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Chapter 8
Enhanced Utilization of Biotechnology Research and Development Innovations in Eastern and Central Africa for Agro-ecological Intensification

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Abstract The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) through its Agrobiodiversity and Biotechnology Programme is enhancing the utilization of biotechnology research and development innovations in Eastern and Central Africa (ECA). We present successes in the application of biotechnology to enhance the productivity of cassava, sweet potato, banana, maize and sorghum in ECA. These products—drought tolerant maize, sorghum resistant to *striga*, as well as the technology for producing and distributing disease free planting materials of cassava, sweet potato and banana to farmers—are central for the agro-ecological intensification of farming systems in the central African highlands.

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Introduction

The livelihoods of about 280 million people in ECA are supported by agriculture on approximately 300 million ha. This agriculture is based on agro-ecological systems that are highly vulnerable to biophysical constraints, such as drought, pests and disease. To address these constraints, ASARECA was developed as a forum for promoting agricultural research and strengthening relations between national agricultural research systems and the international agricultural research system (ASARECA 2006). The strategy recognizes the pivotal role that science and technology can play in addressing constraints to agricultural production as embodied in the Comprehensive Africa Agriculture Development Programme (CAADP) of the African Union. One of its programmes, Agrobiodiversity and Biotechnology, focuses primarily on the utilization of these tools to improve agricultural production (Borlaug and Dowswell 2002; Mugoya and Masiga 2009). Biotechnology offers the promise to improve yield and nutritional quality, as well as human health. Biotechnology is any technique that uses living organisms or substances from such organisms to make or modify a product, to improve plants or animals, or to develop micro-organisms for specific purposes. Agrobiotechnology refers to a range of diverse technologies derived from molecular genetics, plant physiology (especially tissue culture-related techniques), genetic engineering, and the emergent sciences, such as bioinformatics, genomics and proteomics, as applied in crop improvement and management. Here we present the use of biotechnology as an entry point in agricultural intensification as opposed to traditional approaches to enhance the productivity of cassava, sweet potato, banana, maize and sorghum in ECA. These biotechnological tools include the application of tissue culture, conservation biotechnology, genetic engineering and marker-assisted breeding.

Applying Tissue Culture to Improve Farmers' Access to Clean Planting Materials for Cassava, Sweet Potato and Banana

The main constraints to the production of cassava and sweet potato in the ECA sub-region are the high prevalence of pests and diseases, unavailability of suitable varieties, inefficient multiplication and distribution systems, poor market access, and the lack of a conducive policy and regulatory environment. Tissue culture has the potential to produce and rapidly disseminate disease free planting materials in large quantities that are uniform and clean, harvested early, highly marketable, and with uniform yields (Vuylsteke and Swennen 1992; Vuylsteke and Talengera 1998). Tissue culture is an appropriate technique for the delivery of planting materials across countries, as the material can more readily be certified disease free (Van der Linde 2000). In this study, low cost tissue-culture protocols and virus indexing tools for cassava and sweet potato varieties were optimized.

Low cost protocols that have been developed for cassava and sweet potato varieties include those that make use of locally available fertilizers as alternatives to Murashige and Skoog (MS) macro- and micro-nutrients (Ogero et al. 2011, 2012a, b). The produced plantlets are comparable to those produced in full strength MS media and thus support the use of these low cost materials. Other low cost tissue culture options for the production of cassava have been developed to complement and/or aid conventional methods of plant breeding. These protocols make use of low capital investment, cheap labour and low consumption of energy (Ogero et al. 2010).

A DNA-based tool for the detection of viral diseases of sweet potato prevalent in ECA has been developed. This is more effective and sensitive in diagnosing the sweet potato viruses than the currently available protein-based tool and has been recommended for use in quarantine and sweet potato research laboratories (Kim in prep). In addition, a tool, Multiplex RT-PCR, has been optimized that provides a new method for the simultaneous detection of sweet potato viruses and reduces material costs and time compared with several RT-PCR reactions that would be carried out separately for each virus, (Rukarwa and Mukasa 2011). An in-vitro thermotherapy procedure that eliminated sweet potato virus infection was validated (Rukarwa and Mukasa 2011). Up to 77 % of the plants were virus free. A Reverse Transcriptase-Polymerase Chain Reaction (RTPCR) based on a primer pair tool that detects viruses associated with cassava brown streak disease (CBSD) has been improved to simultaneously detect the two viruses (UCBSV and CBSV) and has been validated (Mbanzibwa and Mukasa 2011).

These virus detection tools, the use of planting materials free from pests and disease, and the elimination of viruses will ensure farmers' access to pest and disease free planting materials that will complement traditional approaches to increase the production of cassava, sweet potato and banana for sustainable intensification. The use of tissue culture has other advantages. For example, tissue cultured banana varieties mature early (12–16 months, compared with 2–3 years from the conventional banana), produce bigger bunch weights (30–45 kg) compared with 10–15 kg from conventional material with a higher annual yield/unit of land (40–60 t/ha against 15–20 t/ha previously realized with conventional material).

Other Biotechnology Innovations That Have Been Generated and Utilized in ECA

The programme has facilitated the transfer of banana tissue culture to smallholder farmers, developed a tissue culture certification system, and facilitated the work of the tissue culture business network (TCBN). This was done through partnership with Agrogenetic Technologies Limited (AGT) and AGROBIOTEC LTD. These activities have enabled more than 1,000 farmers to have access to banana plantlets free from pests and diseases, which may increase their production from the current production of 5 t/ha to their potential production of 60 t/ha. A draft certification scheme has been developed for facilitating the exchange of banana tissue culture planting materials (Komayombi et al. 2012). This will provide assurance to buyers/importers of tissue cultured materials that the materials being purchased are what they are claimed to be by the producer or seller. This will reduce fears that pathogens capable of causing systemic infections on their host plants can be transmitted through vegetative materials from infected mother plants to the young plants. Clean planting materials is a key in increasing the levels of production which is important in addressing food security concerns in the ECA region. In addition, a draft strategic plan for TCBN has been developed and is under review by the stakeholders. This plan will help in sourcing for investments in TCBN to facilitate the implementation of its objectives of promoting tissue culture business development, strengthening partnerships, exchanging business information/scientific data, building capacity, providing policy advice/advocacy and creating technology/product delivery mechanisms (TCBN 2012).

I. **Conservation for sustainable availability of cassava and sweet potato germplasm**

Cultivated and landraces of cassava and sweet potato have been collected, conserved using conservation biotechnology techniques, and are being characterized. This tool conserves germplasm in the form of test- tube plantlets or artificial seeds, and by cryopreservation (Shang 1984; Xia and Zhu 1987; Dodds 1988; Engelmann 1991; Towill and Jarret 1992; Tang et al. 1994; Blakesley et al. 1997; Guo et al. 1997). This will enhance long-term *ex situ* conservation and the sustainable utilization of cassava and sweet potato plant genetic resources of actual and potential value for the benefit of present and future generations. To enhance the utilization of these materials for breeding and identifying the genes responsible for resistance to CBSD, a genetic linkage map of resistance to CBSD is being developed. This map forms the basis for understanding the genetic basis of tolerance to CBSD in cassava cultivars (Nachinyaya and Kiroba) in order to rapidly and efficiently breed improved varieties (Ferguson in prep).

II. **Genetic engineering of maize for drought tolerance**

The programme has developed and is making available engineered maize genotypes tolerant to drought and adapted to ECA. This was done using genetic engineering approaches of gene up-regulation, under-regulation (silencing), and drought inducible expression of candidate genes. To date, 16 maize genotypes have successfully been transformed with 11 genes conferring drought tolerance; *Annexin p35, Annat1, NHX1, XVPRX2, XVSAP1, XVG6, IPT, CBF 1, PMI, amiRNA and Bar genes*. The maize genotypes developed using these genetic engineering technologies are being advanced and evaluated in the glasshouse at Kenyatta University in preparation for drought stress experiments and field trials. This approach has generated drought tolerant maize much faster than traditional approaches. These maize lines will form a major component in agricultural intensification.

Fighting *Striga* with Resistant Genes Deployed to Boost Sorghum Productivity

The programme utilized modern biotechnology tools to identify and map quantitative trait loci (QTLs) associated with resistance to *striga* and assigned them to their specific chromosomal locations by tagging them with tightly linked markers This will improve the precision with which these QTLs are being exploited through map-based cloning for resistance genes and in breeding the varieties that farmers prefer or the market demands *Striga* resistance genes were introgressed from the donor parent N13 into farmer preferred sorghum backgrounds Tabat, Wad Ahmed, and AG8 from Sudan; Hugurty from Eritrea; Ochuti from Kenya; and IS8193 from Rwanda, using marker assisted selection (MAS). Fifty- six superior *striga* resistant BC3 lines were generated (Masiga et al. in prep). Twenty-two lines are currently being evaluated in Sudan, Eritrea, Kenya, Uganda, Tanzania and Rwanda for agronomic performance and *striga* resistance with the aim of releasing them for commercial use in ECA. These resistant lines are important entry points leading towards agricultural intensification.

Lessons Learnt and Consequences for Agro-ecological Intensification of Agriculture

Cassava, sweet potato, maize, banana and sorghum are the main farming enterprises and form a major component of central African farming systems. Farming involving these enterprises is practised by smallholder subsistence farmers in ECA who are experiencing low production due to both abiotic and biotic constraints. Among the key constraints is drought for maize; pests and diseases for banana, sweet potato and cassava; and *striga* on sorghum.. We have learnt that by supplying farmers with vegetatively propagated crops that are free from diseases we can significantly improve the production of such crops. These disease free planting materials can be produced using low cost tissue culture technologies. Private sector laboratories can distribute the clean planting materials to the farmers. By developing sorghum resistant to *striga* using MAS, we have generated a key variety that can be used in the agricultural intensification system as *striga* is the main constraint to sorghum production in ECA. For agro-ecological systems where drought is the main constraint to maize production, transformation technologies have been used to develop maize resistant to drought. If farmers have access to this, it will form a major component in agro-ecological intensification of agriculture. We conclude that biotechnology has made a significant contribution to the intensification of farming systems. The region however needs to speed up the process of facilitating the formulation and implementation of the biosafety regulations.

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