from benefiting from the revolution? Are there any plans or research efforts to
improve the yield potential of crops using biotechnology?

Dr. Eseza Kakudidi (Dept. of Botany, Makerere Univ.): Africa lacks the critical mass of knowledge
required for proper deployment of biotechnology. The Department of botany at Makerere
University is starting a bachelor’s degree program in biotechnology. There is need to enlighten
people on practicing agriculture. The majority of would be enlightened farmers are not practicing
agriculture. Also certain varieties when released to farmers quickly get other problems, such
as succumbing to new diseases. What causes this? For example the mosaic resistant cassava
varieties developed by NARO quickly succumbed to the brown streak virus disease.

Prof. Rubaihayo: The green revolution was not promoted in Africa. There is need to improve
yield at farm level, and then think about increasing variety yield potential. Uganda needs skills
training, even at higher levels of education. Farming needs inputs, markets and other resources
to make it viable. Brown streak virus disease was not a major problem in Uganda, at the time
CMD resistant varieties were being released

David Talengera (NARL -NARO): Can we achieve much from green revolution using our own
indigenous crops such as bananas, cassava etc? Or we need to concentrate on cereals?
Participant: Can we convince African politicians to embrace a new green revolution?

Kennedy Igbo Kwe (FAO - Uganda): What are the challenges institutions face in developing
biotechnology in Uganda and Africa?

Prof. Rubaihayo: We can’t run away from cereals if we are to feed our population. The only
indigenous crops are millets and sorghums. We missed the green revolution, let’s embrace
and utilize available technologies. Ugandan politicians are very educated, but sometimes they don’t make rational decisions, and don’t act quickly in development programs. Institutions are working but action is not visible. Several challenges hinder development, but political ideologies are sometimes the main problem.

**Peter Wamboga:** Science institutions and scientists should learn to communicate frequently to the public, as these normally have the knowledge needed by farmers

**Theresa Sengooba (PBS):** The problem may be due to the low priorities given to agriculture. The entire system does not favour quick action on any innovation. MPs and politicians are aware and very supportive of biotechnology, but the systems frustrate processes. On the management of crop diseases, it is a common problem in disease management that new diseases or strains of the causal organism can come up and attack a new variety developed for resistance to another disease.

**Peter Wamboga:** MPs are positive about biotechnology and have promised to support the bill once it gets to parliament

**Makara Arthur:** Several efforts were made to establish biotech regulation but there are still delays in the system. Prof. Rubaihayo should guide us on a way forward to achieve this goal. There is need for increased science communication, from all stakeholders. There is also need for science ministry to be created, as then science programs and policies will have clear focus. UNCST, the government organ responsible for science and technology is housed in the Ministry of Finance.

**Prof. Rubaihayo:** Dialogue with the minister of planning can help to push for the bill. For a science ministry to be created, one needs to lobby directly to the president, as it his prerogative to create or establish any specific ministry

**Theresa Sengooba:** How do we work with bureaucrats in ministries? The ministers themselves have been very responsive to biotechnology developments.

**Prof. Rubaihayo:** There is need to liaise with the Permanent Secretary of the finance ministry and the Executive Secretary of UNCST

**Olive Nabukonde:** What is Uganda’s status as regards today’s OFAB theme ‘Agricultural productivity and global food prospects’

**Prof. Rubaihayo:** We still have challenges but some efforts are being made.
Fourteenth OFAB: The status of biotechnology research for genetically-modified (GM) cotton for Uganda

9.1 Background

Uganda’s agricultural sector faces several challenges from erratic rains, diseases, pests, declining soil fertility, lack of quality improved seed and a host of marketing problems. The country as a whole is developing a national Development Plan that should see several reforms aimed at developing key sectors of the economy. Agriculture is one sector that needs a lot of efforts if food and fibre production are to meet the country’s needs. Whereas agricultural marketing and food distribution systems can be addressed through policy and infrastructural reforms, productivity enhancement requires considerable research into crop improvement and agronomy.

The National Agricultural Research Organisation (NARO) is mandated to conduct research to address many of the constraints to agricultural production in the country. The institution has made several interventions including the development of mosaic resistant cassava that brought hope to famine stricken eastern Uganda in the 1990s. Cotton is among the crops under research by NARO, where the National Semi-Arid Resources Research Institute is attempting to address some of the challenges in cotton production.

The major problems cotton farmers face are attack from pests and diseases, low soil fertility, and weed control. The main pests of cotton are bollworms, causing 30-80% yield loss in affected farms. Weeds on the other hand can cause up to 100% yield loss if not well managed. Bollworms are primarily controlled through insecticidal sprays while weeds are managed through hand hoeing - conducted three to five times each season. Chemicals are expensive and also pose health hazards to farmers while hand hoeing to manage weeds is laborious and many farm families lack such labour to manage huge fields. NARO, together with other stakeholders in the cotton industry zeroed on biotech to address bollworms and weed problems in cotton.

Among the technologies considered were Bt cotton to address bollworms and Roundup Ready Flex (RRF) cotton to address weeds. Research is underway at Serere and at Mubuku to evaluate the potential of these technologies under Ugandan conditions. These technologies were developed through genetic engineering that faces controversy among certain groups.

9.2 Highlights of the 14th OFAB in Uganda

The 14th OFAB Uganda Chapter was held on Dec. 18 2009 at Shanghai restaurant in Kampala with the attendance of forty one participants. The meeting was held under the theme ‘The Status of

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Biotechnology Research for Genetically-Modified (GM) Cotton for Uganda, presented by Mr. Pius Elobu, the Trial Manager for the GM Cotton CFT at Serere. OFAB 14 started at 2pm with a BBC documentary on GM experience in different countries.

9.3 Key Presentation: The Status of Biotechnology Research for Genetically-Modified (GM) Cotton for Uganda; Pius Elobu, Trial Manager, Cotton CFT, NaSARRI

Pius is his presentation noted that cotton was introduced into Uganda at the start of the last century and production rose to high levels in the late 1960s. Cotton production has however declined to very low levels. The government of Uganda has made several attempts to increase cotton production through a number of interventions. Several challenges still affect cotton production including low soil fertility, pests and diseases, labour climatic factors etc. Biotech can address weeds and bollworms pests.

He said that the available biotech options are Bt for bollworm resistance and Roundup Ready Flex to control weeds. Uganda needed to find out for herself if GM technology would be appropriate. Applications were made and approved by NBC, MAAIF and President’s Office for the research into GM cotton to be conducted.

He said that trials were planted under confinement at Serere and Mubuku in Kasese. Confinement measures include fencing, restricted access, guards etc. All workers in the CFT were adequately trained on the confinement compliance measures. Two trials were planted; 1) Roundup Ready Flex cotton, this is sprayed with Roundup herbicide to control weeds. Hand weeding is normally tedious to many farmers. There are two RRF varieties being tested. Isolines of these varieties are also included in the trial. The local check BPA 2002 is also included in the experiment. 2) Bt cotton trial. This trail contains two varieties with Bt genes to offer protection against bollworms. Similarly, the isolines of these varieties and the local check BPA 2002 are also included in the Bt cotton trial.

He finally said that cotton bolls at the trial opened 4 months after planting. In conclusion, the trial manager informed the meeting that sensitisation efforts had been initiated to inform the staff at NaSARRI, local leaders within Serere and Soroti in general, media houses in Soroti and farmers.
9.4 Discussions

Peter Wamboga: Parliament should enact a law that would regulate use of GM crops in Uganda.

Olive Nabukonde, ISAAA: How much cotton was planted and what yield was recovered from the trial.

Arthur Makara, Scifode: Scientists in Uganda should be well remunerated. I thank Mr. Elobu for the well prepared presentation that has shown us the progress with GM cotton research at Serere. GM cotton can help improve cotton production. Scifode is part sensitisation efforts for biotech in Uganda. A law is needed to help farmers to access GM crops. Mr. Elobu, Is there any difference between GM cotton and non-Gm cotton yield so far?

Geoffrey Arinatwe, NARL: The varieties mature at once, isn’t this a problem at harvesting if acreage is large and labour are constrained? How are we going to control seed distribution? The varieties are dwarf, aren’t we going to find trouble harvesting (because they are too short)?

David Talengera, NARL: Was sensitization done for farmers in area? Is the four- time spray what is recommended or what farmers use?

Dr. Namaganda, NARL: It is important to understand the economics of GM cotton production. Use of chemicals is also dangerous this could be averted by using Bt cotton. Is the lint quality of the GM seed comparable to our own materials?

Douglas Bhosopo, CDO: CDO is in consultation on the cost of seed to farmers and the cost of the technology to the country. On ownership of the technology, we intend to conduct backcrossing to our own varieties. Ginning outturn is also very crucial if other varieties are better, we shall consider it.

Hon. Twebwita Grace B., Parliament: There is need to disseminate more information to farmers. Parliament is committed to enacting a Biosafety law. Researchers should sensitise more people in other districts.

Pius Elobu: On sensitisation, resources are limited but also this research stage is still far, and when the time comes, we shall test the cotton in other places. On yield, land area is 1.6 ha but the bales recoverable will depend on the GOT. We need to discuss direction for deploying GM cotton. On comparing with local varieties, tests are going to be done soon and result shall be released.

Peter Wamboga: Institutional arrangements in the country control the cotton sector. Science is attempting to revive the cotton sector by addressing some concerns.

Mr. Amos (ginner): Ginners are excited about the technology because it can increase yield. We shall support your efforts.
Dr. Sengooba, PBS: Scientists are working to finding solutions to problems. GM cotton adoption will depend on economics of seed production. The price of seed will be negotiated to levels that are profitable to our farmers. We shall need a strong team to negotiate prices of seed.

Peter Wamboga: Explained that OFAB started in Kenya and this is the 14th in Uganda. OFAB helps to demystify GM myths.

Wilfred Kamulegeya: On comparison of yields, the trials are still at a stage when we are only testing the technology for now. On height of the varieties, in Kasese, varieties are the same height, so this may be an environmental issue rather than the genetic potential of the varieties being tested.

Peter Wamboga: There are other ongoing research in other crops. There are 5 GM cotton trials already; banana (Sigatoka, BBW,), cassava (for resistance to mosaic and brown streak virus), cotton (Bt and HT). All these technologies will not come out unless there is a law in place.

James Masaba (Education Ministry): How has Bt responded to climate change eg. Excessive rains or drought?

Peter Wamboga: Biotech research is ongoing on adapting to drought stress eg. at ABI, where millet and sorghum varieties are being developed with resistance to drought.

Pius Elobu: For cotton, priority areas were pests and diseases.

Peter Wamboga: The WEMA project being executed by NARO and partners is working on producing drought tolerant maize. Mock CFT trials are already underway. I thank everyone for coming. I encourage you to come again.
Appendix I: Paper by Dr. J. Kyambadde

BIOTECHNOLOGY AND BIOREMEDICATION OF POLLUTED ENVIRONMENTS:
RESEARCH AND DEVELOPMENT IN UGANDA

1. Introduction

The increasing concerns over environmental pollution due to discharge of untreated effluents and dumping of untreated solid waste resulted into formulation of policies that guide the management of wastes and also stimulated research into environmental management in order to conserve the environment for future generations. This paper presents a discussion on Biotechnology and bio-remediation of the polluted Environments: Research and Development in Uganda. It begins with a brief on the policy framework for environmental regulation in Uganda, the various sources of environmental pollution, and waste treatment options. The paper also discusses some of the initiatives being undertaken to mitigate environmental pollution. I shall here below outline some bioremediation activities going on in Uganda and place special emphasis on research for development of strategies for the treatment of high-strength industrial wastewaters and municipal solid waste using selected case studies.

2. Environmental policy

The National Environmental Action Plan (NEAP) and the National Environment Management Policy (NEMP)

By 1990, the Government of Uganda had recognized that various environmental concerns existed and the institutional responsibilities were scattered under the different sectors. Consequently, Government developed a National Environment Action Plan (NEAP). The NEAP was a continuous in-country process based on local/popular participation aimed at providing a broad framework for addressing gaps in environment management as well as integrating environmental considerations into the nation’s socio-economic development strategy. The NEAP was closely followed by the formulation of the National Environment Management Policy (NEMP) of 1994. The Policy sets out the overall policy goals, objectives and principles for environmental management. It also sets the agenda for decentralised environmental governance.

The NEMP goal is to achieve sustainable social and economic development, which maintains or enhances environmental quality and resource productivity on a long term-basis that meets the needs of the present generations without compromising the ability of future generations to meet their own needs. The Policy provides strategies to guide and assist decision makers and resource users in determining priorities in the national context and also at the sectoral, private sector and individual level. It provides for integration of environmental concerns in national socioeconomic development planning process, avenues for inter-sectoral cooperation, and comprehensive and coordinated environmental management. As a result, environmental management is now a key criterion for national socio-economic development decisions.

The Policy also recognized the need for sectoral policies in addressing the specific concerns of the identified environmental sectors by providing a framework under which several sectoral policies were developed. These include the 1995 Water Policy, the 1996 National Wetlands...
Management Policy, the 1996 Wildlife Policy, the 2000 Fisheries Policy, the 2001 Forestry Policy and several district environment management policies from 2000 onwards.

In addition, the policy provided a basis for the formulation of a comprehensive environmental legal framework under the 1995 Constitution and the National Environment Act. It also provided a framework for multi-sectoral approaches to resource planning and management of natural resources. These approaches found expression in the various environmental and development policies and in legislation such as the Uganda Wildlife Act, the Water Act, the Land Act, the National Forestry and Tree Planting Act, among others (Akello, 2007).

3. Environmental pollution

In Uganda and the East African region in general, environmental pollution arises from the exponential growth of the human population, explosive urbanization, intensified agriculture and increasing industrial processing that produce large quantities of waste effluents. Such effluents include domestic wastewaters that are rich in nutrients (nitrogen and phosphorus), surface runoff containing pesticides and herbicides from agricultural farms, organic compounds and heavy metals from industrial processing and mining operations.

Other sources of pollution in Uganda, particularly in urban areas include wastewaters from abattoirs and meat processing, fish processing, breweries, distilleries, soft drink manufacturing, oil and soap factories, paint producing factories, tanneries and pharmaceutical industries among others. The water contains pollutants that can have deleterious consequences on the ecological balance and functioning of the receiving environment as well as the public health of downstream end-users of the polluted sites. Such devastating consequences manifest as: toxicity to fish and other aquatic organisms; depletion of dissolved oxygen in receiving water bodies as ammonia or ammonium ions and other organic compounds are highly oxygen demanding; toxicity and bioaccumulation in the food chain for heavy metal contamination; eutrophication when nitrogen and phosphorus are made available to aquatic plants as nutrients; and potential public health risk in drinking water especially when consumed by infants (Bitton, 1999) among others. The recent proliferation of the water hyacinth and the expanding alage-rich water zones along the shores of Lake Victoria are typical signs of nutrient enrichment within the lake due to human activities, notably untreated domestic, municipal and industrial effluents.

In Kampala, about 1500 tonnes of municipal solid waste are generated daily, of which only about 50% is collected and disposed of by Kampala City Council (KCC), while the rest is indiscriminately disposed of (Kyambadde et al., 2006). The fractions of MSW collected and properly disposed of in other towns of Uganda are similarly low ranging from 0.18 – 0.63 (Table 1; Kyambadde et al., 2006; NEMA, 2009). Also of the total effluent from industrial and domestic sources in the city, 10% is treated and the rest is discharged untreated (NWSC, 2000).

Thus, although wastewater treatment facilities (Table 2) and municipal solid waste disposal sites are available in many towns of Uganda, their capacity and level of efficiency are still major challenges. Moreover, the wastewater treatment and MSW collection and disposal capacity in Uganda has not grown in tandem with the high increases in urban population and industrial processing. Hence the discharge of raw urban sewage, industrial process effluents, and agricultural wastes into lakes (especially Lake Victoria) and rivers coupled with the open damping of MSW in un-gazetted areas is a major problem.
Table 1: Estimates of MSW generated and collected for final disposal at gazetted sites in ten municipalities of Uganda

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Total MSW Generated (Gg/Yr)</th>
<th>Fraction of MSW collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fort portal</td>
<td>32.49</td>
<td>0.416</td>
</tr>
<tr>
<td>Jinja</td>
<td>87.24</td>
<td>0.418</td>
</tr>
<tr>
<td>Kabale</td>
<td>33.58</td>
<td>0.254</td>
</tr>
<tr>
<td>Kasese</td>
<td>83.99</td>
<td>0.180</td>
</tr>
<tr>
<td>Lira</td>
<td>72.72</td>
<td>0.347</td>
</tr>
<tr>
<td>Mbale</td>
<td>26.29</td>
<td>0.631</td>
</tr>
<tr>
<td>Kampala</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mbarara</td>
<td>79.57</td>
<td>0.300</td>
</tr>
<tr>
<td>Mukono</td>
<td>42.71</td>
<td>0.598</td>
</tr>
<tr>
<td>Soroti</td>
<td>35.08</td>
<td>0.300</td>
</tr>
</tbody>
</table>

4. Waste treatment options

The various forms of wastes described above are amenable to biological treatment. Microbially-mediated processes, compared to many conventional wastewater treatment techniques involving physico-chemical means, have been shown, where feasible, to be cost effective environmental solutions for partial or complete transformation of environmental pollutants to non or less toxic forms.

Various configurations for conventional biological treatment of wastewaters have been developed and the process configurations rely on the maintenance of high microbial population densities in the systems often as fixed films (biofilms) or as a suspension (activated sludge). Biofilm processes are among the oldest technical processes in the field of biological wastewater treatment aimed at removing carbon, nitrogen and phosphorus (Metcalf and Eddy, 2003). These include trickling filters and immersed carriers. Trickling filters consist of a bed of support materials over which wastewater is uniformly distributed. The wastewater percolates over the biofilm growing on the carrier material (usually gravel although low-density plastic media such as polystyrene or polyvinyl chloride are now used) to achieve a very high biofilm specific surface area.

In immersed carriers (biofilters), a reactor is packed with a filter medium to which microorganisms can become attached and is operated in either up-flow or down-flow mode. The filter is continuously submerged in wastewater while the wastewater is aerated from beneath the medium.

Rotating biological contactors have also been widely used for biological treatment of wastewaters (carbon removal and/or nitrification). They consist of closely spaced circular plastic discs, partly submerged in wastewater and gently rotated to allow growth of the biofilm and alternately expose it to pollutants in wastewater and oxygen in the air, respectively.
### Table 2: Overview of clean water supply and wastewater treatment in Uganda

<table>
<thead>
<tr>
<th>Town/Area</th>
<th>Targeted Population</th>
<th>% with piped water</th>
<th>% with sewerage</th>
<th>Wastewater treatment facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arua</td>
<td>68,000</td>
<td>26</td>
<td>0</td>
<td>No</td>
</tr>
<tr>
<td>Bushenyi</td>
<td>10,526</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Entebbe</td>
<td>116,000</td>
<td>60</td>
<td>5</td>
<td>Stabilization pond</td>
</tr>
<tr>
<td>Fortportal</td>
<td>41,500</td>
<td>80</td>
<td>-</td>
<td>Communal Septic tank; Sewage lagoon</td>
</tr>
<tr>
<td>Gulu</td>
<td>85,000</td>
<td>52</td>
<td>5</td>
<td>Stabilization pond</td>
</tr>
<tr>
<td>Jinja</td>
<td>200,720</td>
<td>79</td>
<td>29</td>
<td>Stabilization pond</td>
</tr>
<tr>
<td>Kabale</td>
<td>41,450</td>
<td>89</td>
<td>10</td>
<td>Stabilization pond</td>
</tr>
<tr>
<td>Kampala</td>
<td>1,248,000</td>
<td>55</td>
<td>8</td>
<td>Conventional treatment plants</td>
</tr>
<tr>
<td>Kasese</td>
<td>55,167</td>
<td>77</td>
<td>-</td>
<td>Septic tanks, Sewage lagoons</td>
</tr>
<tr>
<td>Lira</td>
<td>91,400</td>
<td>60</td>
<td>15</td>
<td>Stabilization pond</td>
</tr>
<tr>
<td>Masaka</td>
<td>80,000</td>
<td>72</td>
<td>11</td>
<td>Conventional treatment plants, Sewage lagoons</td>
</tr>
<tr>
<td>Mbale</td>
<td>75,661</td>
<td>79.4</td>
<td>30</td>
<td>Stabilization pond</td>
</tr>
<tr>
<td>Mbarara</td>
<td>68,037</td>
<td>73</td>
<td>6</td>
<td>Stabilization pond</td>
</tr>
<tr>
<td>Soroti</td>
<td>41,000</td>
<td>34</td>
<td>&lt;10</td>
<td>Stabilization pond</td>
</tr>
<tr>
<td>Tororo</td>
<td>42,473</td>
<td>64</td>
<td>7</td>
<td>Stabilization pond</td>
</tr>
</tbody>
</table>

Adapted from the homepage of National Water and Sewerage Corporation (http://www.nwsc.co.ug/)

It was not until 1950s that activated sludge systems were preferred to biofilm processes in practice. The activated sludge process is designed primarily for carbon, nitrogen and phosphate removal from wastewaters. The system relies on dense microbial populations being mixed in suspension with the wastewater under aerobic conditions. The system configuration typically consists of a sequence of primary anoxic, primary aerated, secondary anoxic and secondary aerated zones followed by a clarifier.

In recent years, fluidized-bed processes have become prevalent because the carriers provide a large surface area capable of maintaining a high cell density, significantly increasing the volume efficiency, and thus achieving high loading and specific removal rates (Rostron et al., 2001). In addition, they require relatively small reactors and may afford protection from toxic shocks.

Wetlands have also been used for wastewater treatment worldwide. Initial feasibility studies were carried out in during the early 1950s in Germany. In Uganda, wetlands are being subjected to wastewater discharges from municipal and industrial sources, and have received agricultural and surface mine runoff, irrigation return flows, urban storm water discharges and leachates. The functional role of wetlands in improving water quality has been a compelling argument for the preservation of natural wetlands (GoU, 1995; GoU, 2001). However, concerns remain over the possibility of harmful effects resulting from toxic materials and pathogens that are present in many wastewater streams. There are also concerns over the potential for long-term degradation
of natural wetlands due to the addition of nutrients, human encroachment, and changes in the natural hydrologic conditions influencing these systems (NEMA, 1996). Thus, constructed wetlands are now viewed as a potential alternative technology for mitigating further pollution and degradation of the environment while offering open space and visual amenities (U.S EPA, 2000).

The constructed wetland technology is based on the complex natural processes involving concreted interactions between the plants, the substrata and the inherent microbial community to accomplish wastewater treatment in a more controlled and predictable manner through physical, chemical and biological processes.

Constructed wetlands have been successfully applied worldwide for biological treatment of municipal and industrial wastewater (Cooper and Findlater, 1990; Hammer et al., 1993), agricultural wastewater (Knight et al; 2000; Schluz and Peall, 2001) as well as surface runoff (Kao et al., 2001).

5. Biotechnology and bioremediation of polluted environment

Environmental pollutants such as polycyclic aromatic hydrocarbons (PHAs), polychlorinated biphenyl's (PCBs), pesticides, petroleum hydrocarbons, heavy metals and nutrient-rich organics are released into the environment, where they cause deleterious effects to wildlife and humans, owing to their inertness, being recalcitrant and toxic. However, the existence of microorganisms and plants capable of utilizing, degrading or accumulating such compounds has made the applications of such organisms in cleaning up of the environment a workable strategy. Therefore, bioremediation (the application of bacteria and fungi and Phytoremediation (the application of plants) to clean-up the environment, are the two feasible and safe approaches which offer promise regarding environmental reclamation and sustainable use. For instance, bioremediation has been shown to be an efficient and cost-effective treatment method for the cleanup of contaminated soils worldwide. Consequently, it has become one of the most promising technologies to consider in remediating contaminated sites in North America, Europe, Asia and Australia.

The technology of bioremediation can be classified into Ex-situ and In-situ bioremediation whereby in situ bioremediation involves a direct action of the bioremediating agents (microorganisms, plants, and insects) on pollutants at the site of pollution which could be soil, water etc while in Ex situ bioremediation, the toxic material (pollutant) is collected from the polluted sites and the selected range of microorganisms carry out the bioremediation at a designed place. This process is an improved method over the in situ bioremediation method. The bioremediation agents which are used for biodegradation or clean up of contaminated sites are tested for the natural capability to bring about biodegradation and/or cleanup.

6. Bioremediation and wastewater treatment in Uganda

The application of bioremediation technologies to clean up contaminated sites in Uganda is still at research and development stages. The responsibility of treating effluent discharges in Uganda rests with National Water and Sewerage Corporation. However, owing to the rapid population growth, urbanization and a growing industrial sector, NSWC is not in position to handle all the
effluent discharges, more specifically industrial wastewater. Besides the reasons highlighted above, the efforts of industries to connect their effluents to NWSC sewer lines are hampered by the high connection costs involved which industries are supposed to foot. Thus with a profit-making vision, vis-à-vis wastewater treatment which has no financial returns, the small and medium-scale industries opt to discharge untreated wastewaters into the environment.

Conventional wastewater treatment is expensive because it requires: large capital investment to operate and maintain; skilled labour force, high energy inputs and chemicals. Therefore it is less attractive for developing countries such as Uganda where it installed in only two towns i.e Kampala and Masaka. The other towns in Uganda are utilizing stabilization ponds (Table 2 above). Although Stabilization ponds are recognized by government as appropriate technology for organic matter, nutrients and bacteria removal, and are also sustainable in terms of operation & maintenance, they are often neglected, poorly maintained and not upgraded due to financial constraints and lack of direct benefits. Consequently, effluent that does not meet NEMA standards is discharged from these treatment systems.

A few industries have tried to put in place mitigation measures to evade environmental pollution (Plates 1, 2 &3). These systems primarily reduce COD and suspended solids but nutrient removal is still a major problem and hence do not meet the required discharge standards. However, it’s worth acknowledging that they have moved a step ahead in protecting and conserving the environment as required by the National Environment (Delegation of Waste Discharge Functions) Instrument of 1999, where the functions vested under section 26(1) (C) of the National Environment Act of requiring and ensuring that an operator of a plant undertakes pretreatment of effluent before discharge into any water in accordance with the act and the standards are delegated to the Directorate of Water Development (DWD). Thus, ideally industries must get discharge permits from DWD prior to implementation of their operations in Uganda.

Table 3: Characteristics and onsite pre-treatment of selected industrial wastewater in Uganda

<table>
<thead>
<tr>
<th>Industry</th>
<th>Wastewater characteristics</th>
<th>On-site primary treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kasese Cobalt Ltd</td>
<td>Metals</td>
<td>Separator, constructed wetland (CW)</td>
</tr>
<tr>
<td>Abattoir</td>
<td>BOD, COD, TSS, N&amp;P</td>
<td>None</td>
</tr>
<tr>
<td>Brewery</td>
<td>BOD, COD, detergents</td>
<td>Activated sludge</td>
</tr>
<tr>
<td>Fish processing</td>
<td>BOD, COD, N&amp;P, Oils</td>
<td>Ponds/none</td>
</tr>
<tr>
<td>Meat processing</td>
<td>BOD, COD, TSS, N&amp;P</td>
<td>None</td>
</tr>
<tr>
<td>Oil and soap</td>
<td>BOD, COD</td>
<td>Oil separator, Septic tank</td>
</tr>
<tr>
<td>Battery production</td>
<td>Heavy metals, oils, acids, lubricants</td>
<td>Neutralization</td>
</tr>
<tr>
<td>Diary</td>
<td>BOD, COD, N&amp;P, detergents, oils</td>
<td>None</td>
</tr>
<tr>
<td>Galvanizing</td>
<td>Metals, lubricants, acids</td>
<td>None</td>
</tr>
<tr>
<td>Paints</td>
<td>Heavy metals, Xenobiotics</td>
<td>None</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>BOD, COD, Xenobiotics</td>
<td>None</td>
</tr>
<tr>
<td>Soft drinks</td>
<td>BOD, COD, N&amp;P, detergent</td>
<td>None/Ponds</td>
</tr>
</tbody>
</table>
7. Pipeline bioremediation research in Uganda

Some of the bioremediation activities going on/undertaken in Uganda include among others:

7.1. Phytoremediation

Makerere University Department of Biochemistry and Institute of Environment and Natural resources have for the past 8 years investigated the potential of aquatic macrophytes in removing nutrients, organic pollutants and metals from municipal and mine wastewaters. Selected locally available aquatic plants are now in the process of being applied in bioremediation of sites polluted with heavy metals and nutrients (plate 4) under large-scale field conditions.

Similarly, way back between 1996 and 1999, the potential of using constructed wetlands as a cheaper and yet effective alternative for treating domestic wastewater in tropical environments was investigated by Tom Okurut at pilot-scale level at Jinja-Kirinya National Water and Sewerage Corporation Sewage anaerobic lagoons. The research investigated Cyperus papyrus and Phragmites mauritianus. Units planted with these plants showed high pollutant removal efficiencies of over 70% for settled BOD and COD; 80% of the input TSS; and significant removal of faecal coliform contamination.

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Plate 1: Effluent Treatment Plant at Uganda Breweries Limited, Luzira

For this paper, all photo credits to J. Kyambadde
Plate 2: Effluent Treatment Plant at Green Fields (U) Ltd Fish Factory in Entebbe

Plate 3: Wastewater pit (drained by NWSC) at Elgon Leather Co., Kawempe

Table 4: Wastewater characteristics at Elgon Leather Co., Kawempe

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PIT Wastewater</th>
<th>Uganda Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>9.6</td>
<td>6.0 – 8.0</td>
</tr>
<tr>
<td>Conductivity</td>
<td>96600μS/cm</td>
<td>1500μS/cm</td>
</tr>
<tr>
<td>TDS</td>
<td>47600mg/l</td>
<td>1200mg/l</td>
</tr>
<tr>
<td>Colour</td>
<td>5000TCU</td>
<td>300TCU</td>
</tr>
<tr>
<td>Nitrate-N</td>
<td>14mg/l</td>
<td>20mg/l</td>
</tr>
<tr>
<td>COD</td>
<td>200mg/l</td>
<td>100mg/l</td>
</tr>
<tr>
<td>Chloride</td>
<td>15860mg/l</td>
<td>500mg/l</td>
</tr>
</tbody>
</table>
7.2. Microbial bioremediation

The Department of Biochemistry has isolated microbial agents with potential applications in bioremediation activities of polluted environments such as open damping sites, landfills, wastewater discharge/receiving sites or habitats. Such agents include protein (Plate 5), cellulose (Plate 6) and lipid degrading bacteria. The hydrolytic potential of these agents has been tested at lab-scale (Plate 7) and some are being tested under large-scale field conditions (Plate 12).

Research and development of bioremediation technology aimed at mitigating pollution due to effluent from abattoirs is underway. With funding from the Swedish International Development Cooperation Agency (Sida) under the East African Regional Programme and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development (BIO-EARN), and collaboration with City Abattoir, Kampala, a multi-million wastewater treatment system has been set up at City Abattoir, Bugolobi. Abattoir wastewater treatability tests have been conducted at Makerere University, and are now in the last phase of implementing the laboratory-scale research outputs (Plates 8 & 9) into field-scale actions (Plate 10).

Plate 5: Agar-diffusion assay showing protease-producing bacterial isolates. Isolates were cultured using casein as carbon source to induce protease production.
Plate 6: Agar-diffusion assay showing cellulase producing bacterial isolates. Isolates were cultured on granular cellulose as carbon source to induce cellulase production.

Plate 7: Lab-scale aerobic SBR treating abattoir effluent at the Department of Biochemistry, Makerere University

Plate 8: Animal slaughtering operations at City Abattoir
The field-scale system shall have a daily wastewater treatment capacity of about 60,000 litres, and by applying selected and evaluated naturally occurring microorganisms into bioreactors containing abattoir wastewater in sufficient numbers and compatibility to attack the waste constituents and effectively break them down into their most basic compounds (Bioaugmentation). The resultant treated water shall further be polished in constructed wetland units (phytoremediation) to scrap the remaining nutrients and suspended solids prior to discharge or reuse of the treated wastewater for washing/cleaning purposes.

Plate 9: Untreated effluent discharged by City Abattoir

Plate 10: A lab-scale sequencing batch reactor treating abattoir effluent at Makerere University

Plate 11: Raw and treated abattoir effluent from pilot sequencing batch reactor (SBR) plant operations at Makerere University.
Municipal solid waste (MSW) is a big problem in Uganda where waste generation and collection are not in tandem with each other. This results into pile up of refuse at collection centers and consequently degradation at these sites releasing noxious gases, toxic leachate and spreading disease (Plate 13). Research involving biotreatment of municipal solid waste using a consortium of microorganisms has been undertaken by team of scientists at Makerere University.

Plate 12: Wastewater Treatment Plant being installed at City Abattoir, Bugolobi

Plate 13: Municipal Solid Waste at a collection centre in Fort Portal
Department of Biochemistry. Various municipal solid waste (MSW) streams in different towns across Uganda were characterized and degradation tests carried out. Outputs such as biogas (plate 14) can serve as useful bio-energy while the nutrient rich sludge can be used as soil conditioner.

In addition, research involving the aerobic degradation of organic refuse using isolated naturally occurring microorganisms is on-going at Biochemistry Department, Makerere University. This would generate nutrient-rich compost that would serve as a soil conditioner and also minimize greenhouse gas emissions (e.g. Methane).

Other bioremediation activities done in Uganda include the water hyacinth control on Lake Victoria. Following the signing of a cooperative relationship between Uganda and Egypt, a bioremediation strategy involving the application of two types of weevils imported from Benin was employed to control the nasty water hyacinth on the Lake. Since the weevil programme started, over six billion weevils were released to fight the water hyacinth and 90% of the nasty plant was destroyed.

8. Conclusions and recommendations

As shown above, the basis for environmental regulation, and research for development of bioremediation technologies in Uganda is well established. What needs to be done is to solicit support for funding by the Government of Uganda into environmental biotechnology sector to facilitate research for development of bioremediation technologies to protect and conserve the environment as required by the Millennium Development Goal No. 7 which aims at ensuring environmental sustainability and improved livelihood. There is also need to enforce environmental protection laws, improve public awareness, create and strengthen partnerships between the private sector and public institutions involved in environmental biotechnology research. It is evident from this paper that about 90% of effluents discharged into the environment by the industrial sector in Uganda is untreated, causing detrimental impacts on the receiving ecosystems.
Moreover, with the increasing trends in urbanization, industrial processing and now the emerging petroleum explorations in Uganda, more hazardous wastes and hydrocarbon-based wastes from petroleum processing shall soon be released into the environment. Therefore, the position of bioremediation in the research arena will shift upwards in ranking and its prospects for future applications are high.

7 References

Akello C.E, 2007. Environmental Regulation

Cooper, P.F., Findlater, B.C. 1009.

Constructed wetlands in water pollution control. New York: Pergamon Press

GoU, 1995. National Policy for the conservation and management of wetland resources, Kampala:
Government of the republic of Uganda (GoU), Kampala.


CONTRIBUTION OF GREEN REVOLUTION AND AGRO BIOTECHNOLOGY TO FOOD SECURITY AND SUSTAINABLE AGRICULTURE

Abstract

The first Millennium Development Goal (MDG) falls short of food security aspirations in seeking only to reduce by half the proportion of the world’s population experiencing hunger by 2015. The vast majority of the world’s hungry live in rural areas and therefore addressing agriculture and population growth is vital to achieving food security. Food insecurity is expected to get worse worldwide with the explosion in world food prices in 2008. Food insecurity exists when people are undernourished as a result of the physical unavailability of food, their lack of social or economic access to adequate food, and/or inadequate food utilization. This truncation of human development undermines a country’s potential for economic development. FAO estimates of 815 million people undernourished in the period 2000-2002 in developing regions which is another indicator of food insecurity and poverty is about 17% of the populations of the developing regions. Moreover, these progress assessments predate the explosion in world food prices in 2008.

The prevailing agricultural systems are variously described as “conventional farming” and “modern agriculture”. Conventional farming systems vary from farm to farm and from country to country. Food production worldwide has risen in the past 50 years. The World Bank estimates that between 70 percent and 90 percent of the recent increases in food production is the result of conventional agriculture rather than greater acreage under cultivation.

Through the application of modern techniques of biotechnology to agriculture, breeders can make precise genetic changes that impart beneficial properties to the crop plants and animals which provide us with food and fiber. Agricultural biotechnology has helped farmers increase yields, enabling them to produce more food per acre and reduce the need for chemicals, pesticides, water, and tilling, thereby providing benefits to the environment as well as to the health and livelihood of farmers. Through specific design, biotechnology also can be used to enhance the nutritive value of staple foods to improve overall nutrition and health. Agricultural biotechnology, although not a silver bullet, holds great promise to boost food production in both the developed and the developing world and to reduce agricultural vulnerability to the impact of pests, viruses, and drought. Genetic engineering which is part of modern biotechnology has provoked much disagreement as to its appropriate use in sustainable agriculture which involves the attempts to ensure the profitability of farms while preserving the environment (American hostage Dictionary).

This technology has created precise genetic products such as crop plants engineered for herbicide tolerance (HT), drought tolerance (DT), insect resistance (IR), etc. and bacteria engineered to produce drugs for livestock which has reduced chemical use in crop agriculture, imparted beneficial properties to the crop plants which produce enhanced food and fiber and improved animal health thus creating sustainable applications in agriculture.

In Africa, a number of institutions exist which are trying to promote the development of modern biotechnology. However, the continent is still lagging behind in the adoption and utilization of
modern biotechnology. Only South Africa, Egypt and Burkina Faso have commercial planting of GMOs, but over twenty countries are engaged in GMO research and development. At least ten countries have field trials of GMOs and at least another 24 countries have the capacity and institutions to conduct research and development into Agricultural biotechnology.

The benefits of GMO crops have been estimated to be $6.872 billion in 2007 up from $115 million in 1996. The 2007 income gains were equivalent to 16% of the value of global crop protection market. The accumulated global value for the eleven year period since biotech crops were introduced in 1996 is estimated at US $42.4 billion.

There is great potential in developing North-South and South-South collaborations supporting biotechnology R&D and capacity-building in developing regional and local innovation areas.

**Food security and hunger**

The Green Revolution was the notable increase in cereal-grains production in Mexico, India, Pakistan, the Philippines, and other developing countries in the 1960s and 1970s. This revolution resulted from the introduction of hybrid strains of wheat, rice, and maize and the adoption of modern agricultural technologies, including irrigation and heavy doses of chemical fertilizer. The Green Revolution was deployed in several developing countries and it yielded dramatic results, nearly doubling wheat production in a few years. The extra food produced by the Green Revolution is generally considered to have averted famine in India and Pakistan; it also allowed many developing countries to keep up with the population growth that many observers had expected would outstrip food production.

Of recent the first millennium Goal has called for eradicating extreme poverty and hunger. This goal is based on agriculture. The hunger target is monitored on the basis of two indicators: the first refers to the minimum food consumption a person needs to lead a normal and healthy life and the second refers to child malnutrition measured as low weight-for-age on the basis of child weight in an international reference population. These two indicators also define food security which to a large extent refers to the availability of food and one's ability to access it. A household is considered food secure when its occupants do not live in hunger or fear of starvation. Food security, therefore, is the condition in which everyone has access to sufficient and affordable food; it can relate to a single household or to the global population. The first Millennium Development Goal (MDG), hence falls short of food security aspirations in seeking only to reduce by half the proportion of the world’s population experiencing hunger by 2015.

Eradicating hunger and poverty requires an understanding of the ways in which these two injustices interconnect. Hunger and the malnourishment that accompanies it, prevents poor people from escaping poverty as it diminishes their ability to work and care for themselves and their family members. Food insecurity exists when people are undernourished as a result of the physical unavailability of food, their lack of social or economic access to adequate food, and/or inadequate food utilization. Food-insecure people exhibit physical symptoms caused by energy and nutrient deficiencies resulting into vulnerability to attack by various diseases. If left unaddressed, hunger sets in motion an array of outcomes that perpetuate malnutrition, reduce the ability of adults to work and to give birth to healthy children, and erode children’s ability to learn and lead productive, healthy, and happy lives. This truncation of human development undermines a country’s potential for economic development. Hunger is therefore a cause as well as a consequence of poverty as malnutrition impairs the ability to learn or to work and reduces resistance to disease.
New poverty estimates published by the World Bank reveal that 1.4 billion people in the developing World (One in four) were living on less than US$1.25 a day in 2005, down from 1.9 billion people (one in two) in 1981 (World Bank, 2008). Poverty, therefore, has been more widespread across the developing world for over 25 years. In Africa, poverty is predominantly a rural phenomenon and is much lower among those with non-agricultural self-employment (over 20%) than those dependent on agriculture (45%). FAO (2008) estimates of 848 million people undernourished in the period 2003-2005 has been on the rise and by 2007 had reached 923 million people. Unfortunately, the public expenditures for agriculture and rural development in most developing countries do not reflect the importance of the sector to national economies or people’s livelihoods. Children’s health and cognitive development is especially sensitive, to the extent that the majority of child mortality is attributed to malnutrition. The second MDG indicator is the proportion of children under age 5 who are underweight in relation to their age. This situation has changed only from 32% to 26% in the period 1990-2006 (Figure 1).

![Figure 1: Underweight prevalence in children under five, by region (2000–2006): Source: One World. Net 23 August 2008.](image)

UNICEF (2008) has predicted that 51 countries are unlikely to reach 16%, the MDGs target by 2015. Moreover, these progress assessments predate the explosion in world food prices in 2008. UN Secretary-General Ban Ki-Moon has warned that “high food prices threaten to undo the gains achieved so far in fighting hunger and malnutrition” (Ban Ki-Moon, 2008).

Countries in Africa and South Asia can be blamed for their prolonged lack of investment in rural economies which account for about 75% of world hunger. For example, African governments are yet to meet their 2003 Maputo Declaration commitment which called for 10% of national budgets to be dedicated to agriculture by 2008. Uganda, allocated only 3.5% to agriculture this financial year! The majority of developing countries have food deficits, a serious problem for those lacking foreign currency to purchase expensive imports. On the basis of African’s estimates of 1.5 ton/ha and population growth of about 3% in 2005, Sub-Saharan Africa is expected to have a grain shortage of 88.7 million tones by 2025 (FAO, 2005).
Sustainable agriculture

Sustainable Agriculture which involves the attempts to ensure the profitability of farms while preserving the environment (American hostage Dictionary) can only become possible if Governments particularly of the developing world embrace Agriculture as the engine of development. Of the eight Millennium Development Goals, MDG 1 which calls for halving hunger and poverty by 2015 in relation to 1990 depends on agriculture the most and will for the foreseeable future remain important for rural development where more than 80% of the population live. In the recent past, “sustainability” has gained increasing acceptance as a concept for achieving the goal of a sustainable planet, one that will accommodate the basic needs of its present inhabitants while preserving the resources that will enable future generations to flourish. Although certainly not mainstream at this point, sustainable agriculture is now being addressed by the agricultural community in significant ways.

In spite of universality of a sustainable agriculture concept, agreement as to what is required to achieve it has not been universal. As more parties get on board of sustainable agriculture efforts, perceptions about what defines sustainability in agriculture become less clear. The prevailing agricultural systems are variously described as “conventional farming” and “modern agriculture”. We try to carry out innovations in our present food production systems to ensure their capability of maintaining their productivity and environmental soundness indefinitely. Because of these innovations, food production worldwide has risen in the past 50 years. The World Bank estimates that between 70 percent and 90 percent of the recent increases in food production is the result of conventional agriculture rather than greater acreage under cultivation (World Bank, 2008). Conventional farming systems vary from farm to farm and from country to country, however, they share many characteristics including rapid technological innovation and large capital investments in order to apply production and management technology. This is where agriculture in most tropical and sub-tropical countries which form the bulk of developing countries goes wrong as it is characterized by small farms which are intensively cultivated with low to no capital investments including low to no fertilizer use. These farming systems will inevitably negatively impact on the state of environmental resources used by agriculture and will, therefore, not be compatible with sustainable agriculture.

The great advances in crop yields since the 1970s, symbolized by the “green revolution”, are blamed for their negative ecological impact. The FAO (2008 ) suggests that 75% of food biodiversity was lost in the 20th century whilst 80% of the world’s dietary energy is now supplied by just 12 crops. The green revolution is also credited with the responsibility for significant degradation of soil quality and severe depletion of water resources. Governments of developing world must, therefore, come in to provide the necessary conditions on a long term basis for sustainable agriculture to become a reality in most of these regions.

Biotechnology

The biotechnology tools used in agricultural research include: tissue culture and molecular techniques which together form what is commonly referred to as modern biotechnology. Through the application of modern biotechnology to agriculture, breeders can make precise genetic changes that impart beneficial properties to the crop plants and animals. Agricultural biotechnology has helped farmers increase yields, enabling them to produce more food per acre and reduce the need for chemicals, pesticides, water, and tilling, thereby providing benefits to the environment as well as to the health and livelihood of farmers. Through specific design, biotechnology also can be used to enhance the nutritive value of staple foods to improve
overall nutrition and health. Agricultural biotechnology, although not a silver bullet, holds great promise to boost food production in both the developed and the developing world and to reduce agricultural vulnerability to the impact of pests, viruses, fungi, bacteria, and drought. It is, therefore, one of the primary ingredients in the world’s effort to combat food insecurity and malnutrition.

Although farmers have been practicing biotechnology in the broadest sense i.e. plant and animal breeding to achieve certain traits since domestication of the crops and animals, it is the recent breaking of the genetic code that has pushed this science into a new era of modern biotechnology. Modern biotechnology has several tenets but it is the tenet of genetic engineering where DNA from a different species is transferred to another to create a genetically modified organism (GMO) that provokes much controversy among sustainable agriculture advocates. This technology has created precise genetic products such as crop plants engineered for herbicide tolerance (HT), drought tolerance (DT), insect resistance (IR), etc. and bacteria engineered to produce drugs for livestock which has reduced chemical use in crop agriculture, imparted beneficial properties to the crop plants which produce enhanced food and fiber and improved animal health thus creating sustainable applications in agriculture. Through specific design, biotechnology also has been used to enhance the nutritive value of staple foods to improve overall nutrition and health. This technology is clearly compatible with sustainable agriculture but some people still express the concern of the possible risks involved in its use. The Union of Concerned Scientists’, for example, list perceived potential risks related to GMOs as: new allergens in the food supply, antibiotic resistance, production of new toxins, concentration of toxic metals, enhancement of the environment for toxic fungi; gene transfer to wild or weedy relatives and increased weediness, change in herbicide use patterns, squandering of valuable genes and gene complexes such as those manifested in locally adapted landraces of domesticated crops and animals, pest susceptibility genes, creation of new or worse viruses, and other so far unknown harms (UCS 2007).

The proponents of GMO technology, however, suggest that the main problem related to agro-ecosystem management is the major driving force behind genetic erosion in crops including variety replacement, land clearing, overexploitation of species, population pressure, environmental degradation through intensive cultivation and overgrazing, policy and changing agricultural systems and ecological uniformity imposed by the development of modern agriculture.
In spite of the very many concerns, the countries and the area sown to genetically engineered crops are rapidly increasing (Table 1).

Table 1: Global Area of biotech crops in 2006 & 2007 by Country (Million Hectares)

<table>
<thead>
<tr>
<th>No.</th>
<th>Country</th>
<th>2006</th>
<th>%</th>
<th>2007</th>
<th>%</th>
<th>+/-</th>
<th>% increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>USA*</td>
<td>54.6</td>
<td>53</td>
<td>15.7</td>
<td>50</td>
<td>+3.1</td>
<td>+6</td>
</tr>
<tr>
<td>2.</td>
<td>Argentina*</td>
<td>18.0</td>
<td>18</td>
<td>19.7</td>
<td>17</td>
<td>+1.1</td>
<td>+6</td>
</tr>
<tr>
<td>3.</td>
<td>Brazil*</td>
<td>11.5</td>
<td>11</td>
<td>15.0</td>
<td>13</td>
<td>+3.5</td>
<td>+30</td>
</tr>
<tr>
<td>4.</td>
<td>Canada*</td>
<td>6.1</td>
<td>6</td>
<td>7.0</td>
<td>6</td>
<td>+0.9</td>
<td>+15</td>
</tr>
<tr>
<td>5.</td>
<td>India*</td>
<td>3.8</td>
<td>4</td>
<td>6.2</td>
<td>5</td>
<td>+2.4</td>
<td>+63</td>
</tr>
<tr>
<td>6.</td>
<td>China*</td>
<td>3.5</td>
<td>3</td>
<td>3.8</td>
<td>3</td>
<td>+0.3</td>
<td>+9</td>
</tr>
<tr>
<td>7.</td>
<td>Paraguay*</td>
<td>2.0</td>
<td>2</td>
<td>2.6</td>
<td>2</td>
<td>+0.6</td>
<td>+30</td>
</tr>
<tr>
<td>8.</td>
<td>South Africa*</td>
<td>1.4</td>
<td>1</td>
<td>1.8</td>
<td>2</td>
<td>+0.4</td>
<td>+29</td>
</tr>
<tr>
<td>9.</td>
<td>Uruguay*</td>
<td>0.4</td>
<td>&lt;1</td>
<td>0.5</td>
<td>&lt;1</td>
<td>+0.1</td>
<td>+25</td>
</tr>
<tr>
<td>10.</td>
<td>Philippines*</td>
<td>0.2</td>
<td>&lt;1</td>
<td>0.3</td>
<td>&lt;1</td>
<td>+0.1</td>
<td>+50</td>
</tr>
<tr>
<td>11.</td>
<td>Australia*</td>
<td>0.2</td>
<td>&lt;1</td>
<td>0.1</td>
<td>&lt;1</td>
<td>-0.1</td>
<td>-50</td>
</tr>
<tr>
<td>12.</td>
<td>Spain*</td>
<td>0.1</td>
<td>&lt;1</td>
<td>0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>--</td>
</tr>
<tr>
<td>13.</td>
<td>Mexico*</td>
<td>0.1</td>
<td>&lt;1</td>
<td>0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>--</td>
</tr>
<tr>
<td>14.</td>
<td>Colombia</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>--</td>
</tr>
<tr>
<td>15.</td>
<td>Chile</td>
<td>--</td>
<td>--</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>--</td>
</tr>
<tr>
<td>16.</td>
<td>France</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>--</td>
</tr>
<tr>
<td>17.</td>
<td>Honduras</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>18.</td>
<td>Czech Republic</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>--</td>
</tr>
<tr>
<td>19.</td>
<td>Portugal</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>--</td>
</tr>
<tr>
<td>20.</td>
<td>Germany</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>--</td>
</tr>
<tr>
<td>21.</td>
<td>Slovakia</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>--</td>
</tr>
<tr>
<td>22.</td>
<td>Romania</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;-0.1</td>
<td>--</td>
</tr>
<tr>
<td>23.</td>
<td>Poland</td>
<td>--</td>
<td>--</td>
<td>&lt;0.1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
<td>--</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>102.0</td>
<td>100</td>
<td>114.3</td>
<td>100</td>
<td>+12.3</td>
<td>+12</td>
</tr>
</tbody>
</table>

*Mega-biotech countries growing 50,000 hectares, or more, of biotech crops. Source: Clive James, 2007

According to the International Service for the Acquisition of Agri-biotech Applications (ISAAA), GMO crops were grown by approximately 8.5 million farmers in 21 countries in 2005, up from 8.25 million farmers in 17 countries in 2004 (James, 2004). The largest increase in biotech crop area in any country in 2005 was in Brazil, estimated at 44,000 km² (94,000 km² in 2005 compared with 50,000 km² in 2004 James, 2006). India had by far the largest year-on-year proportional increase, with almost a threefold increase from 5,000 km² in 2004 to 13,000 km² in 2005 (James, 2005).
The Joint Research Centre, the European Union’s scientific and technical research laboratory and an integral part of the European Commission, has released its report on the “Scientific and technical contribution to the development of an overall health strategy in the area of GMOs” indicating that:

- There is a comprehensive body of knowledge that already adequately addresses current food safety issues including those dealing with GM products; it is considered by the experts as sufficient to assess the safety of present GM products.
- Developments in biotechnology will require even more sizeable efforts to maintain an adequate capacity to deal with novel products.
- Such R&D efforts need to be firmly inscribed in an international context.
- It is essential that a forum is created where stakeholders meet regularly to share expertise, to identify areas of improvement, to forecast upcoming developments and to anticipate needs for scientific and technical efforts.

Willy De Grief, Secretary General of EuropaBio, the European Association for Bioindustries, said “That food made from biotech crops is safe for human and animal consumption is not exactly news. We hope that the European policymakers who have insisted on verifying this fact again will now act in accordance with the findings in the form of more timely and actual approvals of biotech products” (De Grief 2008). The Group of Eight (G8) meeting in July 2008 in Japan endorsed modern biotechnology in agriculture and agreed to promote science based risk analysis of biotechnology (ww.isis.com). Also in July 2008; the Chinese Premier When Jiabao announced allocation of $3 billion in state support for the development new biotechnology varieties over the next 15 years. This clearly shows that China intends to use biotechnology as a key means to address food security and re-affirm its position that the technology can be used safely. This strong pro-biotech policy suggests that major food crops may soon break free from a long regulatory limbo and be permitted for planting. China has commercialized a number of genetically modified plants since 1997 including: rice, cotton, maize, soybean, tomato, sweet pepper, petunia, poplar, and papaya. China is now the sixth largest producer of agricultural biotechnology crops in the world by acreage, behind the United States, Argentina, Brazil, Canada, and India at 3.8 million hectares in 2007 (ISAAA, 2008).

The new ingredient in modern biotechnology is knowledge and with global knowledge-based economy, societies that are best able to generate knowledge will be better able to overcome constraints to sustainable wealth creation. In realization of this fact, the African Union Heads of State in January 2007 declared a 20 year strategy on African Biotechnology with specific technology goals that included interalia, development and harmonization of National and Regional regulations that promote safe use of modern biotechnology, establishment of African Biosciences initiative (ABI)( including Biotech, Biodiversity and Indigenous knowledge) and innovative communities in different sub-regions of the continent (Health biotech for SA, Animal Biotech for EA, Forest Biotech for CA and Biopharmaceuticals for NA). In addition to educational institutions especially universities and research centers, a number of institutions exist in Africa which are trying to promote the development of modern biotechnology (Table2).
Table 2: Institutions involved with Agro- biotechnology in Africa.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Location</th>
<th>Area of responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa Biosafety network of expertise (ABNET) established 2008</td>
<td>Burkina Faso</td>
<td>Support capacity building in Africa</td>
</tr>
<tr>
<td>Biosciences East Central Africa network (BECANET)</td>
<td>Nairobi, Kenya</td>
<td>Drive development of biotech &amp; other biosciences in E&amp;C Africa.</td>
</tr>
<tr>
<td>South Africa biosciences network (San Bio)</td>
<td>Pretoria, South Africa</td>
<td>Develop biotech in southern Africa.</td>
</tr>
<tr>
<td>West Africa biosciences network</td>
<td>Dakar, Senegal</td>
<td>Develop biotech in West Africa region</td>
</tr>
<tr>
<td>North Africa biosciences network (NABNET)</td>
<td>Cairo, Egypt</td>
<td>Africa north of Sahara</td>
</tr>
<tr>
<td>Regional economic communities initiatives</td>
<td>Each sub region of the Africa region</td>
<td>Harmonize biosafety &amp; develop regional regulatory guidelines</td>
</tr>
<tr>
<td>Africa biotechnology biosafety Policy plat form (ABBPP)</td>
<td>At FARA</td>
<td>Prepare Africa for international events on biotech &amp; biosafety. Build Capacity &amp; awareness for potential role of biotech in Africa.</td>
</tr>
<tr>
<td>African Agricultural Technology Foundation (AATF)</td>
<td>Nairobi, Kenya</td>
<td>Facilitates &amp; promote private public partnership &amp; deliver.</td>
</tr>
<tr>
<td>Program for biosafety systems (PBS)</td>
<td>Ghana, Kenya, Mali, Uganda, Malawi</td>
<td>Assist in development of biosafety legislation &amp; training in biosafety &amp; Risk communication</td>
</tr>
<tr>
<td>The Agricultural biotech support project11 (ABSOP11) USAID Funded</td>
<td>Uganda, Kenya, Mali</td>
<td>Helping Uganda to transform to resistant black sigatoka banana &amp; Mali to transform tomato to resist Yellow leaf curl.</td>
</tr>
<tr>
<td>Biotech NGOs e.g. AfricaBio, ISAAA, ABSF, AHBFI</td>
<td>Kenya, South Africa, Zimbabwe</td>
<td>Support development &amp; utilization of Agro-biotechnology Products</td>
</tr>
<tr>
<td>Anti GMOs, GNOs include Greenpeace, GRAINS</td>
<td>-</td>
<td>Show serious concern about GMOs and active in almost all African countries.</td>
</tr>
</tbody>
</table>

Many African countries have embraced agro-biotechnology but very powerful anti GMOs institutions especially NGOs supported by concerned non Africans do exist and exert their influence. The challenges that Africa still faces include: formulating and implementing biosafety legislations that encourage innovations and trade, building capacity, strengthening IPR regimes and creating awareness and informing the public. Only South Africa has commercial planting of GMOs, however, over twenty countries are engaged in GMO research and development. At least ten countries have field trials of GMOs and at least another 24 countries have the capacity and institutions to conduct research and development into Agricultural biotechnology (Table 3).
### Table 3: Status of genetic engineering and Product utilization in Africa.

<table>
<thead>
<tr>
<th>Country</th>
<th>GMO R&amp;D</th>
<th>Field trials</th>
<th>Commer-</th>
<th>GMO food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Egypt</td>
<td>Maize, Sugarcane, Cotton, Banana</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Morocco</td>
<td>Tomato</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tunisia</td>
<td>Potato</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Kenya</td>
<td>Sweet potato, Beans, cassava, cotton</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Mauritius</td>
<td>Sugarcane</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Mozambique</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Namibia</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>South Africa</td>
<td>Vegetables, Grains, fruits, Tree, Roots, &amp; tubers</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Tanzania</td>
<td>Cotton, Banana, Cassava</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Zambia</td>
<td>Cassava, cotton</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>Tobacco, Cotton, Maize, cowpeas, Sorghum, potato, tomato</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Benin</td>
<td>cowpeas</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>cotton</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ghana</td>
<td>Pearl millet, cowpea</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mali</td>
<td>cotton</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Niger</td>
<td>cowpea</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Maize, Cassava, Sweetpotato, Yam, Banana</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Senegal</td>
<td>Cowpeas</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Uganda</td>
<td>Bananas</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
</tbody>
</table>

About thirty countries have ratified the catangena protocol on biotechnology. So the debate in Africa is about polices, investments and strategies to ensure that Africa is in position to harness the benefits of biotechnology and does not miss out on the gene revolution as it did on the green revolution. Africa has woken up to the realization that in the end, the non-adopters of biotechnology will be obliged to adopt competitive products of biotechnology by those regions with advanced technologies. Africa’s ability to effectively use existing and emerging biotechnologies like in all developing world, will depend largely on the level of investment in building physical, human, institutional and societal capacities. More specifically, Africa’s regional innovation communities will need to specifically focus on creating and reforming existing knowledge-based institutions, especially universities, to serve as centers of diffusion of new technologies into the economy. The dependence on international cooperation will need a paradigm shift towards a new emphasis on individual country competence-building. Investing in critical capabilities is central to the developing world’s ability to move very fast.

Agricultural biotechnology has helped farmers Worldwide to increase yields which enable them to produce more food per acre and reduced the need for inorganic fertilizers, pest sides, water.
and tilling thereby providing benefits to the environment as well as to the health and livelihood of farmers. The contribution of GM crops to a reduction in the environmental impact of production agriculture has been demonstrated on the areas devoted to GM crops (Table 4).

Table 4: Impact of changes in the use of herbicides and insecticides from growing GM crops globally, 1996-2006.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Change in volume of active ingredient used (million kg)</th>
<th>Change in field EIQ impact (in terms of million field EIQ/ha units)</th>
<th>% change in ai use on GM crops</th>
<th>% change in environmental impact associated with herbicide &amp; insecticide use on GM crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM HT soybeans</td>
<td>-62.4</td>
<td>-5,536</td>
<td>-4.4</td>
<td>-20.4</td>
</tr>
<tr>
<td>GM HT maize</td>
<td>-46.7</td>
<td>-1,172</td>
<td>-3.9</td>
<td>-4.6</td>
</tr>
<tr>
<td>GM HT cotton</td>
<td>-32.1</td>
<td>-616</td>
<td>-14.3</td>
<td>-14.5</td>
</tr>
<tr>
<td>GM HT canola</td>
<td>-7.9</td>
<td>-372</td>
<td>-12.6</td>
<td>-24.2</td>
</tr>
<tr>
<td>GM IR maize</td>
<td>-8.2</td>
<td>-452</td>
<td>-5.0</td>
<td>-5.3</td>
</tr>
<tr>
<td>GM IR cotton</td>
<td>-128.4</td>
<td>-5,628</td>
<td>-22.9</td>
<td>-24.6</td>
</tr>
<tr>
<td>Totals</td>
<td>-285.7</td>
<td>-13,776</td>
<td>-7.9</td>
<td>-15.4</td>
</tr>
</tbody>
</table>

Source: Brookes & Barfoot. 2007.

Since 1996, the use of pesticides on the GM crop area has been reduced by 286 million kg of active ingredient, a 7.9% reduction, and the overall environmental impact associated with herbicide and insecticide use on these crops has been reduced by 15.4%. In absolute terms, the largest environmental gain has been associated with the adoption of GM HT soybeans and reflects the large share of global soybean plantings accounted for by GM soybeans. The volume of herbicides used in GM soybean crops decreased by 62.4 million kg (1996-2006), a 4.4% reduction, and, the overall environmental impact associated with herbicide use on these crops decreased by 20.4% relative to the volume that would have been used if this cropping area had been planted to conventional soybeans. Major environmental gains have also been derived from the adoption of GMIR cotton since 1996, farmers have used 128.4 million kg less insecticide in GMIR cotton crops (a 22.9% reduction), and this has reduced the associated environmental impact of insecticide use on this crop area by 24.6%.

GM technology has had a very positive impact on farm income derived from a combination of enhanced productivity and efficiency gains (Table 5).
Table 5. Global farm income benefits from growing GM crops, 1996-2006 ($ million)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Increase in farm income, 2006</th>
<th>Increase in farm income, 1996-2006</th>
<th>Farm income benefit in 2006 as % of total value of production of these crops in GM-adopting countries</th>
<th>Farm income benefit in 2006 as % of total value of global production of crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM HT soybeans</td>
<td>3,091</td>
<td>17,455</td>
<td>6.74%</td>
<td>5.58%</td>
</tr>
<tr>
<td>GM HT maize</td>
<td>296</td>
<td>1,111</td>
<td>0.64%</td>
<td>0.35%</td>
</tr>
<tr>
<td>GM HT cotton</td>
<td>21</td>
<td>814</td>
<td>0.13%</td>
<td>0.08%</td>
</tr>
<tr>
<td>GM HT canola</td>
<td>227</td>
<td>1,096</td>
<td>8.55%</td>
<td>1.49%</td>
</tr>
<tr>
<td>GM IR maize</td>
<td>1,131</td>
<td>3,634</td>
<td>2.47%</td>
<td>1.35%</td>
</tr>
<tr>
<td>GM IR cotton</td>
<td>2,149</td>
<td>9,567</td>
<td>13.15%</td>
<td>7.85%</td>
</tr>
<tr>
<td>Others</td>
<td>26</td>
<td>93</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>6,941</strong></td>
<td><strong>33,770</strong></td>
<td><strong>6.2%</strong></td>
<td><strong>3.8%</strong></td>
</tr>
</tbody>
</table>

Note. All values are nominal. n/a = Not applicable. Others = virus-resistant papaya and squash. Totals for the value shares exclude ‘other crops’ (i.e., relate to the four main crops of soybeans, maize, canola, and cotton). Farm income calculations are net farm income changes after inclusion of impacts on yield, crop quality, and key variable costs of production (e.g., payment of seed premium, impact on crop protection expenditure).


In 2006, the direct global farm income from GM crops was $6.94 billion. This is equivalent to having added 3.8% to the value of global production of the four main crops of soybeans, maize, canola, and cotton. Since 1996, farm incomes have increased by $33.8 billion. The largest gains in farm income have arisen in the soybean sector, largely from cost savings. The $3 billion additional income generated by GM HT soybeans in 2006 was equivalent to adding 6.7% to the value of the crop in the GM-growing countries or adding the equivalent of 5.6% to the $55 billion value of the global soybean crop in 2006. These economic benefits should, however, be placed within the context of a significant increase in the level of soybean production in the main GM-adopting countries. Since 1996, the soybean area in the leading soybean-producing countries of the United States, Brazil, and Argentina increased by 60%. Substantial gains have also arisen in the cotton sector through a combination of higher yields and lower costs. In 2006, cotton farm income levels in the GM-adopting countries increased by $2.15 billion and since 1996, the sector has benefited from an additional $9.6 billion. The 2006 income gains are equivalent to adding 13.1% to the value of the cotton crop in these countries, or 7.8% to the $27.3 billion value of total global cotton production. Significant increases to farm incomes have also resulted in the maize and canola sectors. The combination of GM IR and GM HT technology in maize has boosted farm incomes by $4.74 billion since 1996. Important farm
income benefits arising from GM HT soybeans in South America, Argentina, Brazil, Paraguay, and Uruguay, GM IR cotton in China and India, and a range of GM cultivars in the United States illustrate the growing level of farm income benefits being obtained by the farmers of GMOs.

Conclusion

The developing world will need to immediately expand and create infrastructure in order to tap into the opportunities that arise from biotechnology to ensure that the developing does not miss out on the biotechnology era. Emphasis should be put on maximizing the benefits associated with new technologies while reducing their negative impacts. Equally important is a consideration of the long term implications of non-adoption of emerging technologies. The essential point, therefore, is developing and harmonizing regulations governing issues of bio-safety and trade in biotechnology products and services rather than non adoption. There is great potential in developing North-South and South-South collaborations supporting biotechnology R&D and capacity-building in developing regional and local innovation areas. Countries and emerging Regional Innovation Communities need to identify ways of improving cooperation among the regions of Africa, Asia and Latin America to effectively address issues pertaining to biotechnology.

References


John Ikerd, as quoted by Richard Duesterhaus in Sustainability’s promise, Journal of soil and Acton and Gregorich, 1996. (Editors), the Health of Our Soils: Toward Sustainable Agriculture in Canada (Publication 1906/E Chapter 1; Ottawa:


[Shaping Agriculture for the Twenty-First Century: Biotechnology, (Union of Concerned Scientists (UCS)). Available at UCS Website: http://www.ucsusa.org/food_and_environment/genetic_engineering/

Chuck Hassebrook and Gabriel Hegyes, Choices for the Heartland: Alternative Directions in Biotechnology and Implications for Farming (Rural Communities and the Environment; Ames IA: Iowa State University, 1989), p. 3. NAL Call # S494.5 B563H37.


UNICEF UK News: News item: The tragic consequences of climate change for the world’s children: 29 April 2008 00:00

1. Global food crisis looms as climate change and population growth strip fertile land
2. Africa may be able to feed only 25% of its population by 2025