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# OPPORTUNITIES AND CHALLENGES IN APPLYING BIOTECHNOLOGY FOR AGRICULTURAL DEVELOPMENT IN UGANDA

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**Hellen B. Apio[1], Rodney Okwasimire[2], Mildred Nakanwagi[3], Edrick Bwambale[3]**

**Edited by:** Joshua R Muhumuza[1], Dr. Barbara M Zawedde[1*]

[1]National Agricultural Research Organization; [2]Makerere University, Kampala; [3]Uganda Christian University, Mukono

✉ bzawedde@naro.go.ug | bmugwanya@gmail.com



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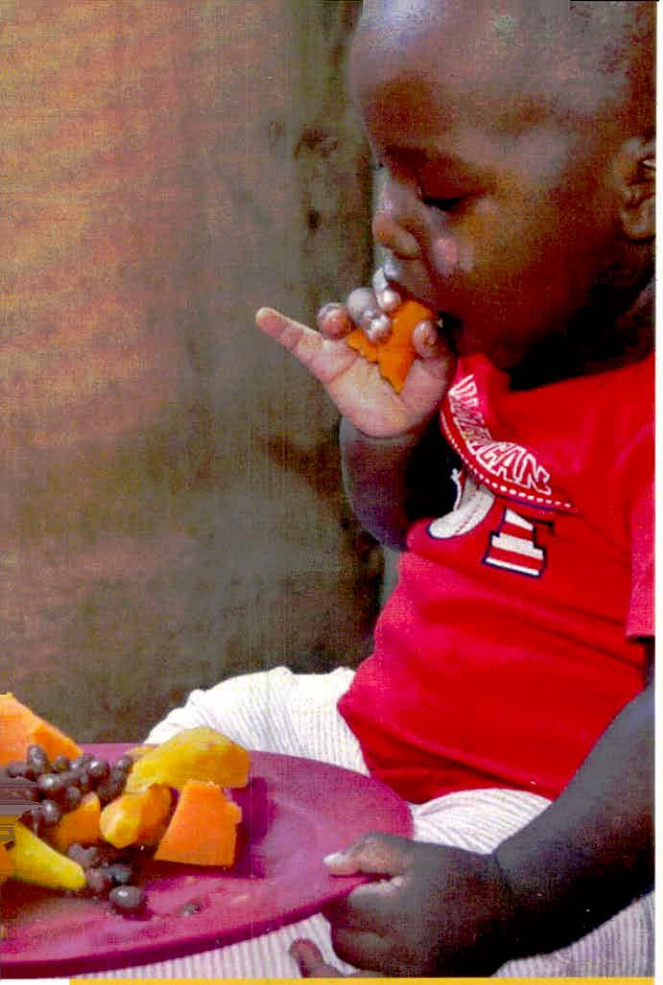


# Introduction

The term biotechnology was coined by the Hungarian engineer –Karl Ereky in 1919. According to Karl Ereky, biotechnology referred to all lines of work by which products are produced from raw materials with the aid of living organisms (Verma *et al.*, 2011). Applications of biotechnology are potentially unlimited. It encompasses basic knowledge from different disciplines like Biochemistry, Genetics, Chemistry, Microbiology, Engineering and Computer Science for biological agents (Almeida *et al.*, 2011). Biotechnology was defined in the international Convention on Biological Diversity as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use." It plays an important role in human health for designing new medicines and diagnostic tools. In agriculture, it's applied in tissue culture, marker assisted breeding and genetic engineering, in industry for massive production of food products, drugs and chemicals as well as waste degradation. However biotechnology has presented a number of opportunities and challenges which will be addressed here.

# Executive Summary

Biotechnology is the use of living systems and organisms to make and modify processes and products that improve our lives. Biotechnology has applications in four major areas; agriculture, medical and pharmaceutical sector, industrial and environmental sector, the marine and aquatic sector. It has been used to produce disease-resistant, drought tolerant and bio fortified crops, livestock improvement; development of vaccines, insulin for diabetic patients, treatment therapies for HIV, anemia and cancer; production of biofuels and bioplastics, value addition and waste management. The challenges associated with the use of biotechnology include; lack of adequate human capacity, lack of appropriate policies in place to strengthen research and development, lack of adequate government support, financing of biotechnology and the attitudes of the public towards products produced from the technology. This policy brief will provide information on the opportunities and challenges of Biotechnology.

# Opportunities for Biotechnology in Agriculture

The biotechnology industry was developed around techniques like gene cloning, directed mutagenesis, DNA sequencing, RNA interference, biomolecule labeling and detection, and nucleic acid amplification. These tools are being used to address the biotic and abiotic factors affecting the crops in the country. The crops on which biotechnology tools are being used in research include: cassava, banana, maize, potatoes, rice and sweet potatoes. Most of the work is conducted at the National Crops Resources Research Institute (NaCRRI) and National Agricultural Research Laboratories (NARL), institutions under National Agricultural Research Organisation (NARO).

The greatest threat to cassava production is the cassava brown streak disease (CBSD). Genetic engineering technology was used to introduce CBSD resistance into the Ugandan farmer-preferred cassava varieties. Tissue culture techniques are being used to ensure that farmers preferred varieties are conserved. Other techniques like somatic embryogenesis are being used to produce target tissue for genetic engineering and regrowth making it possible to transfer the technology to other farmer preferred cultivars.

At the National Agricultural Research laboratories (NARL) under NARO, in collaboration with the Centre for Tropical Crops and Bio-commodities, Queensland University of Technology, Australia developed GM bananas with enhanced nutrient composition to

address Vitamin A deficiency (VAD) and Iron Deficiency Anaemia (IDA). Also a gene from sweet pepper has been introduced into banana to impart resistance to bananna bacterial wilt.

Environmental factors such as water availability and salinity play a major role in determining changes in productivity of a crop. Nitrogen-Use Efficient, Water-Use Efficient and Salt-Tolerant (NEWEST) Rice project in a collaboration agreement between the African Agricultural Technology Foundation (AATF) and NaCRRI under NARO are testing triple stacked nitrogen-use efficient, water-use efficient and salt tolerant rice lines developed using biotechnology tools (NEWEST report, 2014). The Water Efficient Maize for Africa (WEMA) is testing a stacked Bt maize containing two Bt toxins, Cry2Ab2 and Cry1A.105. Both are insecticidal toxins isolated from the bacterium *Bacillus thuringiensis* (WEMA report, 2019). This strategy has minimized the use of pesticides on the crop and thier exposure to the environment.



Many farmers that are growing the Irish potato (*Solanum tuberosum*) are getting low yields. This is associated with the high incidences of epidemic diseases like late blight and bacterial wilt. Kachwekano Zonal Agriculture Research Institute (KaZARDI), one of the zonal institutions under NARO, is employing tissue culture techniques to multiply disease free seeds to increase productivity. The team has also produced a disease resistant Irish potato variety using biotechnology to enable high yields for food security and income generation.

In 1993, the Food and Drug Administration (FDA) approved recombinant bovine growth hormone (rBGH) developed by Monsanto to be injected into dairy cows to enhance milk production. The government of has continued to ensure that Artificial Insermination (AI) used in livestock to ensure that better breeds are produced. Due to that decision, the Animal Breeding Centre was transformed into a National Animal Genetic Resources Centre and Data Bank (NAGRC) by an Act of parliament (David Balikowa, 2011) making it possible for private investors to import semen for AI.

Healthcare biotechnology refers to a medicinal or diagnostic product or a vaccine that consists of, or has been produced in, living organisms and may be manufactured via recombinant technology (recombinant DNA). Biotechnology encompasses medicines and diagnostics that are manufactured using a biotechnological process, but also gene and cell therapies and tissue engineered products. It also provides unique, targeted and personalized therapeutic and diagnostic solutions for particular diseases or illnesses. The technology has facilitated production of hormones like interferons, cytokinins, steroids and human growth hormones. Gene therapy for prevention and control of diseases like hemophilia cystic fibrosis, development of vaccines and antibodies for rabies, HIV (Almeida *et al*, 2011).

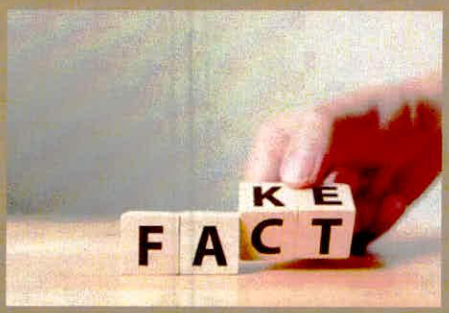
Biotechnology has been instrumental in initial drug discovery and screening stages, supporting research for new drugs (Ronald Evens and Kenneth Kaitin, 2015). Two types of hemophilia can now be distinguished, namely, hemophilia A and hemophilia B. These two blood clotting factors are produced by recombinant techniques. The first dosage obtained through biotechnological processes, was approved by the FDA In 1982. Recombinant human insulin is used for the treatment of patients with diabetes. It's available on the market as (Humulin®, Novolin®, Velosulin®). Treatment of diseases like anaemia due to chronic renal failure, HIV infection and cancer, has been possible using Erythropoietin alpha (Almeida *et al.*, 2011), and countries like Uganda are beneficiaries of these drugs.

Malaria continues to be a threat to human livelihoods. The vaccine development process is slow and mosquitoes have become resistant to insecticides used for treating bed nets (Thomas W. Scott, *et al.*, 2002). As a result, the Ugandan government plans to breed genetically-modified mosquitoes as part of a strategy to fight malaria. Efforts are underway to establish an insectarium, where research on breeding these mosquitoes to spread a genetic mutation that is lethal to malaria-causing species will be conducted. This research is currently conducted by the Uganda virus research institute (UVRI) (Daily monitor 2019).




In the industrial sector, biotechnology is being applied in production of chemicals and bioremediation. Bioremediation is the use of living organisms for the recovery or cleaning up of a contaminated medium such as soil, sediment, air, or water. The technology takes advantage of the metabolic processes of different organisms for degradation or sequestering and concentration of different contaminants (Marcin Cyprowski *et al.*, 2018). It is also applied to situations where there has been either accidental or intentional release of pollutants or chemicals that pose a risk to human, animal, or ecosystem health. Soil bioremediation, involves the optimization of the metabolic pathways of bacteria or fungi for degradation of hydrocarbons, aromatic compounds, or chlorinated pesticides while phytoremediation involves the use of plants for bioaccumulation of metals. Biomaterials and bioplastics are being developed today using biotechnology to compliment the traditional energy systems, in order to produce sustainable biochemicals (John J. Kibane., 2016).

# Challenges of biotechnology




The greatest hurdle biotechnology faces in Uganda, is associated with funding. The capital required to set up and sustain these state-of the art facilities is too expensive. This may include water, electricity, internet, monitoring field trials, accessing data bases like gene bank, expensive equipment and skilled personnel. When these systems are not in place, it becomes a challenge to use the tool (Ecuru and Naluyima, 2010).

There is need establish a system where the key players both locally and internationally interact, in order to create synergies between biotechnology programmes, therefore fostering inclusion of biotechnology into institutional programmes.

Among the concerns is the fear that antibiotic resistance genes used in developing genetically modified (GM) crops, would lead to people developing resistance to the antibiotics if administered in hospital.

Another issue is the possibility of having super weeds that can no longer be controlled by herbicides, as well as destabilization of the ecology of the environment, in relation to the GMO mosquito.

The negative publicity associated with the activists against the technology is another concern. Some claim that the products of the technology may result into production of toxic products which in turn may result in allergies that may be hard to cure. There are also fears of having this technology used by the wrong people to produce biological weapons of warfare.

There are many misconceptions about the technology. Many claim seeds from the technology don't germinate and can't be replanted for the next season, while others say the products from the technology affect the soil structure and nutrient profile. This creates an opportunity to educate the public about such misconceptions.

Despite repeated attempts to explain to policy makers how genetically modified organisms are developed, so that they can appreciate the reasons why a law is required to facilitate the research activities, Policy makers have failed to pass the approved bill into law.

There is need to address the administrative bottlenecks associated with the procurement of laboratory consumables as well as services by having properly laid out work plans anchored with co-ordinated financial management systems. There is also a need to encourage the private sector participate in commercialization of bioscience innovations.

Biotechnology has been and continues to be utilized to address the challenges in the fields of health and pharmacology, agriculture for both crops and animals, industry and environment. Given that there are different players involved in utilization and application of this technology, it is key to educate and create champions for the technology.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*For more information, contact:*

National Agricultural Research Organisation (NARO)
Plot 11-13 Lugard Avenue, Entebbe
Tel: +414 320512,320341/2
Email: dgnaro@naro.go.ug
www.naro.go.ug

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