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Transforming Agriculture for Improved Livelihoods

Situational Analysis of the Current State of Tissue Culture Application in the Eastern and Central Africa Region

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Foreword

The AGROBIO Programme of ASARECA has a cardinal role to enhance the utilisation of agro-biodiversity and biotechnology research towards the development of innovations in the East and Central African (ECA) region. The ECA region that comprises of nearly 400 million people is characterised by: a) small-scale farmers who predominate agriculture production; b) significant crop yield gaps when compared to other parts of the world where similar crops are grown; and c) increasing incidences of drought. These features have in part contributed to the consistent poverty and food insecurity problems that are prevalent in the ECA region. Thus, initiatives that increase crop productivity within the ECA region, will hugely impact on the resident communities that primarily depend on crop cultivation.

Plant tissue culture which involves culture of explants on nutrient media under sterile conditions, is one of the proven biotechnology applications that has hugely impacted on crop improvement. Notable of these applications have been: micro propagation, germplasm preservation, generation pathogen-free plants, embryo rescue, haploid production and genetic engineering. It suffices to note that the aforementioned applications in tissue culture are commonplace in other parts of the world, where agricultural production is critical.

Basing on the positive contribution of tissue culture in other parts of the world, I am convinced that its adoption and/or application can be useful in the ECA region, whose crop production is below optimal owing to severe biotic constraints. Sweet potato and cassava can be considered as model crops that can testify to this. These two crops: a) are widely grown in the ECA region; b) have huge genetic diversity that is maintained under the risky *in situ* conservation system; and c) yield below their potential largely due to multiple viral infections.

Regrettably, documentation on application of tissue culture in the ECA region is limited. The only information available is that contained in a 2006 workshop proceeding "Tissue Culture: Status, Potential and Challenges in the ASARECA Region" That report, that wasn't widely circulated, only highlightened the little co-ordination in tissue culture among different actors in the ECA countries. Accordingly, this situation analysis report was a response to this knowledge gap and thus documents the existing tissue culture capacity in terms of human resources and physical infrastructure.

This situation analysis covered six of the 10 ASARECA member countries: Kenya, Tanzania, Uganda, Rwanda, Burundi and Ethiopia. To my knowledge, this is first comprehensive situation analysis report on the current state of tissue culture in the ECA region. Through this analysis, a number of challenges and opportunities were identified. This compilation presents valuable information that will help scientists, donors and policy makers make informed-decisions on issues related to tissue culture application within the ECA region. Besides, this information also helps define and develop intervention programmes and their management. This compilation could also benefit students and lectures in identifying appropriate research and/or institutions for undertaking collaborative training on tissue culture. It is my sincere hope that later analyses will cover commodity-based undertakings and any other advances in tissue culture. Finally, I extend my heartfelt thanks to colleagues who have worked tirelessly to get this assignment done.

Dr. Fina Opio
Executive Director, ASARECA

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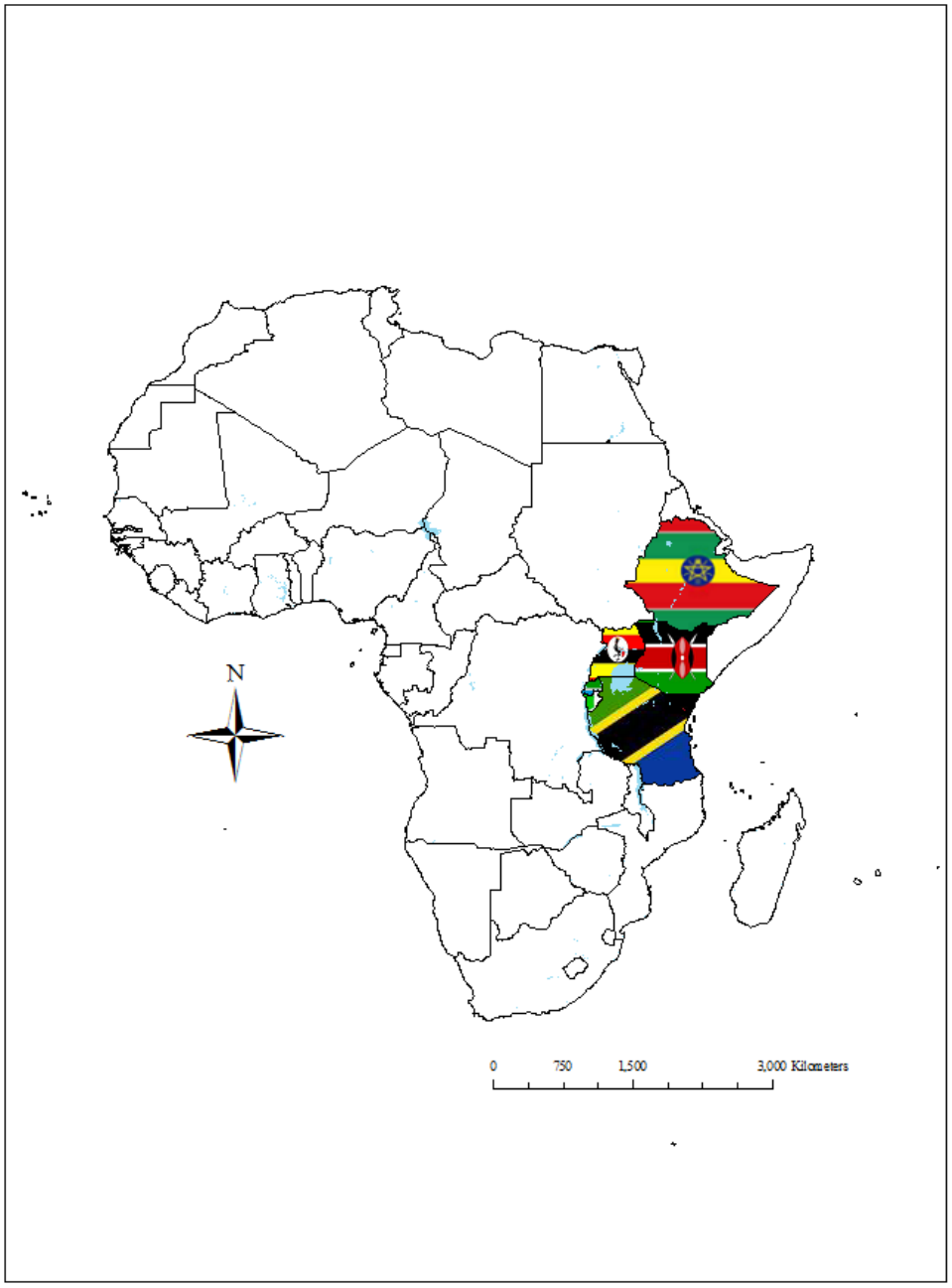
List of Abbreviations

AAU	Addis Ababa University
AGT	Agro-Genetic Technologies
AGROBIOTECH	Agro and biotechnologies
ABRC	Agricultural Biotechnology Research Centre
ARI	Agricultural Research Institute
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
BIO-EARN	East African Regional Programme and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development
CIRAD	Centre de cooperation Internationale en Recherchй Agronomique pour le Development
CRF	Coffee Research Foundation
DRT	Directorate of Research and Training
EAHB	East African Highland Banana
ECA	Eastern and Central Africa
ELISA	Enzyme-Linked Immunosorbent Assay
EAPTC	Ethiopian Association for Plant Tissue Culture
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agricultural Organization
FARA	Forum for Agricultural Research in Africa
GTIL	Genetics Technologies International Ltd
INIBAB	International Network for the Improvement of Banana and Plantains
INES	Institutd'Enseignement Superieur
IITA	International Institute of Tropical Agriculture
CIP	International Potato Centre
ISAAA	International Services for the Acquisition of Agric-biotech Applications
ISABU	Institut des Sciences Agronomiques du Burundi
ISAR	Institut des Sciences Agronomiques du Rwanda
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KARC	Kizimbani Agricultural Research Centre
KARI	Kenya Agricultural Research Institute
KZARDI	Kachwekano Zonal Agricultural Research Institute
KIST	Kigali Institute of Science and Technology
MARI	Mikocheni Agricultural Research Institute
NACRRI	National Crops Resources Research Institute
NARL	National Agricultural Research Laboratories
NARO	National Agricultural Research Organisation
NARS	National Agricultural Research System
NGO	Non-Governmental Organization
NPGRC	National Plant Genetic Resources Centre
NUR	National University of Rwanda
SUA	Sokoine University of Agriculture
TaCRI	Tanzania Coffee Research Institute
TRFK	Tea Research Foundation of Kenya
CRF	Coffee Research Foundation
UDSM	University of Dar es Salaam
UoN	University of Nairobi
USA	United States of America
USAID	United States Agency for International Development
VIRCA	Virus Resistant Cassava for Africa

Map of Study Area



The situation analysis was conducted in six countries within the East and Central Africa region: Ethiopia, Kenya, Uganda, Rwanda, Burundi and Tanzania

Executive Summary

Objective:

Tissue culture has since the beginning of the 20th Century been an important tool for application within the realms of cell biology, plant modification, germplasm storage, micropropagation, and product formation. For crops where tissue culture has been successfully applied, it has resulted into increased agricultural productivity. However, limited information is available on tissue culture in the East and Central African (ECA), a region that largely depends on agriculture. Thus, a situational analysis of the current state of tissue culture applications in the ECA was conducted to determine the existing capacity in terms of human resources and physical infrastructure.

Methodology

The study was conducted in 2008 in six countries namely: Kenya, Tanzania, Uganda, Rwanda, Burundi and Ethiopia. Information was collected (using a structured questionnaire) on status, potential, benefits and challenges of tissue culture applications in different institutions. The study also included literature review on status of biotechnology in the ECA region and secondary data available from previous studies. Further, face to face interviews with scientists and other stakeholders involved in tissue culture activities were conducted. A total of 49 institutions were contacted.

Key findings

The study revealed that there has been some investment made to promote tissue culture application within the ECA region, and that over the past five to ten years the number of research scientists and tissue culture infrastructure has been somewhat increasing in both public and private sector. The target crops and/or plants include: staples crops, horticultural crops, tree plants, medicinal plants and flowers. It was observed that tissue culture is predominately used for *in vitro* micropropagation and virus elimination. Haploid development and genetic transformation techniques were on a limited scale of utilization in Kenya, Uganda and Ethiopia.

Countries differ significantly with regard to quality of tissue culture infrastructure and the involvement of private sector. For instance, in Kenya up to eight institutions were directly involved, while in Burundi only four institutions are directly involved. In Rwanda no private laboratory exists, while in Kenya, up to three private laboratories are available. This analysis also identified non-governmental organisations (NGOs) and Universities actively involved in tissue culture training and/or awareness.

It suffices to note that most of the surveyed institutions don't have a critical mass of human resource, laboratory infrastructure and adequate financial resources to realise the potential of tissue culture in the ECA region. Other key constraints affecting the tissue culture industry include: high operation costs, inadequate facilities for virus indexing and certification, misconceptions about tissue culture products, weak linkages among tissue culture stakeholders, limited local suppliers of tissue culture reagents and inadequate national and/or regional policy frameworks to support private sector involvement in tissue culture.

Recommendations

Clearly, the benefits of tissue cultural towards increasing agricultural productivity in the ECA region can only be realised if the aforementioned challenges are addressed. This calls for real Government support and commitment, which should find in place functional and mutually beneficial collaboration among the different stakeholders involved in the tissue culture development and delivery pipeline.

Chapter 1:

Background to the Situation Analysis and Design

1.1 The Need for Tissue Culture

Tissue culture or *in vitro* culture is a technique through which small plant organs, embryos, cells or protoplast are aseptically isolated and grown on artificial nutrient media under controlled environment into complete plants. Since the inception of tissue culture in the 20th Century, it has made great progress from the sole purpose of demonstrating totipotency to several applications in both academic and applied sciences: micropropagation, germplasm conservation, embryo rescue and production of (haploid plants, transgenic plants, pathogen-free plants and secondary metabolites). Indeed, plant tissue culture is now an integral part of most crop improvement programmes.

It suffices to note that most of the aforementioned tissue culture applications are of practical relevance within the ECA region, whose agricultural production is unfortunately below optimum! This low productivity is associated with both regional staple crops (cassava, bananas, potatoes, sweet potatoes, maize, rice, sorghum, millets and wheat) and non-staple crops (horticultural crops, pulses and oilseeds). All these crops exhibit significant yield gaps when compared to production of similar crops in other parts of the world (FAO, 2009). Varying biotic stresses and agronomic practices largely explain for these yield differences.

Tissue culture applications notably, germplasm conservation, micropropagation, production of pathogen-free plants, embryo rescue and perhaps genetic transformation, offer hope in reversing these yield gaps in the ECA region. Firstly, germplasm conservation; all plant/crop genetic resources which includes (obsolete cultivars, local varieties, recently released varieties, genetic stocks, and wild relatives) can be conserved through tissue culture for purposes of genetic integrity and diverse utilization patterns. Undoubtedly, germplasm conservation is appropriate for all the staples and non-staple crops grown in the ECA region.

Secondly, micropropagation; this tissue culture application is useful in fast-tracking availability of elite planting material to the farming community. It suffices to note that many farmers in ECA cultivate inferior varieties in part, because of limited access to the elite varieties; this is exacerbated for crops like cassava, sweet potato and banana that inherently have low multiplication rates.

Thirdly, production of pathogen-free plants; this is particularly relevant for regional germplasm exchange and/or for cleaning elite varieties that aren't immune to virus infection. This is particularly relevant for cassava in the face of cassava brown streak disease (CBSD) outbreak in the ECA region. Fourthly embryo rescue, this holds great promise not only for facilitating wide crosses, but also for obtaining plants from inherently weak embryos and/or haploid plants. Embryo rescue has been successfully utilized in several crops (Sharma et al 1996), and can thus be adopted by breeding programmes within the ECA region.

Lastly, genetic transformation; this tissue culture application can be justified in cases where desirable phenotypes can't be attained through conventional breeding techniques. Cases for support include: weevil resistance in sweet potato, brown streak virus resistance in cassava, and drought tolerance. These are classical recalcitrant problems in the ECA region that can be mitigated through genetic transformation.

It's thus apparent from the foregoing narration that tissue culture applications (germplasm conservation, micropropagation, production of pathogen-free plants, embryo rescue and perhaps genetic transformation) offer huge potential in uplifting crop production in the ECA region, as witnessed in other parts of the world where its commonplace .

1.2 Specific Developments Leading to the Situation Analysis

Upon recognising the role that biotechnology tools such as tissue culture can play towards addressing Africa's most pressing concerns (food insecurity and poverty), countries in the ECA have in the recent years, been in the process of building their capacity to effectively use and integrate biotechnology in agricultural research. Indeed, it's on this premise that ASARECA commissioned a project *"Applying Tissue Culture to Improve Access to Cassava and Sweet potato Clean Planting Materials for Farmers in Eastern and Central Africa"* This project (2008-2012) is currently being implemented in eight countries: Burundi, Democratic Republic of Congo, Ethiopia, Kenya, Madagascar, Rwanda, Tanzania and Uganda.

In parallel, information collated by ASARECA in the past few years indicated that there was limited information on the extent of application of biotechnology in the ECA region. Also, there is limited information on technology transfer, crop indexing, tissue culture business development, seed delivery partnerships, research for development and information networks. Worse still, was the fact that accurate information on trained personnel involved in tissue culture as well as tissue culture infrastructure is limited. This study was a response to this information gap. Accordingly, this situation analysis was commissioned by ASARECA in order to generate comprehensive information and data on the status of tissue culture application in the ECA sub-region. This analysis was conducted in line with terms of reference contained in Appendix I.

1.3 Situation Analysis Design

The situation analysis aims were to collect information on status of tissue culture applications in six ECA countries (Uganda, Rwanda, Burundi, Kenya, Ethiopia and Tanzania). The objectives were:

1. To determine the existing tissue culture capacity in terms of human resources and physical infrastructure in selected ECA countries

2. To document challenges and tissue culture research projects being implemented in the selected ECA countries.

To achieve these objectives, a consultant was hired and tasked to travel to the six countries to collect this information. In each country, in-depth observations and face to face interviews were conducted with scientists and support-staff involved in tissue culture activities in academia, National Agricultural Research Systems (NARS), non-Governmental Organisations (NGOs) and in private laboratories (see Appendix II for the questionnaire used).

The interviews and observations conducted in each country were systematic and gave a fairy accurate picture of the status of tissue culture in the respective countries. To get further insights into tissue culture capacity available, literature searches on status of biotechnology in the ECA region and secondary data available from previous studies was undertaken. This situation analysis was conducted between 1st and 21st September 2008, and involved contact with a total of 49 organisations.

Chapter 2:

Findings

This report summarises information collected from the most relevant public and private organisations involved in tissue culture undertakings in the ECA region. The information was gathered from 12 universities, 28 NARIs, 7 private laboratories and 2 NGOs. Hereafter, a brief on status of tissue culture in each country is presented.

2.1 Status of Tissue Culture Capacity in Kenya

Available information suggests that tissue culture application in Kenya commenced in the early 1980s. By then, tissue culture was used in pyrethrum (*Chrysanthemum cinerariifolium*) and citrus production by Kenya Agricultural Research Institute (KARI) and the University of Nairobi's (UoN; Department of Crop Science). Over time, tissue culture applications by KARI and other public and private institutions have expanded to cover other crops and ornamental plants.

Key institutions presently involved in tissue culture activities in Kenya include: Kenya Agricultural Research Institute (KARI); Genetics Technologies International Ltd (GTIL); Jomo Kenyatta University of Agriculture and Technology (JKUAT); University of Nairobi (UoN); Coffee Research Foundation (CRF); Tea Research Foundation (CRF); Mimea International Limited; Oserian TC Lab; Africa Harvest; and the International Services for the Acquisition of Agric-biotech Applications (ISAAA). No contact was made with the Biosciences Eastern and Central Africa (BecA) hub at Nairobi. To date, Kenya is one of the few countries in the ECA region that has developed a significant capacity for agricultural biotechnology (see Tables 1, 2, and 3), with scientists from the public research institutions playing a key role (Table 4). Hereafter, a brief on each of the aforementioned institutions involved in tissue culture in Kenya is presented.

2.1.1 Kenya Agricultural Research Institute (KARI)

Kenya Agricultural Research Institute (KARI) is the largest research organization carrying out agricultural biotechnology research in Kenya. KARI took its first step in biotechnology research in the late 1980s, when its scientists began using tissue culture to propagate elite planting materials. Among the crops covered by these early efforts were pyrethrum and potatoes (*Solanum tuberosum*). However, over the past three decades tissue culture application has expanded to cover more crops to include: cassava (*Manihot esculenta*); sweet potato (*Ipomoea batatas*); sugarcane (*Saccharum officinarum*), coffee (*Coffea Arabica*), citrus fruits, oil palm (*Elaeis guineensis*), fruit trees and medicinal plants. KARI has also worked closely with a number of public research institutions and private companies in Kenya; through these partnerships, transference of verified technologies from KARI has somewhat been achieved.

It suffices to note that KARI has a number of centers undertaking tissue culture activities, notable of which include: 1) KARI-Thika (working on banana, *Musa spp*; *Macadamia spp*; sweet potato and flowers); 2) KARI-Biotechnology Centre (developing protocols for cassava and sweet potato transformation and for micropropagation of virus-free planting materials of oil palm, banana and vanilla); 3) KARI-Kakamega (cassava and sweet potatoes); 4) KARI-Njoro (cassava, sweet potatoes, banana, oil palm, and potato; wheat double haploids have also been generated); 5) KARI-Molo (pyrethrum); and 6) KARI-Tigoni (for production of basic seed of Irish potato). All these tissue culture activities are coordinated by the KARI Biotechnology Centre, Nairobi.

Tables 2 and 3 present information on both human and laboratory tissue culture capacity within the KARI centers. It's evident that the centers are at different capacity levels. For instance, some centers like KARI-Thika have staff with master's degree as the highest level of training, while at KARI-Njoro, it's a PhD. Ironically, KARI-Thika has 3 laminar flow hoods, while KARI-Njoro has only one laminar flow hood (Table 2).

Contamination is a major challenge in most tissue culture laboratories; lack of a water purification apparatus as witnessed in some of the centers can worsen this problem. Thus, the capacity requirements of most KARI centers include the need for refurbishment of some facilities, equipment, establishment of screen/weaning facilities and human resource capacity building. KARI institutes that should be given high priority are KARI Biotechnology Centre and KARI-Njoro

2.1.2 Jomo Kenyatta University of Agriculture and Technology (JKUAT)

Jomo Kenyatta University of Agriculture and Technology (JKUAT), established in 1981, is a relatively new University in Kenya. The JKUAT's Institute of Biotechnology Research (IBR) was only established in 1994, and is involved in applying tissue culture techniques for producing disease-free seedlings mainly of banana, sweet potato, Aloe vera and other plants such as Jatropha.

Two outstanding tissue culture projects that the University has implemented were: 1) *Production and Dissemination of Disease free Sweet potato and Cassava* (2006-2009) that was supported by BIO-EARN; and 2) *Mass Propagation of Tissue Culture Banana with Improved Protection against Pathogens and Nutrient Uptake Using Endophyte Technology"* that was undertaken in collaboration with the International Institute of Tropical Agriculture (IITA). In addition, the university has two BSc programs that have courses in plant tissue culture and biotechnology (Annex III). The University also undertakes M.Sc. and PhD training in biotechnology and also provides short courses in plant tissue and organ culture. In terms of human and infrastructure capacity, JKUAT has modern laboratory with well trained and skilled researchers and support staff (Tables 2 and 3).

2.1.3 University of Nairobi (UoN)

The Department of Plant Science and Crop Protection (formally Department of Crop Science), of the University of Nairobi (UoN) initiated tissue culture work in 1983. The Department's biotechnology activities are mainly focused on citrus, cassava, sugarcane and pyrethrum. In addition the Department is involved in: 1) development of tissue culture protocols for ornamental plants, 2) training of both graduate and postgraduate students in different aspects of tissue culture.

For human capacity for tissue culture, the Department has 2 PhD holders, who are supported by staff with either master's or bachelor's degree training in tissue culture (Table 3). The scope and nature of tissue culture activities conducted (and also proposed to be conducted) at UoN require that equipment, laboratory space and human resource capacity be increased. Short term training of laboratory technicians and other technical staff in specialised skills (e.g. virus elimination and disease diagnostic) would be extremely beneficial.

2.1.4 Coffee Research Foundation (CRF)

The Coffee Research Foundation (CRF), a center of excellence for coffee research in Kenya, was established as a company limited by guarantee in 1964. The principal objective of the Foundation is to promote research and/or investigate all issues pertaining coffee. CRF started tissue culture activities in the 1980s and was largely involved in the rapid and efficient mass propagation of coffee planting material. The foundation has recently optimized tissue culture techniques for rapid multiplication and dissemination of one of its elite variety (Ruiru II).
In addition, CRF has also been involved in the development of *in vitro* propagation systems for plants used for intercropping with coffee notable of which include: vanilla, bananas and pineapples. CRF has been able to commercialize coffee (~ 200,000 seedlings), bananas (~ 5000 seedlings). For human and

infrastructure capacity, the facility is manned by one professional staff with PhD level-training and is moderately equipped. The tissue culture investment at CRF should suffice mainly because its research focuses on only one commodity, coffee

2.1.5 Tea Research Foundation of Kenya (TRFK)

The Tea Research Foundation of Kenya (TRFK) was established in 1980 and this replaced the Tea Research Institute of East Africa. The principle objective of TRFK is to promote research and investigate problems related to tea production and utilization in Kenya. The TRFK started its tissue culture activities in 1990s. The foundation is focusing on the application of in vitro micropropagation of tea and eucalyptus clones showing fast growth. Just like for the CRF, tissue culture investments in TRFK should be given low priority because the institute's research mandate is largely limited to tea micropropagation.

2.1.6 Genetics Technologies International Ltd (GTIL)

Genetics Technologies International Ltd (GTIL) is a privately owned Kenyan company that has become a key player in up-scaling the production and marketing of tissue culture plantlets. Established in 1995, the company has a production capacity of ~ 7-10 million plantlets per year and has developed protocols to produce plantlets of a number of crops that are staples within the ECA region (Table 1). The commodities for which plantlets are already available include: key vegetative staple crops (banana, potatoes and sweet potatoes); industrial crops (pyrethrum, sugarcane, coffee and vanilla); horticultural crops (mangoes, avocados, citrus fruits, passion fruits, pawpaw, strawberry and pineapples); tree plants (*Eucalyptus*, *Acacia*, *Tectona* and *Jatropha*); and medicinal plants (*Prunus africana*, *Moringa oleifera*, *Artemisia annua* and *Azadirachta indica*).

GTIL plantlets are generally sold within Kenya and to neighboring countries including South Africa. It suffices to note that GTIL was recently involved in micropropagation of 30,000 elite cassava plantlets for distribution to six countries: Burundi, Democratic Republic of Congo, Kenya, Rwanda, Tanzania and Uganda. This assignment was financed by the Catholic Relief Service under the "Great Lakes Cassava Initiative" project. GTIL has recently opened a base in Tanzania in order to effectively reach more clientele; this new outlet is currently propagating Eucalyptus.

2.1.7 Mimea International Limited

Mimea International Limited is another private tissue culture facility established in Kenya in 2004 for production of quality planting materials of: banana, vanilla, horticultural crops (passion, citrus, mangoes papaya) and tree species (*Jatropha*, *Moringa oleifera,* Azadirachta *indica, Prunus africana*) and flowers (Table 1). The company currently employs nine full-time staff and produces between 50,000 to 70,000 banana seedlings and about 100,000 eucalyptus seedlings per year.

2.1.8 Oserian TC Lab

The Oserian TC lab is a private tissue culture laboratory in Kenya that was established in I992 in response to the expanded demand for high quality cut flower production. Currently, the laboratory produces Statice, Gysophila, Gerbera and Lilies, which are meant for either local or foreign markets. Recently, the Oserian TC lab has also engaged in production of banana plantlets.

2.1.9 Africa Harvest

Africa Harvest Foundation International (Africa Harvest), headquartered in Nairobi, Kenya, is a non-profit organisation established in 2002 to promote the use of advanced science and technology products to improve agricultural productivity in Africa. Though not directly involved in tissue culture application, Africa Harvest's technical programs are relevant to tissue culture. In fact, since 2002, Africa Harvest has, amongst other things achieved the following: a) helped stakeholders gain a better understanding of biotechnology and tissue culture through provision of factual information and forum for active debate; b) successfully introduced tissue cultured banana to the rural poor and helped set farmer- based company –Tissue Culture Banana Enterprise Ltd; c) provided training and mentoring for tissue culture technology dissemination; d) helped with development of promotion and dissemination approaches for tissue culture planting materials; and e) provided marketing information and access.

2.1.10 International services for the Acquisition of Agric-biotech Applications (ISAAA)

The International Services for the Acquisition of Agric-biotech Applications (ISAAA) is a not-for-profit international organisation that shares the benefits of crop biotechnology to resource-poor farmers in developing countries, through knowledge sharing initiatives and the transfer and delivery of proprietary biotechnology applications. The African centre of ISAAA (*Afri*Center) was established in 1994 and is based in Nairobi, Kenya. Its portfolio of projects include: 1) a tissue culture project to support banana production in Kenya and other East African countries, and 2) a program for the micropropagation and distribution of multipurpose trees. Through these projects ISAAA has concentrated on technology transfer, improved communication and knowledge sharing. In addition ISAAA have a global electronic newsletter –the CropBiotech newsletter that is disseminated weekly.

It's apparent from the foregoing that tissue culture application in Kenya is: a) currently being undertaken by both public and private institutions, operating at different capacities; b) applied on a number of commodities including staples crops, horticultural crops, tree plants, medicinal plants and flowers; c) predominately used for *in vitro* micropropagation and virus elimination; haploid development and genetic transformation techniques applications are on a limited scale of utilization; and d) largely supported by research undertakings and/or outputs by scientists from public research institutions notably KARI and JKUAT.

Table 1. Overview of tissue culture applications in selected institutions in Kenya

Institution	Target commodity/ focus
Public Research Institutions	
KARI- Thika	Tissue culture of banana, Macadamia, Sweet potato and flowers
KARI-Molo	Pyrethrum
KARI- Biotech Centre	Tissue culture of cassava, sweet potato, oil palm, banana and vanilla. Genetic transformation of cassava and sweet potato
KARI-Njoro	Tissue culture of cassava, banana, sweet potato, potato, and oil palm Wheat double haploid generation through embryo rescue
KARI-Kakamega	Tissue culture of sweet potato and cassava
KARI- Tigoni	Irish potatoes
KARI- Muguga	Tissue culture of sweet potatoes, pyrethrum and ornamentals
Public Universities	
University of Nairobi (UoN)	Tissue culture of citrus fruits, banana, ornamentals, sugarcane and pyrethrum
Jomo Kenyatta University of Agriculture and Technology (JKUAT)	Tissue culture of banana, sweet potato, Aloe vera and Jatropha.
Private non-commercial Institutions	
Coffee Research Foundation (CRF)	Tissue culture of coffee, banana and vanilla.
Tea Research Foundation (TRF)	Tissue culture of tea and *Eucalyptus*
Private and Commercial Institutions	
Genetics Technologies International Ltd (GTIL)	Tissue culture of banana, potatoes, sweet potatoes, pyrethrum, sugarcane, coffee, vanilla, mangoes, avocados, citrus fruits, passion fruits, pawpaw, strawberry, pineapples, *Eucalyptus*, *Acacia*, *Tectona, Jatropha*, *Prunus africana*, *Moringa oleifera*, *Artemisia annua* and *Azadirachta indica*
Oserian TC Lab	Tissue culture of cut flowers
Mimea International Limited	Mass propagation of banana, vanilla, passion, citrus, mangoes papaya, *Jatropha*, *Moringa oleifera,* Azadirachta *indica, Prunus africana* and flowers
Non-Government Organization (NGO)	
Africa Harvest	Promote the use of advanced science and technology products to improve agricultural productivity in Africa.
International Services for the Acquisition of Agric-biotech Applications (ISAAA)	Promotes knowledge sharing initiatives and the transfer and delivery of proprietary biotechnology applications to poor farmers

Table 2. A checklist of tissue culture equipment available in selected laboratories in Kenya[1]

Equipment	KARI-Biotech	KARI-Thika	KARI-Njoro	JKUAT	UoN	GTIL
Media preparation and autoclaving unit						
Autoclaves	2	1	2	2	2	3
Precision balances	1	1	1	1	2	1
pH Meter	1	1	1	1	1	0
Water purification apparatus	1	0	0	0	1	0
Refrigerated centrifuge	1	0	0	0	0	0
Deep Freezers (-20^{0}C)	1	1	0	0	2	0
Fridge/Freezers ((-4^{0}C))	2	2	1	3	2	1
Hot plate with stirrer	1	1	1	2	2	0
Micro pipettes (sets)	5	1	1	1	2	2
Microwave oven	1	1	1	1	1	0
Rotary shaker	1	0	0	1	1	0
Water distiller (single)	1	1	1	1	1	1
Water distiller (double)	0	0	0	0	0	0
Working area and growth room unit						
Laminar flow hood	1	3	1	3	2	9
Fume hood	1	0	0	1	0	0
Microscope stereo	3	1	0	2	1	0
Microscope dissecting	2	1	2	2	0	0
Tissue culture growth rooms	2	1	1	2	2	5
Other accessories						
Ice maker	0	0	0	1	1	0
Indexing facility	1	0	1	1	0	0
Screen house	5	1	1	1	2	13
Standby generator	1	0	1	0	1	1
Computer	1	0	0	0	1	0

[1]KARI = Kenya Agricultural Research Institute; JKUAT = Jomo Kenyatta University of Agriculture and Technology; UoN= University of Nairobi; GTIL = Genetics Technologies International Limited.

Table 3. Overview of human resource capacity and training needs in selected tissue culture laboratories in Kenya

Institution	Current state				Training needs			
	PhD	M.Sc	B.Sc.	Diploma	PhD	M.Sc	B.Sc.	Diploma
KARI-Biotech	0	5	1	3	1	3	2	3
KARI-Thika	0	1	3	2	1	2	2	4
KARI-Kakamega	0	1	1	2	1	1	1	3
KARI-Njoro	2	1	1	1	1	2	2	4
UoN	2	1	1	2	0	2	0	3
JKUAT	4	1	2	5	0	2	0	3
GTIL	0	0	0	23	0	0	1	4

[1]KARI = Kenya Agricultural Research Institute; JKUAT = Jomo Kenyatta University of Agriculture and Technology; UoN= University of Nairobi; GTIL = Genetics Technologies International Limited.; PhD = Doctorate of Philosophy degree; M.Sc. = Master's degree; B.Sc. = Bachelor's degree; Diploma = Certificate and/or Diploma award

Table 4. A checklist of researchers involved in tissue culture application in Kenya[1]

Name	Institution	Level of Education	Research activity
Esther Kahanji	JKUAT	PhD	Mass propagation, virus elimination, indexing in banana sweet potato and Jatropha
Elijah Ateka	JKUAT	PhD	Mass propagation, virus elimination, indexing in banana sweet potato and Jatropha
Bernard Nyende	JKUAT	PhD	Mass propagation, virus elimination, indexing in banana sweet potato and Jatropha
Edward Mamati	JKUAT	PhD	Mass propagation, virus elimination, indexing in banana sweet potato and Jatropha
Lucy Gitonga	KARI-Thika	MSc	Mass propagation, virus elimination in banana and Macademia
DancunKingangi	KARI-Thika	BSc	Banana tissue culture
Evans Mutima	KARI-Thika	BSc	Banana and flowertissue culture
Mundi Njeroge	KARI-Thika	BSc	Banana and flowertissue culture
Faith Ngothi	KARI-Thika	PhD	Banana tissue culture
Laura Karanja	KARI Njoro	MSc	Banana and sweet potato tissue culture
Okuaro, J	KARI Njoro	MSc	Cassava tissue culture
Joyce Maliga	KARI Njoro	PhD	*O*il palm tissue culture
Ndolo	KARI-Kakamega	MSc	Sweet potato and cassava tissue culture
Irene Njalu	KARI-Biotech lab	MSc	Cassava tissue culture
Paul Kimemia	KARI-Biotech lab	MSc	Cassava tissue culture
Bosiberi betty	KARI-Biotech lab	MSc	Sweet potato tissue culture
John Sitinei	KARI-Biotech lab	MSc	Tissue culture and regeneration of maize
Jayne Binott	KARI-Biotech lab	MSc	Tissue culture and regeneration of maize
John Irungu	KARI-Biotech lab	BSc	Cassava tissue culture

[1]KARI = Kenya Agricultural Research Institute; JKUAT = Jomo Kenyatta University of Agriculture and Technology; UoN= University of Nairobi; GTIL = Genetics Technologies International Limited.

2.2 Status of Tissue Culture Capacity in Tanzania

The level of biotechnology research and utilization in Tanzania is still in its infancy. Of the biotechnology tools, tissue culture is the most widely applied technique. Tissue culture has been mainly employed for mass propagation of virus-free planting material and conservation of vegetatively propagated crops. Institutions involved in tissue culture application in Tanzania include: Mikocheni Agricultural Research Institute (MARI); Agricultural Research Institute (ARI) Mlingano; ARI-Uyole; ARI-Ukiriguru; ARI-Tengeru; National Plant Genetic Resource Centre (NPGRC); Tanzania Coffee Research Institute (TaCRI); Kizimbani Agricultural Research Centre (KARC); Sokoine University of Agriculture (SUA) and the University of Dar es Salaam. The current status of physical infrastructure and human capacity for tissue culture of these institutions is presented in Tables 5, 6 and 7.Hereafter, a brief on each of the aforementioned institutions involved in tissue culture in Tanzania is presented.

2.2.1 Mikocheni Agricultural Research Institute (MARI)

Mikocheni Agricultural Research Institute (MARI) is one of the research institutes under the Division of Research and Training (DRT) of the Ministry of Agriculture and Food Security. This Institute is responsible for the promotion and coordination of agricultural biotechnology activities in the country. Tissue culture activities at MARI were initiated in 1986 by establishment of a tissue culture laboratory to facilitate coconut (*Cocos nucifera*) germplasm exchange. Since then, the institute's mandate has greatly expanded to accommodate other crops which include: cassava, sweet potato, banana, cashew, pineapple, vanilla and coffee. This expanded mandate was also associated with the upgrading of the infrastructure capacity through acquisition of advanced equipment (Table 5) and staff training (Tables 6 and 7). Through a BIOEARN funded project MARI was able to develop capacity for the production of disease-free cassava and sweet potato varieties through cryotherapy and meristem culture in order to facilitate safe exchange of germplasm. MARI has also initiated work on cassava genetic transformation. In addition, the institute offers short term courses (2-4 weeks) on biotechnology and tissue culture.

2.2.2 Agricultural Research Institute (ARI) Mlingano

ARI- Mlingano was established in 1934 with the objective to conduct research for improvement of sisal yield. In partnership with KATANI Ltd, a sisal processing, manufacturing and marketing company, ARI-Mlingano established a tissue culture laboratory for micropropagation of sisal (Table 7). Unfortunately, this laboratory is not fully utilized because of limited operating funds.

2.2.3 ARI-Uyole

ARI Uyole located in Mbeya has recently acquired adequate facilities for undertaking tissue culture applications. The tissue culture laboratory will be used for mass propagation of cassava, potatoes, banana, pyrethrum, and coffee. .

2.2.4 ARI Ukiriguru

ARI Ukiriguru in Mwanza has vast experience in sweet potato and cassava research. The institute has recently completed construction of tissue culture facility. When fully equipped, the laboratory will be used for mass propagation of sweet potatoes, cassava and banana.

2.2.5 ARI-Tengeru

ARI-Tengeru based in Arusha had a tissue culture laboratory that hadn't been in operational for some time because it was lacking some facilities. Currently the institute is working on mass propagation and dissemination of disease-free planting materials for banana and sweet potato, in collaboration with KARI and ISAAA.

2.2.6 National Plant Genetic Resource Centre (NPGRC)

The National Plant Genetic Resources Centre of Tanzania (NPGRC) is among the four divisions under Technical Services Department of Tropical Pesticides Research Institute (TPRI). The center was established in 1991to promote the conservation and sustainable utilization of plant genetic resources. Current tissue culture activities at NPGRC include *In situ* conservation of cassava.

2.2.7 Tanzania Coffee Research Institute (TaCRI)

Tanzania Coffee Research Institute (TaCRI) is a private institute that was established in 2000 to oversee all coffee production activities and to support the rejuvenation of coffee industry in Tanzania. TaCRI aims at the revitalisation of coffee research through the establishment of a well-managed research institute for providing essential services to coffee farmers. The Institute established a tissue culture facility with an annual capacity of ~ 250,000 plantlets through somatic embryogenesis with technical support from Centre de Coopйration Internationale en Recherche Agronomique pour le Dйveloppement (CIRAD) under the European Union funding programme.

2.2.8 Kizimbani Agricultural Research Centre (KARC)

The mandate of KARC in Zanzibar is to conduct agricultural research and development activities for the development of improved crop varieties and farming methods suitable for the conditions in the isles. The centre has established a tissue culture facility for mass propagation of banana in collaboration with the International Network for the Improvement of Banana and Plantains (INIBAP). KARC is also involved in conducting tissue culture work on sweet potato and cassava. Despite this progress, it's apparent that both laboratory and human capacity for tissue culture is limited (Tables 5 and 6) and thus needs to be strengthened.

2.2.9 Sokoine University of Agriculture, Morogoro (SUA)

The history of Sokoine University of Agriculture dates back to 1965 when it started as an Agricultural College offering agriculture diploma training. To date, SUA is a public university that is mandated to teach and undertake research within the faculties of: Agriculture, Forestry and Nature Conservation, Veterinary Medicine, and Science. SUA has a small tissue culture laboratory with weaning facilities for both research and training purposes. The key activity in this laboratory is micropropagation of crops notable of which are bananas. The university has a B.Sc. degree course in biotechnology (Annex 3). Given the role of SUA in undertaking both research and training in tissue culture, it's critical that both its infrastructure and human capacity be strengthened.

2.2.10 University of Dar es Salaam

The University of Dar es Salaam established in 1970s, is one of the biggest public universities in Tanzania. The university has a small tissue culture laboratory which is used solely used for teaching purposes. Just like SUA, given its role in training in tissue culture, it's critical that both its infrastructure and human capacity be strengthened.

It's apparent from the foregoing that tissue culture application in Tanzania is: a) currently being undertaken by public institutions; b) applied on a number of commodities key of which include coconut, banana, coffee, cashew, cassava, sweet potato, sisal, and pyrethrum; c) utilized mainly for micropropagation, cryotherapy, indexing, and conservation; and d) still in its infancy and thus needs concerted support so that it's potential can be fully exploited.

Table 5. A checklist of tissue culture equipment available in selected laboratories in Tanzania[1]

Equipment	A	B	C	D	E	F	G	H	I	J
Media preparation and autoclaving unit										
Autoclaves	1	1	1	2	1	2	1	1	1	1
Precision balances	1	1	2	3	1	1	1	1	1	1
pH Meter	1	1	2	3	1	2	1	1	2	1
Water purification apparatus	0	0	0	1	0	0	0	0	1	0
Refrigerated centrifuge	0	0	0	2	0	0	1	0	1	0
Deep Freezers (-20^{0}C)	1	1	1	3	1	0	0	1	2	0
Fridge/Freezers (-4^{0}C))	1	1	2	2	1	1	1	2	2	1
Hot plate with stirrer	1	1	1	3	2	1	1	1	2	1
Micro pipettes (sets)	0	0	0	2	1	0	0	0	0	0
Microwave oven	0	0	0	1	0	0	0	0	1	0
Rotary shaker	0	0	0	1	0	0	0	0	0	0
Water distiller (single)	1	1	1	3	1	1	1	1	1	1
Water distiller (double)	0	0	0	2	0	0	0	0	0	0
Working area and growth room unit										
Laminar flow hood	1	2	2	3	1	3	1	1	3	1
Fume hood	0	1	0	2	1	0	0	0	0	1
Microscope stereo	1	1	2	4	1	1	1	0	1	2
Microscope dissecting	0	0	0	1	0	0	0	0	0	0
Growth room	1	1	2	3	2	1	1	0	1	1
Other accessories										
Ice maker	0	0	0	1	0	0	0	0	0	0
Indexing facility	0	0	0	1	0	0	0	0	1	0
Screen house	0	1	0	1	1	1	1	1	2	1
Standby generator	0	1	0	1	0	0	0	0	0	1
Computer										

[1]A = ARI-Uyole; B = ARI-Mlingano; C = ARI-Tengeru; D = Mikocheni Agricultural Research Institute; E = ARI-Ukiriguru; F = Tanzania Coffee Research Institute; G = KizimbaniAgricultural Research Centre; H = National Plant Genetic Resource Centre; I = Sokoine University of Agriculture; J = University of Dar es Salaam

Table 6. Overview of human resource capacity and training needs in selected tissue culture laboratories in Tanzania[1]

Institution	Current state				Training needs			
	PhD	M.Sc	B.Sc.	Diploma	PhD	M.Sc	B.Sc.	Diploma
MARI	3	2	0	3	0	2	2	4
ARI- Mlingano	0	1	2	2	1	1	1	1
ARI-Uyole	0	1	0	0	0	2	1	2
ARI-Tengeru	0	1	0	1	0	3	2	2
ARI Ukiriguru	0	0	1	1	-	-	-	-
NPGRC	0	1	0	1	0	2	1	0
KARC	0	1	0	2	0	0	2	0
TaCRI	0	0	1	1	1	1	1	1
SUA	3	2	0	3	1	2	1	3
UDSM	1	0	0	1	2	2	2	3

[1] MARI= Mikocheni Agricultural Research Institute; ARI = Agricultural Research Institute; NPGRC = National Plant Genetic Resource Centre; TaCRI = Tanzania Coffee Research Institute; KARC = Kizimbani Agricultural Research Centre; SUA + Sokoine University of Agriculture; UDSM = University of Dar es Salaam; PhD = Doctorate of Philosophy degree; M.Sc. = Master's degree; B.Sc. = Bachelor's degree; Diploma = Certificate and/or Diploma award

Table 7. A checklist of researchers involved in tissue culture application in Tanzania[1]

Name	Institution	Level of Education	Research activity
Linus Masumbuko	MARI	PhD	Tissue culture of coffee, coconut and banana
Emmarold Mneney	MARI	PhD	Micropropagation- cashew, cassava and sweet potato
Fred Tairo	MARI	PhD	Cryotherapy, diagnostics, indexing –cassava and sweet potatoes
Julius Mugini	MARI	M.Sc.	Diagnostics and indexing of banana
Micah Seth	MARI	BSc	Micropropagation and regeneration of maize and vanilla
Shabani Hamisi	ARI-Mlingano	M.Sc.	Tissue culture of sisal
Beatrice Mlay	ARI-Mlingano	BSc	Tissue culture of sisal
LaddySwai	ARI-Mlingano	BSc	Tissue culture of sisal
Richard Madege	ARI-Mlingano	BSc	Tissue culture, sweet potato and sisal
Benjamin Kiwovele	ARI-Uyole	M.Sc.	Tissue culture pyrethrum
Deusdedit Mbanzibwa	ARI-Ukiriguru	PhD	Diagnostics
IgnasSwai	ARI-Tengeru	M.Sc.	Tissue culture of banana and hort. Crops
RemenSwai	ARI-Tengeru	M.Sc.	Tissue culture of banana and hort. Crops
Haji H. Fundi	KARC	M.Sc.	Tissue culture of banana and cassava
William Hamisy	NPGRC	M.Sc.	PGR conservation and Tissue culture of cassava
A. P. Maerere	SUA	PhD,	Tissue culture of banana and horticultural crops
P. Kusolwa	SUA	PhD	Tissue culture of banana and horticultural crops
T. Msogoya	SUA	PhD	Tissue culture of banana and horticultural crops
F Ismail	UDSM	PhD	Training

[1]MARI= Mikocheni Agricultural Research Institute; ARI = Agricultural Research Institute; NPGRC = National Plant Genetic Resource Centre; TaCRI = Tanzania Coffee Research Institute; KARC = Kizimbani Agricultural Research Centre; SUA = Sokoine University of Agriculture; UDSM = University of Dar es Salaam.

2.3 Status of Tissue Culture Capacity in Uganda

The application of tissue culture in Uganda began in the early 1980s with its incorporation into banana research at the Department of Agricultural Production (formally Department of Crop Science), Makerere University. Since then, there are currently about five institutions involved in tissue culture activities. Key institutions include both public and private sectors. In the public domain, four institutions are involved: Makerere University, National Agricultural Research Laboratories (NARL) based at Kawanda, National Crops Resources Research Institute (NaCRRI), Kachwekano Zonal Agricultural Research Institute (KZARDI), based at Kabale. The three institutes (NARL, NaCRRI and KZARDI), are sister institutes under the National Agricultural Research Organisation (NARO), which has the mandate for coordinating agricultural research in Uganda. The private sector is represented by Agro-Genetic Technologies (AGT), the only private company in Uganda. The current status of physical infrastructure of these institutions is presented in Table 8, while their respective human resource capacity is presented in Tables 9 and 10. Hereafter, a brief on each of the aforementioned institutions involved in tissue culture in Uganda is presented.

2.3.1 Makerere University

The Department of Agricultural Production of Makerere University has a modest laboratory for tissue culture work (Tables 8 and 9). Most tissue culture activities are tailored towards production of disease-free planting materials of cassava, sweet potatoes and banana (Table 10). Support for tissue culture research is sourced from different donors, notable of who are: BIOEARN, Foundation for Agricultural Research in Africa (FARA), World Bank, United States Agency for International Development (USAID) and the Government of Uganda. These funds have been used for both human capacity and infrastructure development. Some of the tissue culture projects that have been implemented include: 1) "*Development of Cleaning, Indexing and Mass Propagation Techniques for Propagation and Dissemination of Cassava and Sweet Potatoes*" which was supported by BIOEARN (2006-2009); 2) "*Sweet Potato Improvement and Clean Seed Production*" which was funded by RUFORUM (2005-2007); and 3) "*Development of Virus Indexing and Mass Propagation Techniques for Propagation and Dissemination of Banana*" with financial assistance from Government of Uganda and the World Bank(2008 - 2010). In addition, the university trains (PhD, M.Sc. and B.Sc.) and conducts short training course (1-2 weeks) in plant tissue culture and biotechnology. The contribution of Makerere University towards both research and student training requires that its human resources be strengthened, as currently it's limited.

2.3.2 National Agricultural Research Laboratories (NARL)

The National Agricultural Research Laboratories at Kawanda (formally Kawanda Agricultural Research Institute; KARI) is one of the public institutes under the leadership of NARO. The goal of NARL is to deploy tissue culture and other biotechnology tools to raise both research efficiency and deliver products previously impossible to generate through conventional means. Tissue culture activities at NARL started in 1994, with the establishment of a tissue culture laboratory to produce coffee and banana planting materials on commercial basis. Currently several tissue culture techniques have been adopted notable of which include: embryo rescue, micropropagation, embyogenic suspension culture, virus elimination and genetic transformation. In the recent years, NARL has been collaborating with regional and international partners in conducting the following research activities: 1) development of embryogenic cell suspension cultures of East African Highland Banana (EAHB) cultivars, which are desirable for genetic transformation projects; 2) development of virus indexing protocols for banana; 3) micropropagation of banana and coffee; and 4) human capacity building.
The ongoing banana genetic transformation work includes: 1) resistance to (bacterial *Xanthomonas* wilt, sigatoka disease, fusarium wilt, weevils and nematodes); 2) improved micro-nutrients (vitamin A and iron); 3) early maturity; and 4) delayed ripening. Todate, NARL is one of the most equiped tissue culture laboratories in Uganda with well-trained and skilled banana researchers and technicians (Tables 8 and 9)

2.3.3 National Crops Resources Research Institute (NaCRRI)

The National National Crops Resources Research Institute (NaCRRI) based at Namulonge, has recently opened up a new tissue culture and genetic transformation laboratory. This laboratory is part of the NaCRRI Biosciences that also hosts the molecular biology laboratory and commodity-based biosafety level-2 screen houses. Tissue culture applications in this laboratory include: micropropagation of cassava and sweet potato; somatic embryogenesis of cassava; cassava double haploid generation; and genetic transformation of cassava and sweet potato.

For cassava genetic transformation, NaCRRI is collaborating with Donald Danforth Plant Science Centre, USA, through the "*Virus Resistant Cassava for Africa (VIRCA)*" project to develop cassava transgenes that are resistant to both cassava mosaic virus and cassava brown streak virus. For sweet potato, NaCRRI is collborating with International Potato Centre (CIP) to generate transgenes resistant to the sweet potao weevil. It suffices to note that NaCRRI is also involved in transformation work of maize (water efficient maize) in partnership with Monsanto, USA. NaCRRI is also well-equiped with skilled cassava and sweet potato researchers and technicians (Tables 8 and 9).

2.3.4 Kachwekano Zonal Agricultural Research Institute (KZARDI)

Kachwekano Zonal Agricultural Research Institute (KZARDI) is another public institution under the leadership of NARO and based in Kabale. A plant tissue culture facility with modern facilities for virus elimination, indexing and mass propagation of potato was established in 2008. The institute is also involved in outreach activities: conducting farmer training, establishing demonstration plots and sensitizing the local communities on the benefits of using tissue culture plantlets for cultivation.

2.3.5 Agro-Genetic Technologies (AGT)

Agro-Genetic Technologies (AGT) was the first private company in Uganda to use tissue culture for *in vitro* micropropagation of different crops on commercial basis. Established in 1999, the company's main objectives are: a) to produce and disseminate good quality, disease-free planting materials of different crops and b) to offer high quality agronomic consultancy services to farmers and other customers. The target commodities for micropropagation include: bananas, pineapples, coffee, tea, cassava, sweet potato, potatoes, ornamentals and selected forest trees. In addition AGT has in-house virus indexing facilities and has established village operated nurseries and demonstration garden for sale and training, respectively.

It's apparent from the foregoing that tissue culture application in Uganda is: a) largely being undertaken by public institutions; it's only one private institution (AGT) that is involved in tissue culture; b) applied mainly on staple crops e.g., banana, cassava, sweet potato and maize; it's only the private institution AGT that targets non-staple crops like pineapples and tea; and c) exploited in micropropagation, genetic transformation, embryo rescue, virus elimination, conservation and generation of haploid plants.

Table 8. A checklist of tissue culture equipment available in selected laboratories in Uganda[1]

Equipment	NARL	NaCRRI	Makerere University	AGT
Media preparation and autoclaving unit				
Autoclaves	6	2	2	3
Precision balances	3	2	2	2
pH Meter	2	2	2	1
Water purification apparatus	1	0	1	1
Refrigerated centrifuge	2	2	2	0
Deep Freezers (-200C)	2	2	0	0
Fridge/Freezers (-40C))	2	2	2	2
Hot plate with stirrer	2	1	2	2
Micro pipettes (sets)	3	1	2	0
Microwave oven	1	0	1	1
Rotary shaker	4	1	1	0
Water distiller (single)	1	0	1	1
Water distiller (double)	1	1	0	0
Working area and growth room unit				
Laminar flow hood	9	5	3	5
Fume hood	1	0	1	0
Microscope stereo	3	0	1	0
Microscope dissecting	2	2	1	0
Growth room	3	3	2	2
Other accessories				
Ice maker	1	1	0	0
Indexing facility	1	1	1	1
Screen house	2	4	1	3
Standby generator	2	2	2	2
Computer	2	2	2	3

[1]Makerere University, information for the Department of Agricultural Production; NARL= National Agricultural Research Laboratories; NaCRRI = National Crops Resources Research Institute; AGT = Agro-Genetic Technologies.

Table 9. Overview of human resource capacity and training needs in selected tissue culture laboratories in Uganda[1]

Institution	Current state				Training needs			
	PhD	M.Sc	B.Sc	Diploma	PhD	M.Sc	B.Sc.	Diploma
Makerere University	1	1	2	2	1	1	2	2
NARL	3	1	4	5	1	2	0	3
NaCRRI	0	2	1	1	1	1	1	3
KAZARDI	1	0	0	2	1	2	0	2
AGT	0	1	5	8	0	0	0	8

[1]Makerere University, information for the Department of Agricultural Production; NARL= National Agricultural Research Laboratories; NaCRRI = National Crops Resources Research Institute; AGT = Agro-Genetic Technologies.

Table 10. A checklist of researchers involved in tissue culture application in Uganda[1]

Name	Institution	Level of Education	Research activity
Setumba Mukasa	Makerere	PhD	Mass propagation, virus elimination, indexing disease diagnostics in cassava, sweet potato and banana
Geofrey Arinaitwe	NARL	PhD	Banana micropropagation, and regeneration/transformation
Josephine Namaganda	NARL	PhD	Mass propagation and virus elimination in banana
David Talengera	NARL	M.Sc.	Banana micropropagation, embryo rescue and transformation
Andrew Kiggundu	NARL	PhD	Banana micropropagation embryo rescue and transformation
Pamela Lamwaka	NARL	B.Sc.	Banana tissue culture, micropropagation and embryogenic cell suspension culture
Grace Bwenje	NARL	B.Sc.	Banana tissue culture, micropropagation and embryogenic cell suspension culture
Betty Namukwaya	NARL	B.Sc.	Banana tissue culture, micropropagation and embryogenic cell suspension culture
Betty Magambo	NARL	B.Sc.	Banana tissue culture, micropropagation and embryogenic cell suspension culture
Henney Bashejja	NARL	B.Sc.	Banana tissue culture, micropropagation and embryogenic cell suspension culture
Alicai Titus	NaCRRI	PhD	Cassava micropropagation, and transformation
Apio-Hellen Beatrice	NaCRRI	M.Sc.	Cassava mass propagation transformation, virus elimination and indexing
Akol Jacinta	NaCRRI	B.Sc.	Cassava micropropagation and double haploid
Buttibwa Mary	NaCRRI	B.Sc.	Cassava micropropagation and double haploid
Makumbi Rose	NaCRRI		Sweet potato tissue culture

[1]Makerere University, information for the Department of Agricultural Production; NARL= National Agricultural ResearchLaboratories; NaCRRI = National Crops Resources Research Institute; AGT = Agro-Genetic Technologies.

2.4 Status of Tissue Culture Capacity in Rwanda

Tissue culture activities in Rwanda began in late 1980s with introduction of *in vitro* culture techniques for production of virus-free potato. With the worldwide growing potential of biotechnology, the Rwandan Government has recognised and appreciated that biotechnology tools and notably, tissue culture technology are of great potential and must be fully explored and utilized to contribute to sustainable food production and income generation. Accordingly, the Biotechnology Unit of Institut des Scienses Agrinomiques du Rwanda (ISAR) was created in 2004 and started with activities of tissue culture for rapid and mass production of disease-free planting materials. Key institutions engaged in tissue culture research and development in Rwanda include: ISAR- Rubona, ISAR-Musanze, National University of Rwanda, Kigali Institute of Science and Technology (KIST) and Institutd' Enseignement Superieur (INES). The current status of physical infrastructure and human capacity in Rwanda is presented in Tables 11, 12 and 13. Hereafter, a brief on each of the aforementioned institutions involved in tissue culture in Rwanda is presented.

2.4.1 ISAR-Musanze

ISAR set up the first tissue culture facility in Rwanda at Musanze (north of Rwanda) in 1988, in order to curb the shortage of seedlings amongst farmers. To date, this laboratory is well equipped and focuses on tissue culture of potato. The lab has a production capacity of about 700,000 - 1,000,000 mini tubers per year. It's worth mentioning that ISAR-Musanze successfully implemented a 3 years project (2008-2011) "*Mass Propagation and Dissemination of Potatoes* with financial assistance from Rwandan Government and Belgium Technical Cooperation. One notable challenge at ISAR-Musanze is the limited human resource (Table 12 and 13), which needs to be urgently addressed.

2.4.2 ISAR-Rubona

ISAR-Rubona is another modern and high quality tissue culture facility in Rwanda operated by ISAR. Based in the south, this laboratory was initially established for mass production of coffee, with an annual target of ~500,000 seedlings. The institute is equipped to undertake tissue culture applications notable of which include: micropropagation, virus elimination, indexing and germplasm conservation. The institutes target commodities include: sweet potatoes, cassava, potatoes, banana and coffee. Just like for ISAR-Musanze, one notable challenge at ISAR-Rubona is the limited human resource (Table 12 and 13), which needs to be urgently addressed.

2.4.3 National University of Rwanda (NUR)

This is the largest university in Rwanda. Located in the city of Butare, the university has a Bachelor's degree program that provides training in breeding and biotechnology, but has no tissue culture laboratory. The curriculum includes a range of plant sciences and tissue culture courses that provide strong theoretical aspects of tissue culture. Strengthening of tissue culture capacity NUR is desirable so that they produce well-grounded cadre of graduates that can be of value to the Rwandan Research for Development programme.

2.4.4 Kigali Institute of Science and Technology (KIST)

Kigali Institute of Science and Technology (KIST) is an institute of higher learning that offers both undergraduate and post graduate degrees in biological sciences and technology. The institute has recently established a Bachelor's degree programme in biotechnology, but has no tissue culture laboratory. Just like for NUR, strengthening of tissue culture capacity KIST is desirable so that they produce well-grounded cadre of graduates that can be of value to the Rwandan Research for Development agenda.

2.4.5 Institut di Enseignement Superior (INES)

Institut di Enseignement Superior (INES) is higher learning Institution that has a Bachelor's degree program in biotechnology, but with no tissue culture laboratory. The institute has a Memorandum of Understanding with ISAR-Musanze for using the latter's tissue culture laboratories for student's practical.

It's evident from the foregoing that tissue culture application in Rwanda is: a) exclusively undertaken by two public research institutions, ISAR-Musanze and ISAR-Rubona; b) applied mainly on staple crops (potato, banana, cassava and sweet potato) and one cash crop, coffee; and c) exclusively limited to micropropagation, virus elimination, and conservation applications.

Table 11.A checklist of tissue culture equipment available in selected laboratories in Rwanda1

Equipment	ISAR-Musanze	ISAR-Rubona
Media preparation and autoclaving unit		
Autoclaves	1	3
Precision balances	3	5
pH Meter	1	4
Water purification apparatus	1	0
Refrigerated centrifuge	2	2
Deep Freezers (-200C)	1	1
Fridge/Freezers (-40C))	2	6
Hot plate with stirrer	1	4
Micro pipettes (sets)	1	2
Microwave oven	1	1
Rotary shaker	2	1
Water distiller (single)	1	1
Water distiller (double)	0	1
Working area and growth room unit		
Laminar flow hood	3	5
Fume hood	0	0
Microscope stereo	1	4
Microscope dissecting	1	0
Growth room	2	9
Other accessories		
Ice maker	0	1
Indexing facility	0	1
Screen house	8	3
Standby generator	2	1
Computer	0	2

Table 12. Overview of human resource capacity and training needs in selected tissue culture laboratories in Rwanda[1]

Institution	Current state				Training needs			
	PhD	M.Sc.	B.Sc.	Diploma	PhD	M.Sc.	B.Sc.	Diploma
ISAR-Rubona	0	1	2	4	1	2	1	3
ISAR-Musanze	0	1	0	5	1	2	0	3
NUR	1	0	0	0	2	3	2	4
KIST	1	0	1	2	1	1	1	4
INES	0	0	1	1	2	3	2	3

[1]NUR = National University of Rwanda; KIST = Kigali Institute of Science and Technology; INES = Institut di Enseignement Superior

Table 13. A checklist of researchers involved in tissue culture application in Rwanda1

Name	Institution	Level of Education	Research activity
Patrick Karangwa	ISAR-Rubona	M.Sc.	Mass propagation, virus elimination, indexing in banana and sweet potato
NtizoSenkesha	ISAR-Musanze	M.Sc.	Micropropagation and virus elimination potato
TonaIsibo	ISAR-Rubona	PhD	Mass propagation of banana pineapples, trees and cassava
Esperance Munganyinka	ISAR Rubona	M.Sc.	Micropropagation in coffee
Antoine Nsabimana	KIST	PhD	Lecturer Biotechnology
Patrick Ntizo	INES	BSc	Lecturer Biotechnology
DhediaDjailo*	NUR	PhD	Lecturer Biotechnology

*Visiting lecturer

2.5 Status of Tissue Culture Capacity in Burundi

As many African countries continue to embrace new technologies against the backdrop of diminishing crop yield, a few public and private institutions in Burundi are gradually harnessing the benefits of tissue culture techniques to boost crop production. Key institutions involved in tissue culture application include two public institutions (Institut des Sciences Agronomiques du Burundi (ISABU) and Burundi University) and two private institutions (Agrobiotech; and Phytolab). The current status of physical infrastructure and human capacity for tissue culture in Burundi is presented in Tables 14, 15 and 16. Hereafter, a brief on each of the aforementioned institutions involved in tissue culture in Burundi is presented.

2.5.1 Institut des Sciences Agronomiques du Burundi (ISABU)

ISABU is the largest agricultural research organization in Burundi. The application of tissue culture at ISABU began in the mid-1990s with its incorporation into production of virus-free planting materials of potato and banana at Gisozi station (ISABU-Gisozi). Over time, tissue culture applications have expanded to other commodities notable of which are: sweet potatoes, cassava, Taro and selected medicinal plants. Both human and laboratory infrastructure at ISABU-Gisozi is limited (Tables, 14 and 15). Thus, there is need to refurbish and equip the tissue culture laboratory and also to re-tool the scientists and technicians involved in tissue culture undertakings.

2.5.2 University of Burundi

The University of Burundi is the only university in Burundi with capacity to undertake tissue culture related activities. However the tissue culture facility is very small and understaffed (see Tables 15 and 16). The laboratory although used mainly for teaching is currently developing protocols for tissue culture of cassava, sweet potatoes, banana, Taro and medicinal plants.
University of Burundi is another institute that should be given investment support; capacity needs are refurbishment, equipment installation and human capacity development to undertake tissue culture activities.

2.5.3 AGROBIOTEC

AGROBIOTECH, established in the late 1990s, is a privately owned company that produces and disseminates tissue culture plantlets in Burundi. The main objective of AGROBIOTECH is to improve quality and quantity of clean planting material. Initially, AGROBIOTECH was limited to production of banana only. Indeed, production of banana plantlets has been increasing steadily from 80,000 plantlets in year 1999 to 330,000 in 2007.

The company is completing the construction of a new facility that will have production capacity of ~1,500,000 plantlets per year and diversification to embrace other crops such as sweet potatoes, cassava, potato, taro, pineapple and tree species to meet the food production and reforestation demands. To ensure that AGROBIOTECH attains its objectives, it has developed a network of nurseries in 5 districts: two in Bujumbura, one each in Gitega, Kirundo, Ngozi and Kayanza districts to ease the distribution of tissue culture derived plantlets to the farmers. AGROBIOTECH also proposes to extend this network of nurseries to 4 other districts.

2.5.4 Phytolab

Phytolab is another privately owned tissue culture laboratory located in Bujumbura, Burundi. This laboratory has a modest lab with production capacity of about 500,000 to 1,000,000 plantlets per year. Phytolab is currently involved in *in vitro* multiplication of disease free seedlings of banana, Taro and potato.

It's evident from the foregoing that tissue culture application in Burundi is: a) undertaken by both public and private institutions; b) applied mainly on staple crops, potato, banana, cassava and sweet potato; c) largely limited to micropropagation and virus elimination applications; and d) has both human and laboratory capacity limitations, which needs to be strengthened.

Table 14. A checklist of tissue culture equipment available in selected laboratories in Burundi

Equipment	ISABU-Gisozi	University of Burundi	AGROBIOTEC	Phytolab
Media preparation and autoclaving unit				
Autoclaves	1	2	2	1
Precision balances	3	2	2	2
pH Meter	1	1	3	1
Water purification apparatus	0	0	0	0
Refrigerated centrifuge	0	0	0	0
Deep Freezers (-200C)	0	1	0	0
Fridge/Freezers (-40C))	1	1	1	1
Hot plate with stirrer	1	1	1	2
Micro pipettes (sets)	1	1	1	0
Microwave oven	1	0	1	0
Rotary shaker	0	1	0	0
Water distiller (single)	1	1	1	1
Water distiller (double)	0	0	0	0
Working area and growth room unit				
Laminar flow hood	1	2	8	3
Fume hood	0	0	0	0
Microscope stereo	1	0	0	1
Microscope dissecting	0	0	0	0
Growth room	1	2	4	3
Other accessories				
Ice maker	0	0	0	0
Indexing facility	0	0	0	0
Screen house	8	1	5	6
Standby generator	1	1	1	1
Computer	1	1	2	0

Table 15. Overview of human resource capacity and training needs in selected tissue culture laboratories in Burundi

Institution	Current state				Training needs			
	PhD	M.Sc.	B.Sc.	Diploma	PhD	M.Sc	B.Sc.	Diploma
ISABU-Gisozi	0	4	2	6	3	4	2	6
University of Burundi*	0	1	3	0	2	1	1	4
AGROBIOTEC	1	0	3	15	1	3	3	10
Phytolab	0	0	0	8	0	0	0	8

*Have received short term training from Kawanda Uganda

Table 16. A checklist of researchers involved in tissue culture application in Burundi1

Name	Institution	Level of Education	Research activity
Michael Ntimdirangeza	ISABU	M.Sc.	Mass propagation and virus elimination in sweet potato
AstereBararyenya	ISABU	M.Sc.	Mass propagation and virus elimination in potato
MichelinaInamahoro	ISABU	M.Sc.	Mass propagation and virus elimination in potato
Ernest Vyizigiro	ISABU	BSc	Mass propagation and virus elimination in potato
Nicolas Niko	ISABU	BSc	Mass propagation and virus elimination in potato, sweet potato, and cassava
DieudonnaeHarahagazwe	ISABU	BSc	Mass propagation and virus elimination in potato
Simon Bigirimana	ISABU	BSc	Mass propagation and virus elimination in cassava
Michel Twizeye	University of Burundi	BSc	Lecturer and tissue culture of cassava, banana, Taro, trees, medicinal plants
Pierre Nintije	University of Burundi	BSc	Lecturer and tissue culture of cassava, banana, Taro, trees, medicinal plants
Domatien Bigirimana	University of Burundi	BSc	Lecturer and tissue culture of cassava, banana, Taro, trees, medicinal plants
GasparolNdarubayemwo	University of Burundi	M.Sc.	Lecturer and tissue culture of cassava, banana, Taro, trees, medicinal plants

2.6 Status of Tissue Culture Capacity in Ethiopia

Tissue culture application in Ethiopia dates back to the 1980's when it was first applied at Addis Ababa University (AAU). By then, the focus was on micropropagation of indigenous forest species notable of which included: *Podocarpus* sp., *Cordiaafricana,* and *Hagenia abyssinica.* Characteristically, these tree species are either difficult to regenerate vegetatively or require long time, and thus the justification to adopt tissue culture for their multiplication. To this list, additional Ethiopian plant species like endod, tef (*Eragrostis tef*) and enset (*Enset ventricosum*) were added.

It suffices to note that a more comprehensive and concerted tissue culture research programme was rolled out by the Ethiopian Institute of Agricultural Research (EIAR) in 2000, with emphasis on protocol optimization for micropropagation and virus elimination in economically important crops and/or plant species including: banana, cardamom, grapevine, citrus, garlic, potato, geranium, enset, coffee, pineapple, black pepper sweet potato cassava and *Aframomumcorrorima*. In addition EIAR contributed towards the development of double haploid plants of *Eragrostistef* and Brassica.

Following remarkable progress made in tissue culture, regional agricultural research institutes like Amhara Agricultural Research Institute and Southern Agricultural Research Institute and some higher learning institutions adopted and expanded tissue culture application in Ethiopia. In addition, private enterprises such as Mekele Plant Tissue Culture Laboratory also joined the public institutions in undertaking tissue culture activities. Indeed, an association dubbed "Ethiopian Association for Plant Tissue Culture (EAPTC) has been formed to further strengthen and/or promote tissue culture for research and development in Ethiopia. The current status of physical infrastructure and human capacity in tissue culture in Ethiopia is presented in Tables 17, 18 and 19.

2.6.1 Federal Research Institutes

The federal research activities are coordinated by the Ethiopian Institute of Agricultural Research (EIAR). EIAR is the oldest and largest organisation carrying out tissue culture R&D in Ethiopia. Key federal institutions presently involved in tissue culture activities include: Holetta Agricultural Research Centre; Jimma Agricultural Research Centre; Melkassa Agricultural Research Centre and DebreZeitAgricultural Research Centre. Hereafter, a brief on these institutions involved in tissue culture is presented.

Holetta Agricultural Research Centre: Holetta Research Centre is located 20 km west of Addis Ababa. The tissue culture infrastructure at HRC has facilities for serological virus indexing and micropropagation of potato, enset, cassava, sweet potatoes, grape and geranium. The institute also hosts the Agricultural Biotechnology Research Centre (ABRC), which is equipped with modern facilities with state of art equipment for molecular biology and tissue culture.

Jimma Agricultural Research Centre: Jimma Agricultural Research Centre, located 300 km south west of Addis is another EIAR centre with a modern tissue culture facility. The tissue culture infrastructure was mainly build for coffee but the facilities are now being used to support other crops including: pineapple, sweet potatoes and spices (cardamom, vanilla ginger).

MelkassaAgricultural Research centre: Melkassa Agricultural Research centre**,** under the EIAR leadership, is based in Oromia. The institute's modest tissue culture facilities are focussed on micropropagation of: banana, sugarcane, sweet potatoes and garlic. Just like other federal research institutes, this institute will need to strengthen its human resource so that they can fully exploit and benefit from tissue culture applications.

DebreZeit Agricultural Research Centre: DebreZeit Agricultural Research Centre, one of the oldest EIAR, has tissue culture facilities for micropropagation of grape vine. The institute also undertakes work on the production of double haploid plants of *tef*. Just like other federal research institutes, this institute will need to strengthen its human resource capacity so that they can fully exploit and benefit from tissue culture applications.

2.6.2 Regional Research Institutes

In Ethiopia, research activities in the regional states are financed and/or controlled by local/regional Governments. The regional agricultural research institutes have recently expanded their capacities to undertake R&D activities in *in vitro* micropropagation in order to meet the ever increasing demand of tissue culture planting materials in their respective geographical areas. The main regional centres with capacity to micropropagate plants through tissue culture technologies include: Bahir Dar Research Centre (Amhara state),Areka Research Centre (South state),AdamiTulu (Oromia state) and Mekelle Research Centre (Tigray State).

Bahi Dar Tissue Culture lab: Bahi Dar tissue culture laboratory activities are coordinated by Amhara Regional Agricultural Research Institute. This laboratory is well equipped; initially focus was on potato micropropagation with potential to expand to other crops as well.

Areka Research Centre: Areka Research Centre is the institute responsible for coordination of root and tubers crop research in Ethiopia. The tissue culture laboratory at Areka is moderately equipped and its target commodity is enst. Training of scientists and technicians in specialised skills (virus elimination, disease diagnostics, indexing) will significantly boost the research capacity of this laboratory.

Adami Tulu Research centre: By the time of conduction of this situation analysis, laboratory at Adami Tulu was being renovated and thus no remarks could be madeon its status of tissue culture.

Mekelle Research centre: Just like for Adami Research Centre, by the time of conduction of this situation analysis, the laboratory was still under construction.

2.6.3 Universities

Addis Ababa was the first university in Ethiopia to start employing tissue culture techniques for micropropagation of plants. Over the past years tissue culture activities have expanded to cover more universities, including Jimma University and Debub University. However, tissue culture facilities at these universities are very small and limited to student practical and other academic activities. Bearing in mind that these universities are the apex institutions of higher learning, there is need to strengthen their research capacity for tissue culture by way of investing in laboratory infrastructure and human resource in order for them to remain relevant to the research and development agenda of Ethiopia.

2.6.4 Private sector laboratories

The involvement of private sector in tissue culture activities in Ethiopia is expanding very rapidly. The key players are: Mekelle Plant Tissue Culture Laboratory and Tsega and Family Company. There are three other emerging private tissue culture laboratories. However, herein, we briefly highlight on the two, Mekelle Plant Tissue Culture Laboratory and Tsega and Family Company.

Mekelle Plant Tissue Culture Laboratory: Mekelle Plant Tissue Culture Laboratory was the first privately owned Ethiopian company that has become a key player in up-scaling the production and distribution of tissue culture plantlets. Established in 2005, the company has modern facilities and currently employs 4 senior staff (1 PhD, 3 BSc) and about 12 technicians (Table 18). The laboratory has a production capacity of ~5 million plantlets per year. This company optimised tissue culture protocols

for mass propagation of banana, lily, pineapples, citrus, vine grapes and various spices. The commodities for which plantlets are already available to farmers include banana, sugarcane, flowers, eucalyptus and grapes. This laboratory will however need capacity for undertaking virus indexing.

Tsega and Family Company: By the time of conduction of this situation analysis, this laboratory was still under construction.

It's evident from the foregoing that tissue culture application in Ethiopia is: a) undertaken by both public and private institutions, with public institutions having a decentralized fashion of operation; b) applied mainly on economically important staple crops, horticultural crops and tree species; c) applied to micropropagation, virus elimination, conservation and haploid line development; and d) associated with significant laboratory infrastructure development, which needs to be supported by commensurate human resource development.

Table 17. A checklist of tissue culture equipment available in selected laboratories in Ethiopia[1]

Equipment	A	B	C	D	E	F	G	H	I
Media preparation and autoclaving unit									
Autoclaves	2	2	1	1	1	1	1	2	1
Precision balances	2	2	1	1	1	2	1	2	1
pH Meter	1	2	1	1	1	1	1	2	1
Water purification apparatus	1	1	1	1	1	1	1	1	1
Refrigerated centrifuge	1	1	1	1	1	1	1	1	1
Deep Freezers (-850C)	2	2	1	1	1	1	1	3	1
Fridge/Freezer Comb	1	1	1	1	1	1	1	1	1
Hot plate with stirrer	3	4	1	1	1	1	1	3	1
Micro pipettes (sets)	1	1	1	1	1	1	1	1	1
Microwave oven	1	1	1	1	1	1	1	1	1
Rotary shaker	1	1	1	1	1	1	1	1	1
Water distiller (single)	1	1	1	1	1	1	1	1	1
Water distiller (double)	1	1	1	0	0	0	0	1	1
Working area and growth room unit									
Laminar flow hood	2	2	2	1	1	1	1	6	1
Fume hood	1	1	0	0	0	0	0	0	1
Microscope stereo	1	1	1	1	1	1	1	1	1
Microscope dissecting	1	1	1	1	1	1	1	1	1
Tissue culture growth rooms	2	2	1	0	0	0	0	0	1
Other accessories									
Ice maker	1	1	0	0	0	0	0	0	1
Indexing facility									
Screen house	2	2	1	0	0	0	0	0	1
Bioreactor	1	1	1	1	0	0	0	0	0
Computer	1	1	1	1	1	1	1	1	1

A = Holetta Agricultural Research Centre; B = Jimma Agricultural Research Centre; C = Melkassa Agricultural Research centre; D= DebreZeit Agricultural Research Centre; E = Addis Ababa University; F = Bahi Dar Tissue Culture laboratory; G = Areka Research Centre; H = Mekele.

Table 18. Overview of human resource capacity and training needs in selected tissue culture laboratories in Ethiopia

Institution	Current state				Training needs			
	PhD	M.Sc	B.Sc.	Diploma	PhD	M.Sc	B.Sc.	Diploma
Public-Federal								
Hol. Agricultural Research Centre	2	2	1	3	0	2	0	4
Jim. Agricultural Research Centre	1	0	1	3	1	1	0	2
Mel. Agricultural Research centre	1	2	2	2	0	1	1	2
Deb. Agricultural Research Centre	1	1	0	1	0	1	0	2
Public-Regional								
Bahi Dar Tissue Culture Laboratory	0	1	1	2	1	2	0	3
Areka Research Centre	1	0	2	3	1	1	1	3
Adami Tulu Research centre	0	2	1	1	1	1	0	2
Mekele Research centre	1	0	3	12	0	1	1	4
Universities								
Addis Ababa University	2	0	0	2	0	1	0	2
Jimma University	1	1	1	1	1	1	0	2
Debub University	1	1	0	2	1	1	0	2
Private Laboratories								
Mek.	1	0	3	12	0	1	1	4

Hol. = Holetta ; Jim. = Jimma; Mel. = Melkassa; Deb. DebreZeit; Mek. = Mekelle Plant Tissue Culture

Table 19. A checklist of researchers involved in tissue culture application in Ethiopia[1]

Name	Institution	Level of education	Research activity
WondiyfrawTefera	Jim.	PhD	Tissue culture protocol development for mass propagation of coffee, pineapple, spices and cassava
LikeleshGugsa	Hol.	PhD	Dihaploid development in tef
Asmare Dagew	Mel.	M.Sc.	Tissue culture protocol development for mass propagation of banana, sweet potato and garlic
Girma Bedada	Hol.	M.Sc.	Tissue culture protocol development for mass propagation of enset, potato, vine, geranium, cassava and sweet potato
TesfayeDisasa	Hol.	M.Sc.	Tissue culture protocol development for mass propagation of enset, potato, vine, geranium, cassava and sweet potato
Abel Debebe	Mel.	M.Sc.	In vitro protocol optimization for mass propagation of banana, sweet potato and garlic
Alemeshet Lemma	Mel.	B.Sc.	In vitro protocol optimization for mass propagation of banana, sweet potato and garlic
Ayelign Mengesha	Jim.	B.Sc	In vitro protocol optimization for mass propagation of banana, sweet potato and garlic
Kebebew Assefa	Deb.	PhD	Dihaploid development in tef
Bezunesh Abere	Hol.	B.Sc	*In vitro* protocol optimization for mass propagation of crops like enset, potato, vine, cassava and sweet potato
Adane Abraham	Hol.	PhD	Mass propagation, virus elimination, indexing, disease diagnostics for banana, enset, sweet potatoes, cassava
Tileye Feyissa	AAU	PhD	Micropropagation of sweet potato & cassava
Legesse Negash	AAU	PhD	Tissue culture of indigenous trees
MulugetaDiro	Arek	PhD	Embryogenesis and micropropagation of enset
Ermias Abate	Bah.	M.Sc.	Micropropagation of potato and banana
Abdul Nasir Bedri	Mel.	PhD	Protocol development for mass propagation of sweet potato, vine and banana.

Hol = Holetta Agricultural Research Centre; Jim = Jimma Agricultural Research Centre; Mel = Melkassa Agricultural Research centre; Deb = DebreZeit Agricultural Research Centre; AAU = Addis Ababa University; BAH = Bahi Dar Tissue Culture laboratory; ARE = Areka Research Centre; 8= Mekele

2.7 A Brief on Constraints and Opportunities of Tissue Culture in ECA Region

During the conduction of the situation analysis, a number of challenges and opportunities associated with tissue culture application within the six surveyed countries (Kenya, Tanzania, Uganda, Rwanda, Burundi, and Ethiopia) were identified. Most of the identified challenges and opportunities appear to cut across the boundaries. It's most likely that these issues are replicated in other countries in sub-Saharan Africa that were not included in this study.

Firstly, constraints; tissue culture application in public and private sectors in the ECA region is limited by several technical, administrative and financial constraints. Finding solutions to these constraints is a must, if at all the potential of tissue culture in uplifting agricultural productivity in the ECA region is to be realised. Undoubtedly, these intervention measures will require an interplay of several individuals and/or institutions that should be supported by appropriate national and/or regional Governments. Some of the key constraints identified included:

a) inadequate funding by national Governments; most countries and/or institutions heavily rely on external funding from development partners,

b) lack of a reasonable number of well-trained and experienced tissue culture personnel; it's regrettable that skills for maintenance and repair of tissue culture equipment is also limited,

c) lack of appropriate tissue culture infrastructure; this is exacerbated by unreliable support services (power and water supplies), and the bureaucratic procurement procedures particularly for purchase of consumables,

d) inadequate national and/or regional policy frameworks to support private sector involvement in tissue culture,

e) the relatively high cost of tissue culture products compared to their conventional counterparts,

f) limited public awareness about proven tissue culture products and technologies,

g) weak collaborative linkages and/or partnership among the different stakeholders along the tissue culture development and delivery pipeline.

Secondly, opportunities; whereas several constraints affecting tissue culture in the ECA region have been highlighted, it is worth noting that there exist enormous opportunities for tissue culture. Some of these opportunities can be exploited at national, regional and/or international level. Certainly, the success of tissue culture is possible if it takes advantage and taps into the available and emerging opportunities within and/or outside the region. Some of the identified opportunities included:

a) the recognition of biotechnology and in particular, tissue culture by key institutions (e.g. NEPAD and FARA) as a tool that can be exploited to increase agricultural productivity on the African continent,

b) the will and interest of development partners to support tissue culture development and utilisation in developing countries faced with huge agricultural challenges,

c) liberalisation of national economies, which makes it possible to sell proven tissue culture products and services within selected countries in the region,

d) the existence of well-established and functional private and public tissue culture institutions; these local, regional and/or international institutions can provide technical guidance to their counterparts in developing countries who are in the process of starting and/or developing their tissue culture capacity,

Chapter 3:

Conclusion and Recommendations

Using the situation analysis methodology, ASARECA commissioned a study to generate comprehensive information on the status of tissue culture application in the ECA sub-region. Specifically, information was gathered on existing tissue culture capacity in terms of human resource and physical infrastructure. This situation analysis covered six of the 10 ASARECA member countries: Kenya, Tanzania, Uganda, Rwanda, Burundi and Ethiopia. Basing on the findings, specific conclusions and recommendations are proposed along the following areas.

I. **Investment in laboratory Infrastructure and human resource:** In general, the current level of infrastructure and human resource quality in public universities and research institutions is not adequate to conduct reasonable and useful R&D in tissue culture. Indeed, in several laboratories surveyed, basic infrastructure and facilities such as distillers, microscopes, autoclaves were either not available or not functioning; water and power supplies were unreliable. Internet connectivity was also limited. The unavailability of qualified staff further exacerbated the already terrible situation! For example, the University of Burundi had only 1 scientist with no technicians, while the NUR and KIST conducted courses in tissue culture, but with no laboratories to provide practical aspects of tissue culture. This is a major drawback that needs to be reversed. In countries (e.g. India, China and South Africa) where tissue culture has been widely adopted, it's observed that significant Government investment and support has been pivotal in the development process. This is what is needed to be replicated in the ECA region, and this can be achieved through suitable policy development and advocacy.

II. **Facilities for disease diagnostics, indexing and certification:** It suffices to note that tissue culture is not 100% efficient in producing pathogen-free plantlets, and this is particularly true for viral pathogens (Mori and Hosokawa, 1977). Thus, there is urgent need to integrate virus-indexing into the tissue culture micropropagation scheme. It was evident from the situation analysis that only a few institutions in the ECA have indexing and/or certification functional facilities. The weight of this problem can be appreciated when one bears in mind the prevalence of devastating viral diseases of cassava, sweet potato and banana in the ECA region. Unquestionably, the success of the tissue culture industry in the region will benefit from the institutionalisation of virus indexing as a mandatory process and in the establishment of effective regulatory system to enforce it. It's also logical for Governments of ECA region to establish accredited testing and certification facilities.

III. **Inadequate information and public awareness:** Lack of public awareness and clear understanding of tissue culture was noted. For instance as a result of the low level of understanding some people think tissue culture-derived plantlets are genetically modified organisms! This is an unfortunate situation because it creates unnecessary doubts among the would-be consumers. It's therefore important that both the public and private sectors jointly undertake aggressive public awareness campaign; this can be achieved through well-coordinated workshops, exhibitions, and media-outlets that target the continuum of tissue culture stakeholders.

IV. **Private sector involvement in tissue culture:** It's apparent from this analysis that private sector involvement in tissue culture in the ECA region is just emerging with about eight private companies: Kenya (3), Burundi (2), Ethiopia (2) and Uganda (1). Unfortunately, these companies don't operate at their optimum! This is contrary to other parts of the world where the private sector plays a significant role owing to Government support. Thus, within ECA region, Government policy reforms that favour and build investor confidence will be desirable

to catalyse private sector investment in tissue culture. Equally important is having excellent public-private tissue culture partnerships that are built on transparency and respectfulness.

V. **Affordability of tissue culture-derived plantlets:** Access by farmers to tissue culture-derived plantlets is limited in part, owing to their high costs when compared to their conventionally produced counterparts. The few farmers that have managed to get them have benefited from subsidies provided by NGOs and/or by development partners. Although this approach isn't sustainable, it can be a catalyst in the initial efforts to jumpstart the adoption of tissue culture plantlets. In parallel, it would be prudent to devise means of reducing the production costs of plantlets. This can be done by investing in less-sophisticated equipment and/or alternative cheap supplies such as cassava starch or sea algae as outlined by Escobar et al (2005). Alternatively, a village-level micro-credit scheme can be established for the sole purpose of providing credit facilities and other relevant support services. Because rural credits are offered to groups, it's critical that farmers be sensitized to form and officially register their groups in order to access credit services from accredited financial institutions. This will help the farmers and farmer-led groups purchase tissue culture-derived seedlings and other necessary agro-inputs.

VI. **Tissue culture protocol optimisation and development:** Its commonplace to observe genotype-specific responses to *in vitro* culture. This was highlightened during the survey. Thus, there is need to develop and/or optimise protocols for key commodities that are of economic importance to the ECA region. This again justifies the need for well-trained tissue culture staff that are able to successfully accomplish these highly specialised tasks. The availability of efficient protocols will not only help speed up the availability of tissue culture materials but also reduce the associated production costs.

VII. **Databases for information management:** Databases are useful resources for storing, managing and retrieving information. Indeed, most efficient and functional institutions should have a centralized database in order for them to make informed-decisions. From this situation analysis, it was evident that functional databases for tissue culture activities in the ECA region were none-existent! This is another critically important support tool that needs attention.

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Annex 1: Terms of Reference

The specific terms of reference were to document the current state of tissue culture of cassava and sweet potato in the ECA. Specifically, the study was aimed at performing the following tasks:-

I. Appraise the current status of knowledge broadly on biotechnology and specifically tissue culture applications in agriculture in the eight (8) ASARECA countries namely, Burundi, Congo DR, Ethiopia, Kenya, Madagascar, Rwanda, Tanzania and Uganda;

II. Review the overall existing tissue culture infrastructure (facilities and equipment) in both the public and private sector;

III. Make an inventory of trained personnel (technicians and scientists) in institutions involved in the tissue culture in the eight (8) countries, including level of training, courses attended and the current training needs for personnel;

IV. Make an inventory of Universities in ECA that have capacity to conduct courses (short- and post graduate) in tissue culture , including the current courses offered;

V. Make an inventory of existing databases of tissue culture applications, their content and accessibility;

VI. Review of the perceptions of tissue culture applications in the ECA, including source and type of information materials available; and

VII. Identify and recommend priority areas where tissue culture investments are most needed.

Annex II: Questionnaire for Inventory of Tissue Culture R& D Activities in the ECA Region

1.0 Basic information about the organizations and contacts

2.0 Please give a brief appraisal of the historical development and current status of knowledge broadly on biotechnology and specifically on tissue culture applications in Agriculture in your country

3.0 Please state number and qualification of trained personnel (technicians and scientists) involved in tissue culture, including level of training, courses attended and training needs of personnel

4.0 Please state number and condition of tissue culture infrastructure (facilities and equipment) in both public and private institutions (*including universities*).

5.0 Please state number of universities that have capacity to conduct courses (short-and postgraduate) in tissue culture, including the current courses offered.

6.0 Please list all completed and currently going Tissue culture projects and their major objectives and funding sources

7.0 Inventory of tissue culture scientists: Please provide names of scientists involved in tissue culture

8.0 Is there existing databases of tissue culture applications? Please state their content and accessibility.

9.0 Were you able to commercialize or put into any economically and socially useful practice, any of TC products? If so, what are those products and at what scale (*give numbers if possible*).

10. Please give an account of perceptions of TC applications in your country

11. What do you think are major constraints to TC applications and commercialization of R&D projects?

12. Please provide reference/publications on status TC/biotechnology in your country (*if any*)

Annex III: Inventory of Universities in ECA Conducting Courses in Tissue Culture and Biotechnology

Country	University	Tissue culture/ biotechnology courses
Tanzania	SUA	BSc-Biotechnology & Laboratory Studies, B.Sc. Horticulture, B.Sc. Crop science
	UDSM	B.Sc. -Molecular Biology & Biotechnology ,B.Sc. Botany
Burundi	University of Burundi	B.Sc. Biotechnology
Kenya	UoN	B.Sc. Microbiology and Biotechnology, MSc Biotechnology, PhD Biotechnology
	JKUAT	B.Sc. Biotechnology
	KU	B.Sc. Biotechnology
	Moi University	B.Sc. Biotechnology; BSc Horticulture
Uganda	Makerere University	B.Sc. Agric, B.Sc. Horticulture, MSc Crop science, MSc Plant breeding and PhD Plant Breeding and Biotechnology
Rwanda	NUR	B.Sc. Plant breeding and Biotechnology
	KIST	B.Sc. Biotechnology
Ethiopia	AAU	MSc. Biotechnology
	Jimma University	MSc. Biotechnology
	Gonder University	B.Sc. Biotechnology
	Mekele institute of Technology	B.Sc. Biotechnology

JKUAT = Jomo Kenyatta University of Agriculture and Technology; UoN= University of Nairobi; SUA = Sokoine University of Agriculture; UDSM = University of Dar-es-Salaam; NUR = National University of Rwanda; KIST = Kigali Institute of Science and Technology; AAU = Addis Ababa University.

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