

banana 2008



Banana and plantain
in Africa: Harnessing
international partnerships
to increase research impact

Leisure Lodge Resort
Mombasa, Kenya
5–9 October 2008

Program & Book of Abstracts





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Organized by:



Supported by:



Foreword

Dear participants,

On behalf of the International Institute of Tropical Agriculture, and its partner organizations Bioversity International, the Forum for Agricultural Research in Africa, the International Society of Horticultural Science and the Kenyan Agricultural Research Institute, we extend a very warm welcome to all of you.

We all are aware of the importance of banana as an essential staple crop for the African continent. However, the time is ripe to think about harnessing this agricultural commodity, which is deeply engrained in everyday life of many Africans, and take it a step further: to a system sustained by an invigorated private sector that actively seeks technological interventions and strengthened market linkages, creating income for the millions of farmers that grow banana everyday. That was the goal with which we approached the initial planning stages of this conference, and the reason why its content is different from that of other banana gatherings that have taken place on the continent. Besides the many scientists present, we actively solicited input from the private sector – large and small, the farmer groups and entrepreneurs, the donors and governments, the policy makers and advocacy groups. We organized the program in order that each day represents a clear theme: Markets and trade, Production, and Innovation Systems. More importantly, the conference will culminate in a final Strategy Day, which will build on the input provided by participants from each of the themes towards the development of a 10-year strategy, the road map that explores and strategizes the possibilities this crucial crop can achieve.

From an initial small gathering, brewed up during a casual field trip in early 2006, it has sparked huge interest and has exponentially grown into a massive international event, with interest far beyond initial expectations. We especially wish to thank the many donors, institutions and companies that have supported this conference, not in the least by facilitating participation of over a hundred participants that would have otherwise been unable to attend. Recent issues such as the stabilizing importance of banana among rising food prices and the initial steps of international banana exports from the African continent undoubtedly added to the interest. This conference, and its structure, clearly fill an urgent need.

Much effort, funding and planning went into this event. Let us not forget why we are here, and work together to ensure its success – enjoyably!

On behalf of the Organizing Committee,



THOMAS DUBOIS
Chair



DANNY COYNE
Vice-Chair

Program

Sunday, 5 October

CONFERENCE OPENING

Meister Room

1700 - 1720	Opening address - Honorable William S Ruto, Minister of Agriculture, Kenya
1720 – 1740	Opening address - Honorable. Janet Mukwaya, Minister of Tourism, Trade and Industry, Uganda
1740 – 1800	Opening address - Rev. Dr. Florence Muranga, Director, Presidential Initiative on Banana Industrial Development, Uganda
1900	All-Tooke Dinner at Bustani Gardens hosted by PIBID, Uganda

Monday, 6 October

GLOBAL TRENDS AFFECTING BANANA

Plenary

Meister Room

Chair: E Mukisira, KARI, Kenya

Convener: P Bramel, IITA

0830 - 0855	Topic to be announced - R Tumusiime, Commissioner, African Union
0855 – 0920	Specialty banana products and niche markets - A Abera Kalibata, State Minister for Agriculture, Rwanda
0920 – 0945	Africa's move - Hartmann, IITA
0945 – 1000	Oversight of strategy development - F Beed, IITA/ Conference Organizing Committee
1000 – 1030	Discussion
1030 – 1100	Coffee/Tea

MARKETS AND TRADE

Plenary

Meister Room

Chair: S Abele, IITA

Convener: J Jagwe, IITA

1100 – 1120	Banana growing for export: innovative approaches in production and marketing- the need for partnerships - C Fehr, Gourmet Gardens, Uganda
1120 - 1140	From tissue culture to the table: an assessment of the East African banana system's potential for raising smallholder farmer incomes - S Harris, TechnoServe, Kenya
1140 – 1200	Exporting bananas for improved livelihoods and social development: evidence and challenges from Latin America and Africa - H Van der Waal, AgroFair Benelux

1200 – 1220	Vademecum on imports of bananas into the EU - B O'Connor, O'Connor and Company, European Lawyers, Belgium
1220 – 1240	Socio-economic impacts of tissue culture banana in Kenya through the whole value chain approach - R Njeru, Africa Harvest, Kenya
1240 – 1300	Discussion
1300 – 1400	Lunch at Diani Restaurant

There will be four parallel sessions after the plenary: Market Segments (Meister), Policies and Trade (Mandhari), Supply (Peponi) and Processing (Likunda)

Parallel Session 1: MARKET SEGMENTS

Meister Room

Chair: S Harris, Technoserve, USA

Convener: R Njeru, Africa Harvest, Kenya

1400 – 1415	Analysis of consumer preferences of banana in Nigeria - OE Ayinde, University of Ilorin, Nigeria
1415 – 1430	Consumer acceptability and willingness to pay for introduced dessert bananas - K Ankakwasa, NCRI, Uganda
1430 – 1445	A strategy to segment the European banana market: label mountain - C Bugaud, CIRAD, France
1445 – 1500	Discussion
1500 – 1515	Opportunities and constraints for dried dessert banana export in Uganda - P Van Asten, IITA
1515 – 1530	Got matooke for Christmas - R Birabwa, IITA
1530 – 1545	Africa has played a minor role in world trade, but this could well change - A Smith, EUROBAN
1545 – 1600	Innovation in banana value chain development in Metema district, northwestern Ethiopia: IPMS experiences - K Berhe, ILRI
1600 – 1615	Discussion

Parallel Session 2: POLICIES AND TRADE

Mandhari Room

Chair: F Opiyo, ASARECA

Convener: B O'Connor, O'Connor and Company, European Lawyers, Belgium

1400 – 1415	Assessing the extent of banana market distortions in Uganda - D Ngambeki, NCRI, Uganda
1415 – 1430	Market dynamics as a key factor influencing banana production: a case study of Igoji division Meru central district in Kenya - FL Gacheri, Egerton University, Kenya
1430 – 1445	A quantitative assessment of the effects on the banana market of the economic partnership agreements and the possible conclusions of on-going bilateral and multilateral trade negotiations - G Anania, University of Calabria, Italy
1445 – 1500	Discussion
1500 – 1515	Structure, Conduct and Performance of the Banana Market in Malawi: case study of Thyolo and Nkhatabay RDPs - FT Nthakomwa, Malawi

- 1515 – 1530 The role of marketing cooperatives in the bargaining position of producers in farm-gate banana prices: evidences from small-holders in southern Ethiopia - AW Getachew, University of Giessen, Germany
- 1530 – 1545 Consumer perceptions towards introducing a genetically modified banana in Uganda - E Kikulwe, Wageningen University, The Netherlands
- 1545 – 1600 Banana market: Africa obliged to innovate - D Loeillet, CIRAD, France
- 1600 – 1615 Supply chain management and public and private participation in banana in Tamil Nadu, India: status, problems and suitable policy measures - A Malaisamy, Tamil Nadu Agricultural University, India

Parallel Session 3: SUPPLY

Peponi Room

Chair: E Simmons, USAID *ret.*

Convener: K Nowakunda, NARO, Uganda

- 1400 – 1415 Banana production characteristics and performance in Uganda - F Bagamba, NCRI, Uganda
- 1415 – 1430 Market-led banana technology and adoption in central and western districts of Uganda - F Ssango, Agribusiness Management Associates, Uganda
- 1430 – 1445 Socio-economic impacts of adoption of new banana varieties on livelihoods of farmers in Kagera region, Tanzania - J Nkuba, ARDI, Tanzania
- 1445 – 1500 Discussion
- 1500 – 1515 An economic assessment of plantain production in River state, Nigeria - BS Fakayode, University of Ilorin, Nigeria
- 1515 – 1530 Determinant of technical, allocative and economic efficiencies in plantain production industry in Ondo state, Nigeria - JO Bifarin, Federal College of Agriculture, Nigeria
- 1530 – 1545 Business approaches for rural wealth creation: how fixing output market failures for poor matooke farmers in Uganda has enabled them to mobilize capital for investment - E Kibugu, Technoserve, Uganda
- 1545 – 1600 Small-scale banana growers prosper in Kenya in a transformed value chain - H Kinyua, Technoserve, Kenya
- 1600 – 1615 Discussion

Parallel Session 4: PROCESSING

Likunda Room

Chair: S Hauser, IITA

Convener: C Fehr, Gourmet Gardens, DR Congo

- 1400 – 1415 Processing businesses: their contribution to rural development - C Staver, Bioversity
- 1415 – 1430 Banana juice production in South Africa - ZC De Beer, ARC - Institute for Tropical and Subtropical Crops, South Africa
- 1430 – 1445 Overview of processing businesses and their support environment in Cameroon - GN Ngho, CARBAP, Cameroon
- 1445 – 1500 Discussion

1500 – 1515	processing businesses and their support environment in Tanzania: their role in poverty alleviation to rural communities - SRB Mgenzi, ARDI, Tanzania
1515 – 1530	Small-scale processors in Nigeria: their potentials, prospects and challenges - SOS Akinyemi, NHRI, Nigeria
1530 – 1545	A study on the analysis of processing businesses and their support environment in Malawi - VE Mshani, Bvumbwe Agricultural Research Station, Malawi
1545 – 1600	Discussion
1600 – 1630	Coffee/Tea break with assorted pastries at Meister Room
1700 - 1800	POSTER and EXHIBITION STANDS - Meister Tent
1730 - 1930	SPECIAL SESSION: Innovating banana system: country perspectives - Meister Room (Organizer: Bioversity)
1730 – 1930	SPECIAL SESSION: Lessons learnt from the first 25 years of Fair Trade banana – Peponi Room (Organizers: COLSIBA, EUROBAN and WINFA)
1900 – 2000	Welcome cocktail at Malaika Terrace/ Baobab Lawn
2000 -	Dinner at Kivulini Beach Cove: “African Beach Fiesta”

Tuesday, 7 October

PRODUCTION

Plenary - Meister Room

Chair: L Wasilwa, KARI, Kenya

Convener: P Van Asten, IITA

0830 - 0850	Overview of current and projected future production issues in Africa - B Delveaux, University Catholiek Leuven
0850 – 0910	Role of biotech and transgenics in in Africa - F Shotkoski, African Biotechnology Support Project 2
0910 – 0930	The potential of tissue culture banana technology in Africa: anticipated limitations and constraints - EM Kahangi, Jomo Kenyatta University of Agriculture and Technology, Kenya
0930 - 0950	The role of national centres of excellence in banana research and development in eastern, central and southern Africa - W Tushemereirwe, Uganda Banana Program, National Agricultural Research
0950 - 1010	The Role of NGO's in addressing regional banana problems – creating synergy through partnerships – lessons learned from Catholic Relief Services management of a multi country and multi partner banana program in East and Central Africa - S Walsh, CRS
1010 - 1030	Discussion
1030 – 1100	Coffee/Tea
1300 – 1400	Lunch at Diani Restaurant

There will be five parallel sessions after the plenary, two in the morning and three in the afternoon: Morning - Plant Health (Meister) and Post-Harvest (Mandhari); Afternoon - Agronomy (Meister), Seed Systems (Peponi), and Genetic Improvement (Mandhari).

Parallel Session 1: PLANT HEALTH

Meister Room

Chair: P Paparu, IITA

Convener: A Viljoen, University of Stellenbosch, South Africa

- 1100 – 1115 Protecting the African banana: prospects and challenges - A Viljoen, University of Stellenbosch, South Africa
- 1115 – 1130 Integrated control of Fusarium wilt of banana - EG Kidane, University of KwaZulu-Natal, Pietermaritzburg, South Africa
- 1130 – 1145 Nematode control on banana and plantain suckers (spp.) through submergence in boiling water - S Hauser, IITA
- 1145 – 1200 Discussion
- 1200 – 1215 The potential benefits of GIS techniques in disease and pest control: an example based on a regional project in Central Africa - H Bouwmeester, IITA
- 1215 – 1230 Crop pests: why pest diagnostics, phytosanitary standards and surveillance is important and what are our roles and responsibilities - J Smith, CSL, UK
- 1230 – 1245 The International Plant Diagnostic Network (IPDN) in Africa: improving capacity for diagnosing diseases of banana and other African crops - S Miller, Ohio State University, USA
- 1245 – 1300 Discussion

Parallel Session 2: POST-HARVEST

Mandhari Room

Chair: E Karamura, Bioversity

Convener: S Hearne, IITA

- 1100 – 1115 Banana and plantain research at CARBAP: evaluation and post-harvest research for development - K Tomekpe, CARBAP, Cameroon
- 1115 – 1130 Cooking quality and utilisation of bananas and plantains grown by households in East Africa - B Onyango, Bioversity
- 1130 – 1145 Carriage of bananas in refrigerated ships and containers: pre-shipment and shipboard factors influencing cargo out-turn condition - A Snowden, Wolfson College, Cambridge, UK
- 1145 – 1200 Discussion
- 1200 – 1215 Effect of mode of ripening on ethylene biosynthesis during ripening of diploid banana fruit - DMA Mbéguié, CIRAD/UMR, QUALITROP
- 1215 – 1230 Cultivar difference in peel blackening of banana fruit during low temperature storage - K Saichol, Kasetsart University, Thailand
- 1230 – 1245 Physico-chemical changes during fruit development and ripening of three cultivars grown in Cameroon - N Ngoh, CARBAP, Cameroon
- 1245 – 1300 Discussion

Parallel Session 3: AGRONOMY

Meister Room

Chair: S Akele, AGIP, Nigeria

Convener: I Van den Bergh, Bioversity

- 1400 – 1415 Methodological considerations on banana and plantain yield determinations - P Van Asten, IITA
- 1415 – 1430 Potential impact of climate change on banana production and bio constraints in sub-Saharan Africa - K Sonder, IITA
- 1430 – 1440 Plantain cultivation in Africa: a review of its production, marketing and research in recent two decades and prospect for the future - J Ganry, CIRAD, France
- 1440 – 1450 Agroecological intensification in banana and plantain: an approach to developing more sustainable cropping systems for both smallholder farmers and large-scale commercial producers - F Côte, CIRAD, France
- 1450 – 1505 Discussion
- 1505 – 1520 Factors driving fertilizer adoption in banana systems in highland banana - L Wairegi, IITA
- 1520 – 1535 Benefits and potential use of arbuscular mycorrhizal fungi in banana and plantain systems in Africa - J Jefwa, CIAT-TSBF, Kenya
- 1535 – 1550 Turning unproductive waterways from dry lands into banana fields - J Ng'ang'a, Research, Community and Organizational Development Associates, Tanzania
- 1550 – 1605 Discussion

Parallel Session 4: SEED SYSTEMS

Peponi Room

Chair: A Shahasi, Clemson University, USA

Convener: J Smith, CSL, UK

- 1400 – 1415 Banana virus indexing in East Africa - A James, Queensland University of Technology, Australia
- 1415 – 1430 Development of a diagnostic protocol for Cucumber Mosaic Virus for screening planting material in Cote d'Ivoire - K Nazaire, CNRA, Cote d'Ivoire
- 1430 – 1445 *In planta* suppressiveness to nematodes and long term root health stability through biological enhancement - R Sikora, University of Bonn, Germany
- 1445 – 1500 Discussion
- 1500 – 1515 Combating phytosanitary constraints to banana production: the Kenyan example - W Otieno, Kenya Plant Health Inspectorate Service, Kenya
- 1515 – 1530 Improved banana planting material in Burundi: the case of Agrobiotech - T Rishirumuhirwa, Agrobiotec, Burundi
- 1530 – 1545 Private tissue culture banana production in Uganda - E Nsubuga, AGT, Uganda
- 1545 – 1600 Discussion

Parallel Session 5: GENETIC IMPROVEMENT

Mandhari Room

Chair: W Tushemereirwe/ A Kiggundu, NARO,
Uganda

Convener: J Lorenzen, IITA

- 1400 – 1415 Overview of banana and plantain improvement in Africa: past and future - J Lorenzen, IITA
- 1415 – 1430 Biofortification of banana: a grand challenge in global health - J Dale, Queensland University of Technology, Australia
- 1430 – 1445 Novel biotechnological approaches for the improvement of East African Highland Banana productivity and utilization - A Kiggundu, NARO, Uganda
- 1445 – 1500 Discussion
- 1500 – 1515 *In vitro* culture and mutagenesis for banana improvement - M Jain, University of Helsinki, Finland
- 1515 – 1530 Chimerism and its implications to conservation strategies of the East African Highland Bananas (AAA-EA) - D Karamura, Bioversity
- 1530 – 1545 Analysis of genetic diversity and relationships in East African "apple" AAB and "Omuraru" AA dessert banana groups using microsatellite markers - M Onyango, KARI, Kenya
- 1545 – 1600 Discussion
- 1600 – 1630 Coffee/Tea with assorted pastries at Meister Room
- 1630 – 1730 POSTER and EXHIBITION STANDS – Meister Tent
- 1730 - 1930 SPECIAL SESSION: Media evening: An open event for researchers to get practical tips and inspiration on making the most out of the media to get their message across – Meister Room (Organizer: WRENmedia)
- 1730 – 1930 SPECIAL SESSION: Documentation and Information Network for Africa (REDIMA): Steering Committee – Peponi Room (Organizer: Bioversity)
- 1930 - Dinner at Bahari Terrace: "Karamu Ya Waswahili – Coastal Night"

Wednesday, 8 October

INNOVATION SYSTEMS

Plenary

Meister Room

Chair: M Stambuli-Niko, ARCADIA, Tanzania

Convener: C Staver, Bioversity

- 0830 – 0900 Bananas and new thinking about pathways for science impact - N Röling, Wageningen University, The Netherlands
- 0900 – 0920 Innovation systems, food security and economic development - JA Francis, CTA, The Netherlands
- 0920 – 0940 Tracking the spill-over of introduced technologies: the case of improved banana germplasm in northeastern Tanzania - JG Mowo, African Highlands Initiative, Uganda

- 0940 - 1000 Turning African farmers into businessmen or marketizing small-holder Agriculture? Reconciling the market versus social varieties of capitalism in the African agribusiness development debate - CMO Ochieng, Ecoagriculture Partners, Kenya
- 1000 – 1010 Meeting demand: what growers need and how to respond - E Boa, CABI, UK
- 1010 - 1030 Coffee/Tea

There will be four parallel sessions after the plenary: Tracking Adoption and Impact (Meister), Turning Farmers into Business People (Mandhari), Innovating Delivery Systems (Likunda), and Profiling Country Perspectives (Peponi).

Parallel Session 1: TRACKING ADOPTION AND IMPACT

Meister Room

Chair: MSR Byabachwezi, ARDI, Tanzania

Convener: J Mowo, IITA

- 1100 – 1115 Community-based organizations and their effect on the adoption of agricultural technologies in Uganda: a study of banana production technology - E Katungi, NCRI, Uganda
- 1115 – 1130 Conditions of adoption of new technique of vegetative multiplication (PIF) in Cameroon: impact on the diffusion of new banana and plantain cultivars - T Lescot, CIRAD, France
- 1130 – 1145 Determinants of adoption and impact of new hybrid bananas in central Ghana - BM Dzomeku, CSIR, Ghana
- 1145 – 1200 Discussion
- 1200 – 1215 Farmers' perceptions and factors affecting the adoption of disease-resistant plantain and banana hybrids in Nigeria - CC Aitededji, IITA
- 1215 – 1230 Networking banana for research and development in ESA: lessons learnt - E Karamura, Bioversity
- 1230 – 1245 Socio-economic impacts of tissue culture banana in Kenya through the whole value chain approach - M Njuguna, Africa Harvest, Kenya
- 1245 – 1300 Discussion

Parallel Session 2: TURNING FARMERS INTO BUSINESS PEOPLE

Mandhari Room

Chair: S Akinyemi, NHRI, Nigeria

Convener: C Ochieng, Ecoagriculture Partners, Kenya

- 1100 – 1115 Diffusion of tissue culture banana technologies to smallholder farmers in Kisii district Kenya, using a micro-credit scheme - ENK Okoko KARI, Kenya
- 1115 – 1130 Empowering small-scale farmers to become competitive in banana production and marketing - K Nowakunda, NCRI, Uganda
- 1130 – 1145 Privatizing the extension service in agricultural sector in Uganda - J Nanyunja, Uganda Environmental Education Foundation, Uganda
- 1145 – 1200 Discussion

- 1200 – 1215 Sustainable banana production by small-scale growers in Kenya - JJ Anyango, KARI, Kenya
- 1215 – 1230 Sustainable business empowerment for small-holders through local service providers: SNV's experiences in developing the banana value chain in Zimbabwe - E Mudyazvivi, Netherlands Development Organisation, Zimbabwe
- 1230 – 1245 Turning farmers into business people: the role of tissue culture bananas in Kenya - J Mbaka, KARI, Kenya
- 1245 – 1300 Discussion

Parallel Session 3: INNOVATING DELIVERY SYSTEMS

Likunda Room

Chair: GV Paka, INERA, DR Congo

Convener: E Boa, CABI, UK

- 1100 – 1115 A regional network of dialogue and exchange platforms to improve the identification of farmers' needs and the dissemination of new banana and plantain cultivars - I Nkapkang, CARBAP, Cameroon
- 1115 – 1130 Lessons from the reorganisation of the health services in Tanzania for agricultural development, particularly the banana industry - M Stambuli-Niko, Tanzania
- 1130 – 1145 Use of partnership extension model to facilitate adoption of IITA plantain and banana based technologies in Nigeria - I Ogunlade, University of Ilorin, Nigeria
- 1145 – 1200 Discussion
- 1200 – 1215 Using strategic entry points and linked technologies for enhanced uptake of improved banana germplasm in the humid highlands of East Africa - K Masuki, African Highlands Initiative, Uganda
- 1215 – 1230 Training requirements of extension workers in banana and plantain technology transfer in southwestern Nigeria - LO Olajide-Taiwo, NHRI, Nigeria
- 1230 – 1245 Building the banana chain in Somalia: support to Agricultural Marketing Services and Access to Markets (SAMSAM) experiences - E Baars, CEFA, Somalia
- 1245 – 1300 Discussion

Parallel Session 4: PROFILING COUNTRY PERSPECTIVES

Peponi Room

Chair: V Mshani, Byumbwe Agricultural Research Station, Malawi

Convener: JA Francis, CTA, The Netherlands

- 1100 – 1115 An innovation capacity analysis to identify strategies for improving plantain and banana productivity and value addition in the Democratic Republic of Congo - P Mobambo, Bioversity

- 1115 – 1130 Meeting the challenge of economic restructuring of the plantain sector in Cameroon - JT Tetang, Bioversity
- 1130 – 1145 Research-extension-farmer linkage system on banana and plantain in Nigeria: the diffusion of innovations - Owusa, University of Ibadan, Nigeria
- 1145 – 1200 Discussion
- 1200 – 1215 Agricultural science, technology and innovation: plantain case study in Ghana - I Egyir, University of Ghana, Ghana
- 1215 – 1230 Analysis of the agricultural science, technology and innovation systems: a case study of banana in Tanzania - AP Maerere, Sokoine University of Agriculture, Tanzania
- 1230 – 1245 Innovation in banana value chain development in Metema district, north-western Ethiopia: IPMS experiences - Adelaja, ILRI
- 1245 – 1300 Discussion
- 1330 – 1400 POSTER and EXHIBITION STANDS – Meister Tent
- 1330 – 1420 Lunch at Diani Restaurant or packed lunch for field trips
- 1400 - Field trip and excursion (Mombasa Town, Mombasa international port and banana market, snorkeling and dolphin watching tour, Banana 2008 Fun Golf for beginners, Safari to Shimba Hills)
- 2000 - Dinner at Fisherman's Cove/ Mnazi Cove: "Pirate's Night"

Thursday, 9 October

STRATEGY

First Plenary: Building strategies to mobilize the banana sector in Africa

Meister Room

Chair: F Beed, IITA

Convener: P Bramel, IITA

- 0830 – 0850 Empowering small-scale farmers through banana processing plants - A Tibaijuka, UN/UN-HABITAT, Kenya
- 0850 – 0910 Donor perspective on strategy development - J Kalders, DGDC, Belgium
- 0910 – 0930 Promoting research for health and prosperity - R Kahane, Global Horticulture Initiative, Tanzania
- 0930 – 0940 Discussion
- 0940 – 1000 Role and perspectives of ASARECA - F Opio, ASARECA
- 1000 – 1020 After 10 years of research: what needs to change? - R Markham, Bioversity
- 1020 – 1030 Discussion
- 1030 – 1100 Coffee/Tea

SECOND PLENARY: Reporting by theme coordinators from previous sessions

Meister Room

Chair: R Markham, Bioversity

Convener: P Bramel, IITA

- 1100 – 1125 Markets and Trade - S Abele, IITA
- 1125 – 1150 Production - D Coyne and S Hauser, IITA
- 1150 – 1215 Innovations Systems - C Staver, Bioversity
- 1215 – 1300 Open forum to identify types of organizations and partnerships required
- 1300 – 1400 Lunch at Diani Restaurant
- 1400 – 1730 Break-out sessions to develop commodity-specific strategies with focus on local, regional and international markets

Break-out Session 1: EAST AFRICAN HIGHLAND BANANA

Meister Room

Chairs: F Beed, IITA and I Van den Bergh, Bioversity

Convener: S Hearne, IITA

- 1400 – 1530 Participatory session
- 1530 – 1600 Coffee/Tea
- 1600 – 1730 Continuation of participatory session

Break-out Session 2: DESSERT BANANA Mandhari Room

Chairs: S Abele, IITA and C Staver, Bioversity

Convener: S Canney, Pipal

- 1400 – 1530 Participatory session
- 1530 – 1600 Coffee/Tea
- 1600 – 1730 Continuation of participatory session

Break-out Session 3: PLANTAIN

Peponi Room

Chairs: S Hauser, IITA and R Markham, Bioversity

Convener: W Wilson, Intersol

- 1400 – 1530 Participatory session
- 1530 – 1600 Coffee/Tea
- 1600 – 1730 Continuation of participatory session

1930 GALA DINNER at Bustani Garden, with prizes,
awards, closing remarks and live music

Friday, 10 October

PROMUSA: Working Group on Production Meister Room

- 0900 – 0915 Welcome message by Working Group Chair and Vice-Chair
- 0915 – 0930 Report of meeting in South Africa by Working Group Chair
- 0930 – 1030 Roundtable discussion of Working Group Objectives
- 1030 – 1100 Coffee/Tea
- 1100 – 1230 Developing joint research proposals around three selected themes* + Identifying Core Team
- 1230 – 1400 Lunch at Diani Restaurant
- 1400 – 1530 Continuation of Developing joint research proposals around three selected themes + Identifying Core Team
- 1530 – 1600 Coffee/Tea
- 1700 – 1730 Effective collaboration within the Working Group/
Role of chairpersons/Collaboration with other Working Groups

Acknowledgement

Organizing Committee

In addition to scientists from IITA, the Organizing Committee is complemented by scientists from the partner organizations, Bioversity, Kenya Agricultural Research Institute (KARI), and the National Agricultural Research Organization of Uganda (NARO).

Thomas Dubois, IITA (Chair)

Daniel Coyne, IITA (Vice-Chair)

Lusike Wasiwa, KARI (Local Organizing Committee Chair)

Steffen Abele, IITA

Monique Beckers, Intektravel

Fen Beed, IITA

Millie Galabuzi, IFPRI/IITA

Stefan Hauser, IITA

Sarah Hearne, IITA

Violet Kirigua, KARI

Richard Markham, Bioversity

Alice Muchiri, IITA

Florence Muranga, PIBID

John Mutua, Leisure Lodge & Golf Resort

Beatrice Sakwah, IITA

Charles Staver, Bioversity

Wilberforce Tushemereirwe, NARO

Piet Van Asten, IITA

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Scientific Committee

The Conference Organisers wish to thank members of the Scientific Committee of each of the sessions for their valuable input and contributions, prior to, during and following the conference.

Markets and trade

Steffen Abele, IITA (Chair); Arega Alene, IITA; Thomas Dubois, IITA; Clemens Fehr, Gourmet Gardens; Shaun Ferris, CRS; Christian Fischer, University of Bonn; Frank Hartwich, IFPRI; John Jagwe, IITA; Victor Manyong, IITA; Rose Njeru, AfricaHarvest; Kephass Nowakunda, NARO; Bernard O'Connor, O'Connor and Partners; Matin Qaim, University of Hohenheim; David James Watson, IITA

Production

Daniel Coyne, IITA (Chair); Stefan Hauser, IITA (Chair); Fen Beed, IITA; James Dale, Queensland University; Bruno Delvaux, University Catholique de Leuven; Jacky Ganry, CIRAD Jim Lorenzen, IITA; Sarah Hearne, IITA; Franklin Rosales, Bioversity; Julian Smith, Central Science Laboratories; Kai Sonder, IITA; Rony Swennen, Katholieke University Leuven; Kodjo Tomepke, CARBAP; Leena Tripathi, IITA; Piet Van Asten, IITA; Bernard Vanlauwe, CIAT; Inge Van den Bergh, Bioversity; Altus Viljoen, University of Stellenbosch

Innovation systems

Charles Staver, Bioversity (Chair); Eric Boa, CABI; Judith Francis, CTA; Jeremias Mowo, African Highlands Initiative; Cosmans Ochieng, IFPRI; Martha Stambuli-Niko, Tanzania

Strategy

Fen Beed, IITA (Chair); Richard Markham, Bioversity (Chair); Steffen Abele, IITA; Paula Bramel, IITA; Sue Canney, Pipal; Sarah Hearne, IITA; Stefan Hauser, IITA; Inge Van den Bergh, Bioversity, Warren Wilson, Intersol. Special thanks also for the time and effort of the Chairpersons of the various sessions during the conference.

Strategy for banana in Africa

What does it take to transform a crop that is part of the agricultural and cultural landscape into an engine of economic development? Bananas in their diverse forms – sweet dessert fruit, starchy cooking bananas, juicing bananas and plantains – originate from Asia. However, people have been growing them in Africa for more than two thousand years – very much longer than maize or cassava, for instance. Nobody knows who brought bananas to Africa or exactly when but in this new home they have certainly been adopted with enthusiasm. People in the highlands of Central Africa eat more bananas than anyone else in the world while in the lowlands of the Congo basin farmers grow a greater diversity of plantains than anywhere else. These tough perennial plants are the backbone of many farming systems, protecting the soil from erosion and surviving floods, drought and civil conflict, to recover quickly and provide people with food when they need it most. In their different forms, bananas can be a starchy staple, an energy-giving snack or an easily digestible weaning food for babies.

Yet in many ways the market for bananas grown in Africa is still in its infancy. It is true that trucks laden with banana and plantain are a familiar sight on the highways leading into many of Africa's major cities, providing a significant income for farmers in the hinterland and for the traders who link them to markets. Ships laden with dessert fruit leave ports on the West African coast and the Horn of Africa, contributing to the balance of trade and providing employment on plantations and in packing sheds. Meanwhile, all across the continent, people are transforming bananas into higher value, more durable products – chips and other snack foods, flour, and beverages – that can be sold into markets nearby and traded overseas. Artefacts woven from banana leaves and fibre provide useful and decorative objects, around homes in the local community or sold to tourists and craft shops in other continents.

Most stakeholders in the banana sector, however, recognise that this is only a beginning, a small fraction of what bananas could contribute to sustainable development in Africa. What is limiting the economic dynamism of the banana sector in Africa? Are key technologies lacking at particular stages in the commodity chain, from genetic resources, through production, post-harvest handling and processing to consumption? Are suitable technologies available, but is knowledge of them and supporting information failing to reach farmers and other intermediaries in the commodity chain? Do farmers, processors and traders have the necessary business skills and market information to allow them to enter and compete in an evolving and ever-more-competitive market? Are input supplies and other infrastructures adequate to support a flourishing banana sector? Do national policy and regulatory environments facilitate and encourage the development of markets and trade?

The intention of the 'strategy day' is to draw together the most important lessons learned from the first three days of the conference, to analyze and synthesize them into a coherent 'road map' which will help to guide the development of the banana sector in Africa. Drawing on the richness of experience and expertise available, the meeting will use participatory approaches to draw out specific recommendations for each major production system and type of market orientation. What needs to be done, how can this be achieved, with whom, when and where, in order for the banana sector to make its full contribution to the well-being of people and the sustainable economic development of Africa? Working together, this unique gathering of experts will seek to provide authoritative answers to these questions and so chart the way ahead for all stakeholders in this important endeavour.

Markets & Trade



Oral Presentations

Plenary: Markets and Trade

Venue: Meister Room

Time: 1100–1300

Banana growing for export: innovative approaches in production and marketing- the need for partnerships

C. Fehr

Gourmet Gardens Ltd., Kampala, Uganda

This article elaborates alternative ways to link subsistence-based banana growing systems to international markets and the need for scientific and marketing partnerships. As part of the health food and organic movement, exotic dried fruits like banana become increasingly more popular. At the same time, the majority of banana grown in East Africa originates from smallholder farms; few of these have the capacity to cater for the volumes demanded by the predominantly overseas markets. Coupled with lack of capacity is skill deficits, and high overhead costs associated with producing and exporting goods from the region. As a result, the potential contribution of banana production to rural poverty eradication rarely materializes. Gourmet Gardens has developed a range of alternative strategies to exploit this market. Farmers are assisted in forming producer organizations and to pool their produce. Centralized processing facilities help to overcome problems related to product quality and overhead costs. Another novelty in the project is the use of organic and fair trade certification and trade-marking to brand and add value to products. Finally, in light of the rapidly changing environmental, social and market challenges, the project strongly depends on professional and functioning partnerships and cooperation. Key challenges are outlined.

From tissue culture to the table: an assessment of the East African banana system's potential for raising smallholder farmer incomes

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¹McKinsey and Company, Nairobi, Kenya; ²TechnoServe Kenya, Nairobi, Kenya

The Bill and Melinda Gates Foundation, McKinsey and Company, and TechnoServe conducted a 2-month study into the East African banana system. The study involved i) a diagnosis of the primary barriers to increasing smallholder farmer income along the value system, ii) a proposed theory of change for governing responsible interventions in the system, iii) a discussion of the two most limiting constraints to successful intervention i.e. market demand and intervention capacity, and iv) a recommendation of what initiatives would successfully raise farmer incomes in the short to medium term i.e including on-farm productivity services, farmer aggregation and small to medium enterprise and wholesale sector development measures.

Exporting bananas for improved livelihoods and social development: evidence and challenges from Latin America and Africa

H. Van der Waal

AgroFair Benelux BV

Small scale banana farmers are traditionally used by large banana marketing companies to buffer fluctuations in supply and demand. As a result, farmers face permanent commercial insecurity. Small farmers can gain direct access to export markets and even share in the upstream revenues. Instead of multinational marketing and production companies controlling the whole supply chain netting the profits, or on a local scale, middle men taking the lion's share of the profit, small farmers can effectively export and market their own bananas, if they organize in a proper way. Such is the experience in various countries in Latin America, where farmer cooperatives have succeeded in entering the European markets with their co-owned banana and fresh fruit importer AgroFair, operating under FairTrade certifications and marketing the fruit under its own Oké brand. As shareholders in AgroFair, the profits are maximally ploughed back into the farmer's communities, instead of being added to shareholder's value in stock exchanges. This improves the quality of the livelihoods of banana farmers and boosts social development throughout communities. At the same time the farmers respect the environment by means of integrated pest management or even organic agriculture, so that their supply chain is not only socially but also ecologically sustainable. Organizational models for farmer and supply chain organization need to be adapted to the context. The cooperative model does not perform equally well in every given circumstance. In Africa, good results have been obtained by a plantation that is partially co-owned by the workers, and by powerful export houses that work entirely in the interest of small producers. This article analyses succinctly the outline of the FairTrade value chain from production to marketing, the lessons learnt, the social advantage that can be assessed, and the opportunities and challenges it presents to African banana producer communities.

Vademecum on imports of bananas into the European Union

B. O'Connor

O'Connor and Company, European Lawyers, Brussels, Belgium

This paper will set out the formal steps to be taken by an exporter seeking to export bananas (and plantain) to the EU market. The paper begins with a quick overview of the prices available for bananas in the EC over the last four years as well as the volumes of trade into the EC and the countries of origin. In addition the introduction gives a brief overview of the EU banana wars and the current status of the ongoing WTO disputes. The body of the paper looks at the formal customs requirements for the import of bananas into the EC including customs duties, VAT duties, customs clearance arrangements and the documentation required. Explanations of key terms are given. The paper then looks at the sanitary and phytosanitary (SPS) requirements for the imports of fresh fruits including the rules relating to agro-chemical residues. Under the heading of food safety the paper examines the traceability requirements applicable to imports, legal standards applicable to the marketing of bananas and the informal private standards applied by many large retailers and supermarkets. The paper also looks at the requirement for selling bananas as organic. A final section of the paper indicates the names and addresses of the main authorities controlling imports in the principal points of import into the EU. As

many exporters might also consider exporting to Switzerland and Norway (not members of the EU), the paper also looks at the main rules applicable in these countries. The VADEMECUM is intended to be a stand alone document containing internet references to the main rules and regulations applicable.

Socio-economic impacts of tissue culture banana in Kenya through the whole value chain approach

F. Wambugu, V. Ndungu and W. Mbutia

Africa Harvest Biotech Foundation International, Nairobi, Kenya

Banana is an important staple food and source of income for small-scale subsistence farmers in Kenya. However, the production of this crop is hampered by various constraints, including pests and diseases. Traditional propagation of banana through suckers as planting material has over the years contributed to the spread of pests and diseases, reducing yields by up to 90%. Banana production received a major setback in the early 1990s (986,000 metric tons in 1992 to 489,000 metric tons in 1996), mainly due to the high incidence of diseases and non-availability of disease-free planting material. Initiatives by KARI, AHBFI, JKUAT and ISAAA, in subsequent years made significant strides in addressing these constraints through the introduction of tissue culture (TC) planting material. Africa harvest through two of its major projects has continued to facilitate the provision of TC planting material to farmers in Central and Eastern Kenya, through the "Whole Value Chain Approach". This has resulted in significant positive socio-economic impacts at individual farmer and community level. The whole value chain approach involves a range of activities, from awareness creation on the TC technology, to development of appropriate marketing systems, and empowerment of farmers through promotion of banana growers associations. Significant specific economic impacts of the TC banana have been achieved by all sections of the country's population including the producers and consumers. The direct and indirect impacts are estimated to be K Shs 6471 million over the past 10 years. There have also been various social impacts. Some of these include i) addition of TC banana plantations to family assets, ii) improvement of household food security iii) reduction in malnutrition, iv) empowerment of women v) improved housing and ability to pay school fees, vi) improved cohesiveness within the community, vii) reduction of anti-social behavior in community, and viii) creation of entry points for other development activities. Various other specific aspects of the socio-economic impacts of TC banana through the whole value chain approach are discussed.

Parallel Session 1: Market Segments

Venue: Meister Room

Time: 1400–1615

Analysis of consumer preferences of banana in Nigeria

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The acceptance of banana fruit is mainly due to its sensorial aspects, nutritional value and convenience, while the identification of customer

needs and desires constitute a critical aspect of marketing. This study looked at consumer preferences of a local market (Ilorin town, Kwara state) regarding fruit quality attributes of fresh mature banana. The analytical tools used include descriptive statistics, ranks and LSD. Data was collected using questionnaires structured for personal interview with 200 people. Quality attributes (variables) questioned and appraised included fruit appearance, color, texture, aroma, flavor and shelf-life. In agreement with consumer preferences, fruits of an ideal mature banana should present characteristics such as 10-12 fingers (fruits), fingers of medium or big size, medium diameter, present angularity, light-yellow pulp color, absence of black spots on peel, firm texture, aroma and flavor of medium intensity, medium sweetness and shelf-life of 7-10 days under natural conditions. The flavor, shelf-life and appearance of the banana fruits are considered the most important attributes at purchase, according to the consumers.

Consumer acceptability and willingness to pay for introduced dessert bananas

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¹National Crops Resources Research Institute, Kampala, Uganda;

²Department of Agricultural Economics and Agribusiness, Makerere

University, Kampala, Uganda; ³International Institute of Tropical Agriculture, Dar es Salaam, Tanzania

The study was done in three countries including Uganda, Kenya and Rwanda. In Uganda, Kampala district, an urban district was sampled. In Kenya, the largest banana market in Nairobi city (Wakulima market) and in Rwanda, two large markets dealing in bananas (Kibisagara and Nyamirambo) were sampled. The study assessed the consumer acceptability and willingness to pay for introduced dessert bananas in Uganda, Kenya and Rwanda. Data comprising of sensory evaluation, prices consumers would be willing to pay, actual market prices paid, socioeconomic and dessert attributes that affect willingness to pay for the introduced dessert banana cultivars were collected and analyzed using ANOVA and a hedonic pricing model respectively. Results indicated that all the three introduced dessert bananas were acceptable to consumers on local and regional markets though rated inferior to 'Gros Michel'. All the sensory attributes of 'KABANA 3H' and 'KABANA 4H' were acceptable to consumers in the local and regional markets. The results further suggested that generally consumers were only willing to pay lower prices for introduced dessert bananas than 'Gros Michel'. At least 50% of the consumers were willing to pay over Ug shs1,000 for an average cluster compared with Ug shs 1180.7 for 'Gros Michel'. On the Ugandan market, customers paid over Ug shs 800 per cluster, a price close to that of 'Gros Michel' (average of Ug shs 1190), while on the regional market, the prices customer paid for the introduced dessert bananas were not different from that paid for 'Gros Michel', indicating a promising market potential for the introduced dessert banana. The hedonic pricing models indicated that some of the socio-economic characteristics like education, household size, income and dessert banana attributes like taste and skin color significantly influenced the willingness to pay for these bananas. It is concluded that, the three introduced dessert bananas have a high market potential. It is recommended that awareness and potential campaigns, market development activities including organizing and training farmers in better methods of growing, handling bananas for both local and export markets; and promotional studies of the introduced dessert bananas among the urban consumers to widen their demand be done.

A strategy to segment the European banana market: label mountain

C. Bugaud¹, M.O. Daribo¹, E. Rosalie², M.P. Beauté², O. Hubert³, C. Dubois⁴, P. Brat⁵, M. Chillet⁶

¹CIRAD, UMR Qualisud, PRAM, Martinique, France; ²CIRAD, UPR Système, PRAM, Martinique, France; ³CIRAD, UMR Qualisud, Station de Neufchâteau, Guadeloupe, France; ⁴CIRAD, UPR Multiplication végétative, Montpellier, France; ⁵CIRAD, UMR Qualisud, Montpellier, France; ⁶CIRAD, UMR Qualisud, Universidade de São Paulo, Faculdade de Ciências Farmacêuticas, São Paulo-SP, Brazil

Banana production is a key economic resource in the French West Indies. It is essential that growers in this region enhance their sales by proposing new products, such as mountain bananas in response to high market competition from other exporting regions where production costs are lower. The quality of mountain bananas is officially recognised in Europe on the basis of a real taste difference. All French West Indian bananas grown over 250 masl according to specifications can be sold under the Mountain banana label. Mountain banana features can be assessed via objective data. At harvest, mountain bananas are denser, bulkier and less susceptible to wound anthracnose caused by *Colletotrichum* *e* than lowland bananas, probably due to their higher mechanical resistance. Sensorial differences have also been documented in ripe bananas. At the same harvest stage and under identical ripening conditions, mountain bananas have a firmer texture, more intense yellowish pulp, and higher sugar and aromatic compound contents. A jury taste test analysis confirmed the sensorial differences between lowland and mountain bananas. However, mountain bananas presented the poorest contents in Mg, P and Ca, partially due to the nature of soil components. The results of a multi-site study indicated that temperature and rainfall during bunch growth are the main factors that distinguish mountain bananas.

Opportunities and constraints for dried dessert banana export in Uganda

P.J.A. Van Asten¹, D. Florent² and S. Apio³

¹International Institute of Tropical Agriculture, Kampala, Uganda ; ²Ecole Supérieure d'Agriculture d'Angers, Angers, France; ³National Crops Resources Research Institute, Kampala, Uganda

In Uganda, dessert bananas ('Apple banana', AAB group, locally known as 'Sukali Ndiizi') are being processed into dried chips for export. A local market for dried dessert banana chips is virtually non-existent. Surveys with five Ugandan exporting companies suggested that export prices of dried banana chips were good (i.e. between 6.5 and 12 USD/kg), but strongly depended on the quality and certification of the product. Major bottle necks to further expand the export seem not related to a lack of demand in Europe, but to the fact that quantities and quality of the exported produce are insufficient. Exporters indicated that one of the major constraints related to producing sufficient volumes is related to the spread of the fungal disease Fusarium wilt (*Fusarium oxysporum* f.sp. *cubense*), which increasingly affects 'Apple banana' production. They also indicated that other dessert bananas on the Ugandan market (e.g. 'Gros Michel' and 'Cavendish') are not processed into dried chips because the processed product is largely inferior to that of 'Apple banana' in terms of taste. This study compares drying, color and taste characteristics (texture, acidity, sugar content and color) of seven alternative Fusarium wilt resistant banana cultivars ('FHIA 01', 'FHIA 17', 'FHIA 23', 'FHIA 25', 'SH 3640/10', 'Yangambi', and 'Kikundi') with 'Apple banana'. European consumers rated the taste

characteristics of 'FHIA 01' at least as good as 'Apple banana' and appreciated its colour more than 'Apple banana'. The taste and colour of other cultivars were generally rated inferior to 'Apple bananas' (i.e. 'FHIA 17', 'FHIA 23', 'FHIA 25', 'SH 3640/10', 'Yangambi', and 'Kikundi'). 'FHIA 01' and 'Apple banana' also had the highest fresh pulp dry matter content (32% and 36%, respectively) compared to other cultivars (27%) and were less sticky than other cultivars ('FHIA 17', 'FHIA 23', 'FHIA 25', 'Yangambi'), which facilitated the processing and packing of the banana chips. This study shows there is potential to further exploit the dried dessert banana export market using Fusarium wilt resistant cultivars.

Got matooke for Christmas

R. Birabwa^{1,2}, P.J.A. Van Asten¹, I.N. Alou^{1,2} and G. Taulya¹

¹International Institute of Tropical Agriculture, Kampala, Uganda; ²Faculty of Agriculture, Makerere University, Kampala, Uganda

In the East African highlands, farmers and scientists have tried to improve banana (spp. AAA-EA group) revenue by improving yields. However, prices of fresh banana are sensitive to changes in supply, which is well illustrated by the large seasonal variations of matooke market prices in Uganda i.e. banana farm-gate prices in November-December (i.e. low supply period) are approximately twice as high as those in July-August (i.e. high supply period) for many areas in Uganda. The food security status, as indicated by farmers, is also strongly positively correlated with banana supply. Despite large fluctuations in farm gate prices and food security status, no efforts have been made to shift banana production towards periods of high banana prices and lower food security status. This study tries to identify how sucker emergence date influences banana yield and time of harvest, with the aim of proposing de-suckering management recommendations that shift harvest time towards low supply periods. The study was conducted on 10 farms in Ntungamo district (southwest Uganda). In each farm, 15 banana mats ('Enyeru') were monitored monthly for sucker emergence date, plant growth, crop management (mulch, weeds, and intercrops), phenological stages, harvest parameters, and pest and disease pressure, for a period of three years (2005-2007). Farmers continued to manage their plantations as they normally did, including desuckering. Plant performance was compared between plants from different emergence and harvest periods i.e. data was grouped into four quarters (1st quarter Jan-March, 2nd quarter April-June, 3rd quarter July-Sept and 4th quarter Oct-Dec). Banana suckers that emerged in Jan-Feb were harvested in Nov-Dec of the following year (i.e. crop cycle duration was 685 days). The average bunch weight of the plants harvested in quarter 1 (16 kg) and 4 (14 kg) were significantly lower than those harvested in quarter 2 (19 kg) and 3 (20 kg). Yields (tons/ha) in the 4th quarter were further reduced due to the fact that the number of bunches harvested was 41% lower than in the 3rd quarter. Despite the lower bunch weights, targeting banana production for high price periods is (i) highly profitable, (ii) will improve food security during periods of low supply, and (iii) will reduce nutrient exports from the farm.

Africa has played a minor role in world trade, but this could well change

A. Smith

European Banana Network (EUROBAN)

Although banana and plantain are crucial to food security in most countries of tropical Africa, the continent's role in the world banana economy has, at least until now, been relatively minor, as the continent's export accounts for less than 4% of international banana

trade in 2007, rising from 3 % in 1985. This growth is driven by a few countries like Cameroon, Côte d'Ivoire and Ghana. However, the strong downward pressure on prices paid to the big fruit companies from the large Northern retail markets – combined with low labor costs and tariff-free access to the EU-27 market – means that the big fruit companies have been actively prospecting for new production locations in the continent. Virtually all exports from Africa go to Europe, with France and the UK being the primary destinations. This is linked to geographical proximity and the shipping lines, but also to the fact that African exporting countries have enjoyed substantial tariff preferences in the single European market since 1993, and are still enjoying bilateral agreements. Virtually all the 2007 export volume of more than 500,000 tonnes is accounted for by medium- and large-scale producers linked to a multinational fruit company. Although banana plantations employ high levels of labor compared to any other export commodity, wages are low and have fallen in relation to the cost of living. Another key feature of industrial banana production is the high level of toxic agrochemical inputs. Although overall levels are lower than in Central America, African workers and neighboring communities report a number of health, safety and environmental problems related to these products. The potential expansion of export banana production in Africa comes at a time when demand in the world market is changing. As consumers have become more and more aware of the social and environmental consequences of industrial banana production, the demand for Fairtrade and organic fruit has grown. By the end of 2007, an estimated one third of the UK market, Europe's second biggest, is accounted for by Fairtrade and organic banana imports. In Switzerland, this figure is over half the total market. Overall, the global market for Fairtrade certified bananas is at 2% of world trade, whilst world organic exports represent an estimated 4%. If African governments and civil society wish to attract benefits of Fairtrade and organic banana production, investors will have to look beyond the traditional banana business model. In the African context, this likely growth in banana exports, must not be at the expense of local food security. A "business as usual" expansion model in Africa would simply reproduce the same model of poor labor conditions, occupational health & safety hazards and long-term negative externalities for the natural environment. Nonetheless, there is growing evidence that the increasing focus by the big banana companies on sustainable development will be better reflected in new operations in Africa. This is an ideal opportunity to learn and apply the lessons from over a hundred years of banana export industry history in Latin America.

Innovation in banana value chain development in Metema district, northwestern Ethiopia: IPMS experiences

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Ethiopia has a diverse agro-ecology and sufficient surface and ground water resources, suitable for growing various temperate and tropical fruits. Although various tropical and temperate fruits are grown in the lowland/midland and highland agro-ecologies, the area coverage is very limited. For example, banana export increased from less than 5,000 tons in 1961 to 60,000 tons in 1972, but in 2003 declined to about 1,300 tons worth less than USD 350,000. The limited development of fruit sector in the country could be attributed to constraints such as limited inputs, skilled manpower and extension approaches and, focus of agricultural development efforts on grain production amongst others. The current government's policy and development strategy prioritizes intensive production and commercialization of agriculture, including fruit production. In an effort to support this change, the International Livestock Research

Institute (ILRI) and the Ministry of Agriculture and Rural Development (MoARD) initiated a five-year project with financial assistance from Canada, called improving productivity and market success (IPMS) of Ethiopian farmers. IPMS follows participatory value chain and innovation systems perspectives and focuses on knowledge-based development of identified agricultural commodities with market potential in 10 pilot learning weredas (districts) in four regional states. One of the weredas is Metema where the project introduced banana production. The objective of this paper is to share IPMS experiences in promoting innovation in banana value chain development in Metema wereda. The paper provides a brief history of banana introduction in Ethiopia, describes the value chain in banana production, input supply and marketing and the various innovations that have been introduced to develop the chain, with a focus on actors and action learning processes. The future outlooks of banana value chain and the reasons for the successful adoption of the innovation and the options to sustain it so that the value chain can respond to changing conditions are highlighted.

Parallel Session 2: Policies and Trade

Venue: Mandhari Room

Time: 1400–1630

Assessing the extent of banana market distortions in Uganda

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The banana marketing system in Uganda is a very complex one with a market chain of eleven actors including the producers and the consumers. Most of the actors especially those between the producers and wholesalers are speculative middlemen who monopolize the market information excluding the farmers. A market study conducted in eight districts selected from central, eastern and western Uganda to assess the extent to which the existence of many middlemen in the market chain has distorted the distribution of profits indicated that the middlemen obtained a market share of 35% as percentage of consumer price while farmers obtained only 20% of the consumer market price. The study further showed that 90% of the banana producers were marketing individually and through middlemen and were getting less than 20% of the consumer prices. The few farmers (about 1%) who were selling as individuals direct to wholesalers and about 5 % who were selling collectively in groups directly to wholesalers or contracted buyers earned 60% of the consumer price.

Market dynamics as a key factor influencing banana production: a case study of Igoji division Meru central district in Kenya

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A large proportion of Kenyan population is engaged in agriculture that accounts for 24.5 % of the gross domestic product (GDP). With a high population growth rate, the demand for food production has increased.

The increasing demand calls for production of a wide range of food crops that will ensure food security and a surplus to earn income for the households. Banana is of major importance for food security and household income. It can be consumed as a fruit, plantain for cooking and animal feeds among other uses. However, despite the crop's potential to satisfy this need in the economy there is a tendency of low production level in high potential areas. Though farmers acknowledge the viability of banana cultivation for commercial purposes as an exit option from the less profitable enterprises, they are reluctant to fully engage in the enterprise. A study was conducted in Igoji division Meru central district to assess the influence of existing market systems on production decisions of the farmers. Eighty farmers were selected randomly and interviewed using structured questionnaires. Data was analyzed using SPSS. Results revealed that the existing marketing system influenced the decisions made by farmers given the farm-gate prices offered and production costs involved. Inadequate technological adaptation and adoption of tissue-cultured banana, pests and diseases, and inadequate information on the economics of production were among the constraints to optimum production. Though markets are liberalized, producer protection from exploitation is necessary for the infant enterprise to reduce the risks involved in trade-off between crops or exit options to enhance food security and income. There is need for farmer training to increase productivity of banana with emphasis on research-extension- farmer linkages.

A quantitative assessment of the effects on the banana market of the economic partnership agreements and the possible conclusions of on-going bilateral and multilateral trade negotiations

G. Anania

Department of Economics and Statistics, University of Calabria, Italy

The paper offers a quantitative assessment of the impact on the banana market of the expansion of trade preferences the EU granted ACP countries with the Economic Partnership Agreements (EPA) and of the possible erosion of these preferences as a result of different possible endings, if any, of on-going WTO negotiations. The results of the simulations performed suggest that the impact of the EPA on the production and consumption of bananas in the EU will be limited, while benefits for ACP countries will be significant (at the expense of MFN exporters). However, a multilateral agreement (the conclusion of the WTO Doha Development Agenda round) or a bilateral agreement between the EU and MFN banana exporters may bring an erosion of the preferential margins currently enjoyed by ACP countries of such an order of magnitude as to cancel out most of these benefits.

Structure, conduct and performance of the banana market in Malawi: case study of Thyolo and Nkhatabay RDPs

F.T. Nthakomwa

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A study was carried out in Thyolo and Nkhata Bay Rural Development Projects (RDP), Malawi, to assess the structure, conduct and performance of the banana market in Malawi. Producers, traders and transporters were interviewed in both the production and marketing areas. The market shares and Herfindahl-Hirschman Index (HHI) calculations indicated that the banana market in Malawi is competitive

in nature. Market margin analysis indicated that the banana market would be fairly efficient if the producers also acted as middlemen. However, retailers were found to be making supernormal profits in all the channels. Simple price correlations indicated that Nkhata Bay-Mzuzu markets and Blantyre-Thyolo markets were slightly integrated and significant at 1% and 5% respectively. The coefficients further indicated that market segmentation existed between Lilongwe and Mzuzu markets.

The role of marketing cooperatives in the bargaining position of producers in farm-gate banana prices: evidences from smallholders in southern Ethiopia

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As in many developing countries, agriculture in Ethiopia remains the dominant occupation and its well-being is crucial to the economy. Major proportions of the population still depend on the agricultural sector albeit the sector is characterized by production of traditional crops for decades. A shift from traditional crop production to high value crops is considered as an important and alternative option in increasing smallholders' income in particular and rural development in general. Promoting small-holder production of export crops is regarded as having a positive spillover effects on input use and food crop productivity, improving market integration and access, and having valuable impacts on the food security and income of small-holder farmers. Of particular importance in the fresh fruit sector in Ethiopia is the potential of banana production and marketing. A huge demand for banana and the market potential in the Middle East and Europe can make the sector significant, compared with others. However, banana production and marketing is still traditional and faces different constraints, such as integration of small-holders into regional and export markets, weak bargaining power coupled with lack of appropriate marketing cooperatives, absence of competitive buyers, and entry barriers and price information asymmetry. Recently, recognizing the role of marketing cooperatives, producers have started to organize themselves and are trying to penetrate the domestic central markets as well as improve their bargaining power. This paper empirically investigates farm-gate banana price-negotiation under asymmetric information using a bilateral bargaining model. It tried to show how memberships in cooperatives affect the bargaining power of small-holders. A regression analysis reveals that cooperative membership positively and significantly affects the bargaining power of small-holder banana growers. The result also confirms that access to central market price information and past trade relationship enables farmers to stick to their initially asked price while they are less committed to their initially asked price when the merchant speaks out the transaction price first.

Consumer perceptions towards introducing a genetically-modified banana in Uganda

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The introduction of a genetically modified (GM) banana in Uganda is not without controversy. It is likely to generate a wide portfolio of

concerns since the technology of genetic engineering is still in its early stages of development. The purpose of this paper is to show how consumers feel about GM banana biosafety risks and the potential challenges for marketing the product. The study analyzes socio-demographic, awareness and attitudinal characteristics of banana-consuming households that would affect introduction of a GM banana in Uganda. The study was conducted in different regions of Uganda, where cooking banana (matooke) is produced and consumed, including urban areas that are big consumers of bananas. Implementation of this procedure allowed us to capture the heterogeneity in preferences across different population segments. The survey sample was drawn using a multistage sampling procedure from the major banana-consuming regions in eastern, central, and southwestern Uganda. Respondents were stratified into rural and urban consumers of matooke and received extra information about the GM banana. A total of 440 households were selected from current village listing for the survey, of which 160 households were from urban areas. The results reveal that consumers trust community local leaders and public agricultural related organizations in controlling and regulating production and release of GM food and crops. Three consumer perceptions were identified: benefit, food, and environmental and future health concern. A comparison of consumer characteristics and consumer perceptions and attitudes yielded interesting results which differed significantly between rural and urban consumers. Consumers in rural areas are more likely to accept introduction of a GM banana than their urban counterparts regardless of whether they grow or buy bananas. Urban consumers are more concerned about likely long-term health effects. The survey results provide information for decision making regarding biotechnology and biosafety regulations for GM bananas in Uganda.

Banana market: Africa obliged to innovate

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Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Montpellier, France

African bananas need access to the European Union (EU) market, where they account for 11% of banana consumed. Only dessert bananas are shipped from Africa even though it is one of the main cooking banana production zones and the European market imports more than 60000 tons of this type of fruit each year. Only Uganda is on the list of the five main suppliers, with tiny quantities amounting to approximately 1000 tons. Practically the whole of the cooking banana/plantain market is supplied by Latin America, with Ecuador and Colombia in the leading positions. As regards dessert banana, Cameroon and Côte d'Ivoire long monopolised African exports to the EU. Ghana has been a new West African exporting country since 2006. Production, export and transport of banana are strongly concentrated in these three countries. The chains are run by a small number of groups of operators, with strong links to European importers. The three countries have mainly one target i.e. the EU market. So far, the latter has been more profitable than other nearby markets (the Mediterranean, the Middle East and Africa). Furthermore, African supplier countries still have very preferential ACP access to the EU for the moment. At the end of December 2007, a few days before the deadline, a major crisis was avoided at the last minute when the main ACP exporting countries partially ratified Economic Partnership Agreements (EPAs). These now govern trade relations between the EU and ACP countries. Since 1 January 2008, bananas from the latter enter the EU under the 'duty free, quota free' (DFQF) regime. Failing to sign EPAs would have led to the levying of EUR 176 customs/per ton of ACP bananas imported, that is to say an annual EUR 160 million on the basis of 2006 figures. Even the supplier countries considered as being well-positioned in terms

of competitiveness such as Cameroon and Côte d'Ivoire would only have survived these payments with difficulty. Indeed, the difference in treatment as regards customs tariffs between the dollar supply zone (Ecuador, Colombia, Costa Rica, Panama, etc.) and the ACP zone balances competitiveness levels. Nevertheless, it will be hard for the very notion of preferential treatment to stand up to the wave of market deregulation and especially that of the European banana market. Indeed, this major tariff advantage for ACP suppliers is called into question by producers in the dollar zone. The African sectors are therefore obliged to find a way of improving their competitiveness at the same rate as the seemingly inexorable fall in the customs dues applied to dollar bananas. Productivity is in fact fairly low in the Latin American production zones and even a marginal improvement could change the terms of trade, given the production volume in these zones. Today, one of Africa's main advantages over its competitors is its closeness to the European market. Intermediate freight-related costs have increased considerably in recent years and have had a strong impact on the profitability of the dollar banana industries. In all cases, the Africa banana sector must resolutely undertake innovations in both production and on markets in order to remain one of the main suppliers of the EU, the leading international market. Essential for banana, it is also a necessity for other fresh export produce such as pineapple and mango that benefit from the virtuous circle of banana (regular transport, large volumes of freight, trade networks, etc.).

Supply chain management and public and private participation in banana in Tamil Nadu, India: status, problems and suitable policy measures

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India is ranked the second largest producer of fruits in the world. Banana is one of the important fruits in India and occupies about 4.24 ha (10.5% in world share) with a production of about 17.4 % in world share in 2005-06. Banana is exported to Middle East, Gulf, Russia, Ukraine and other European countries from India. In Tamil Nadu, area under banana was 0.95 ha with a productivity of 49 tons/ha in 2005-06. Banana being a highly perishable fruit, it is to be marketed within a short span of time. Therefore, a systematic package of practices in banana production will greatly improve productivity and processing to produce value added products and enable the growers to reap maximum benefits. Similarly an efficient marketing system is an important means for raising the income levels of the growers in one hand, and increasing the consumer satisfaction in the other. Considering the hiatus between high production and relatively low exports with domestic consumption showing no distinct off-take, the culprit is squarely laid on the enormous wastage in post-harvest. It is therefore, highly essential to grade the produce brought to the market on scientific line to get remunerative prices. This paper looks into these aspects of supply chain management in banana. The present study attempts to examine the market functions, marketing practices and value chain from the farmer to consumer in terms of handling, value addition, packaging, marketing cost, marketing margin and price spread for banana in Coimbatore, Tiruchirapalli and Thoothukudi districts of Tamil Nadu in India. The results indicated that the poor market efficiency and little farmers share in consumer price was noticed when the number of intermediaries involved in the channel increased, because of higher total marketing cost.

Parallel Session 3: Supply

Venue: Peponi Room

Time: 1400–1615

Banana production characteristics and performance in Uganda

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The highland cooking banana (spp. AAA-EA group) is the most important crop in East African Great Lakes region. In Uganda, production has expanded and productivity increased in the country's southwest and declined in the central region where the crop has traditional roots. Analyzing crop characteristics and performance was imperative to elucidate the factors that have contributed to this change. Performance analysis helps to inform possible investment policies and strategies in the banana sub-sector for both regions. The study was carried out in central and southwest regions of the country, which have divergent production constraints and opportunities. Changes in economic conditions appear to have contributed to the shift in banana production from the central to the southwest. Specifically, increase in non-farm income in the central region reduced farmers' needs for cash income generated from farm production. On the other hand, high food prices increased farmers' needs to rely on own farm production for household needs. There was shift in resource allocation in favor of crops most suited to satisfying household food needs (e.g. sweet potato, cassava and beans) against crops that appear to be more profitable (e.g. bananas) when valued at farm gate prices. In the southwest, farmers adopted technologies and crop activities that were relatively more labor demanding, but more rewarding in terms of cash benefits. Specifically, bananas were adopted because they satisfied both the cash needs and food requirements of the farmers. However, a significant proportion of land (not suited to banana production) is committed to millet production to supplement bananas in terms of food security.

Market-led banana technology and adoption in central and western districts of Uganda

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Eighteen demonstration sites were selected in six districts of Uganda known for growing bananas. Two districts were chosen from the following production categories; Low productivity (Luwero and Mpigi); Moderate productivity (Masaka and Rakai) and high productivity (Mbarara and Bushenyi). In each district three demonstration sites were established to show the effect of high input and low input farmers' practice in banana production. Technologies selected for promotion were those already on shelves and included clean planting materials, use of organic and inorganic fertilizers, mulch and proper crop husbandry practices. In collaboration with private sector, commercial entrepreneurs involved in both local and export banana trade were identified and formed part of the study team, providing an assurance of buying the bananas with right quality and in economical volumes. After one year, fields under rehabilitation showed a significant improvement in the performance of banana plants and banana bunch weights progressively increased from an average of 10 kg to more than 35 kg.

While newly established gardens using tissue culture plants quickly established and within a period of nine months, began to flower. The assurance given to farmers by the buyers stimulated their adoption rate and were able to increase productivity by harvesting two bunches of approximately 45 kg/mat/year. There was an increased demand for agricultural input and thus stimulated investment in rural agro-input stockists. Because of increased production and farmers getting more organized in groups, there was an increase in the number of buyers contacting the farmers than before. Farmers through their executive members improved their management and negotiation skills, and were able to get better prices. It was therefore concluded that, banana production is still possible in the traditional growing districts and that technology dissemination among farmers should always consider buyers and intermediary players within the crop product value chain.

Socio-economic impacts of adoption of new banana varieties on livelihoods of farmers in Kagera region, Tanzania

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²*International Food Policy Research Institute (FPRI), Washington, USA*

In the last two decades, the introduction of new banana cultivars into the banana-based farming systems has increasingly become one of the strategies to revive declining banana production due to pest infestations and low soil fertility. This paper presents the status of adoption and socio-economic impacts of the new banana cultivars on farmers' livelihoods in Tanzania. Both qualitative and quantitative data were collected through use of participatory rural appraisal and structured household questionnaires. The study was conducted in Bukoba, Misenyi and Karagwe districts of Kagera region. Data was analyzed using descriptive statistics, Logit and Tobit regressions and instrumental variable methods. The adoption rate of new banana cultivars was 28.5% and varied by agro-ecological zone, farms' and farmers' characteristics, and the extent of dissemination of banana planting materials. The data revealed that where production constraints predominate, the adoption rates were relatively high compared to areas of low pressure of constraints. Rich-resource households had higher adoption rates than poor-resource households. Age of the household heads, area cultivated per household, ownership of livestock, value of household assets and number of banana mats per household were significantly different between the adopters and non-adopters. The results further revealed that the new banana cultivars had positive impacts on banana bunch yield, food security, increased quality of banana juices and brews, incomes from selling banana bunches or juice/brew, house-sheds and on social relationships. Other impacts of new banana cultivars included reduction of the area planted with root and tuber crops, gained social values, improved social relationships among farmers, strengthened women groups and access to assistances and informal loans. However, there is need to strengthen the means of utilizing the potential benefits accrued from introduction of the new banana cultivars for better livelihoods of farmers.

An economic assessment of plantain production in River state, Nigeria

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This study examined the profitability and resource-use of plantain production in Nigeria, using River State Nigeria as a case study. The study sample respondents comprised of randomly selected 80 plantain producing households. Gross margin and regression analysis were used to analyze farmers' plantain production data. The result showed that plantain farmers in the study area are old and of poor literacy status. Gross margin per hectare of plantain averaged ₦34317 while net farm income averaged ₦31267. Rate of returns on investment and rate of return on capital invested were found to be 173 and 73%, respectively implying that plantain production is a profitable and viable venture. The OLS regression estimate showed that labour did not significantly influence plantain output. However land and planting material: sucker are shown to enhance plantain production. Theft, bad roads, poor producer prices and high cost of fertilizer were identified as major constraints to plantain production. The study therefore recommends subsidy on fertilizer, group marketing of plantain by farmers via their cooperative, provision of basic rural infrastructure (road) and the rehabilitation of existing ones. If effected, these recommendations will better rural life and attract the youth to these areas for increased plantain production.

Determinant of technical, allocative and economic efficiencies in plantain production industry in Ondo state, Nigeria

J.O. Bifarin¹, T. Alimi², O.I. Baruwa² and O.C. Ajewole³

¹Federal College of Agriculture, Akure, Nigeria; ²Obafemi Awolowo University, Ile-Ife, Nigeria; ³University of Ado-Ekiti, Ado Ekiti, Nigeria

The objective of the study was to determine the technical, allocative and economic efficiencies of plantain farmers in Ondo-State. This is because efficiency is a very important factor of productivity growth. In an economy where resources are scarce and opportunities for new technology are lacking, inefficiency studies will be able to show that it is possible to raise productivity by improving efficiency without developing new technology or increasing the resource base. Multi stage sampling technique was used to select 276 plantain farmers. Data was analyzed using the stochastic parametric technique. Findings showed that technical efficiency indices varied from 20% to 87% with a mean of 61%, allocative efficiency from 14% to 83% with a mean of 57% and economic efficiency from 3% to 67% with a mean of 35%, thus indicating that there was great potential for cost saving through improved efficiency at the existing technology and the resource base in the study area. Results of the estimated coefficients indicated that age is significant and has a positive sign for technical and economic inefficiencies; and extension service was negatively correlated with technical inefficiency. These results suggested that if more resources were invested in extension services, there would be improvement in efficiency.

Business approaches for rural wealth creation: how fixing output market failures for poor matooke farmers in Uganda has enabled them to mobilize capital for investment

E. Kibugu

Technoserve, Kampala, Uganda

To improve productivity and income earning ability by the rural poor, major investments in agricultural technologies are required for Africa's small-holders. Where will the money come from? TechnoServe's work with small-holder matooke farmers in Uganda has proved that poor farmers can fund substantial technology investments, but only in the context of trusted and functional output markets. However, past market failures call for innovation in order to address these failures. (i) History of market collapse creates hesitation to take on risk. Integrated business solution: *Develop trust in markets*. (ii) Inefficient value chains minimize value of production. Integrated business solution: *Build Functional Markets*. (iii) Farmers lack power to capture reasonable share of value. Integrated business solution: *Profit from the market*. (iv) Farmers unable to access finance or to access inputs even when money is available. Integrated business solution: *Reinvest profit in production*. (v) Donor subsidies create dependence. Integrated business solution: *Get out*. TechnoServe has applied this model to build a profitable banana industry, which enables investment in production including improved planting materials and good orchard management. Since 2006, TechnoServe has directly supported 3,100 to market 12,000 metric tons of high quality matooke, earning them over USD 1.5 million.

Small-scale banana growers prosper in Kenya in a transformed value chain

S. Harris and H. Kinyua

TechnoServe Kenya, Nairobi, Kenya

Banana production and marketing in Kenya is dominated by very large numbers of small-scale subsistence farmers each growing small quantities of dessert banana. These small farmers all sell their surplus production into numerous brokerage chains that add considerably to the consumer price but actually add very little value in terms of quality and consistency. Banana producers receive a small fraction of the end price paid by consumers and cannot afford to invest in appropriate input supply that would transform their productivity and profitability as growers. TechnoServe has developed a new approach to the banana system that incorporates several factors in operation at the same time i.e. i) organized, trained and focused banana growers groups, ii) product aggregation and standardization that allows for economies of scale and enhanced quality delivered to the consumers, iii) direct market linkages between the growers groups and larger, more organized wholesalers in the urban markets and iv) access to credit and investment in improved input supply and appropriate irrigation technology. As a direct result of these production and marketing innovations, TechnoServe-assisted banana growers are now enjoying much higher prices for their fruit, doubling and even tripling of productivity and income, and greater demand in their marketing channel. These banana growers now see banana as an important cash crop rather than just a subsistence crop with occasional cash sales.

Parallel Session 4: Processing

Venue: Likunda Room

Time: 1400–1600

Musa processing businesses: their contribution to rural development

C. Staver¹, R. Junkin², W. Flores³, I. Gonzales⁴, S.O.S. Akinyemi⁵, G. Ngoh⁶, D. Banda⁷, M. Byabachwezi⁸, C.K. Narayana⁹, N. Masdek¹⁰, A. Arganosa¹¹

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Processing is often proposed to solve seasonal surplus of bananas and plantains, to reduce losses from spoilage and undersized fruits, and to increase farmer incomes. To examine the contribution of small agro-industry to rural development in banana producing areas, study teams from nine countries in Asia, Africa and Latin America categorized current processing businesses by type of product, size of firm and technology used, determined their strengths and weaknesses, and surveyed diverse categories of business service providers used by the processing businesses. Country teams met in October 2006 in Manila, Philippines, to draw conclusions across regions. In the nine countries less than 5% of dessert bananas, about 24% of plantains and between 30-40% of cooking bananas produced are processed. Common products include chips, dried sweet bananas, beer, wine, juice, sauce, baskets and mats from banana fiber, and banana-flavored milk products. The study concluded that although processing enterprises play an important role in the livelihoods of thousands of poor households, their significance as tools for rural development is limited by a number of factors, including seasonality of production, price competition from the fresh fruit market and quality issues. Limitations can be overcome to some extent by systematic and sustained investment in the business services environment accessible to rural populations and in the management capacity of micro and small businesses.

Banana juice production in South Africa

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The banana cultivars grown in the rural areas of South Africa are Pisang Awak (AAB group) (70%) and Cavendish types (AAA group) (30%), in contrast to only Cavendish type bananas in the commercial banana growing areas. Pisang Awak is a hardy banana cultivar that is currently not grown for commercial purposes but as a domestic fruit for home use on small plots and as a fencing shrub. It does not seem to require expert commercial farming skills to cultivate and requires very little in terms of care as compared to established banana cultivars currently on the market. This makes it ideal for exploitation as a commercial crop by rural communities in these areas, however, until recently this potential was overlooked and the fruit was mostly wasted. Since the establishment of a banana juice factory, this cultivar is generating an income. Although Pisang Awak is a lower yielding cultivar, it is a very good juice banana and up to 50% juice concentrate is extracted from the fruit in comparison to the 15%

juice from the Cavendish types. The project is aiming to evaluate several high yielding juice bananas and also to provide farmers with at least 10000 plants in two rural banana growing areas. Technology transfer on banana production is being done, and cooperatives in selected areas to collect banana fruit and transport to ripening rooms and factory are being established. In a later stage, a pack house will be built. This industry can be expanded immensely as the market for banana juice exists and is hardly touched by the present juice production. Because of the organization of cooperatives in different areas, farmers do not require 30 ha or more to create an income producing business. Even with a few hectares of bananas and being part of a cooperative, the farmer will be able to create a good income and prosper.

Overview of *Musa* processing businesses and their support environment in Cameroon

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Banana and plantain (spp.) are staple food in southern provinces of Cameroon and surrounding countries where they play a significant role in the diet of the population. In 2005, a team made of an agronomist, a food technologist, a business advisor and a businessman carried out a study in Cameroon in order to identify the strengths and weaknesses of small businesses as well as their links to providers of different kinds of service and information to solve their problems and expand their production and sales. The investigations focused on processing units dealing with banana or plantain chips, dried bananas and traditional alcohol production. They were described according to the type of product, size of firm and technology used. Some of their support service providers (financial and technical assistance as well as equipment providers) were also characterized. The unprocessed and processed are a source of income in many families or businesses that stimulate agricultural activities in the region, thus providing source of income to the farmers and members of farmer associations, contributing to rural development. The Cameroon small-scale businesses potentially contribute to the improvement of livelihoods.

Musa processing businesses and their support environment in Tanzania: their role in poverty alleviation to rural communities

S.R.B Mgenzi¹, I.M. Mshaghuley¹, C. Staver² and J.M. Nkuba¹

¹Agricultural Research and Development Institute (ARDI) -Maruku, Bukoba, Tanzania; ²Bioversity International, Montpellier, France

Banana is one of the food crops becoming important in contribution of household income. There are minimal efforts in developing the marketing of bananas and their products in Tanzania. Marketing of bananas is among factors that determine the existence of banana fields and types of bananas cultivated by farmers. Expansion of banana cultivation to the marginal areas is limited by the low value of bananas. Processing bananas into long shelf-life bi-products has started in places where there is significant surplus of bananas produced to minimize wastage of bananas and value adding. Major banana products made locally by farmers are juice, beer, distillates, pastries etc. Products like banana wine and confectioneries were developed by scientists and the recipes availed to farmers through

training. Other products from bananas include handcrafts such as table mats, handbags, envelopes, postcards, wall pictures and hats from banana sheaths. Utilization of bananas in Tanzania is limited to a small range of products. Brewing that is a second major use of bananas account for 30% of utilization of bananas. The remaining 8% is distributed in fresh bananas sold outside banana production areas. Selling of processed bananas account for 5%, while fresh sold bananas account for 95%. processing businesses get raw materials within their locality. Specific cultivars of bananas are needed for certain products. Different banana types produce different qualities of products, and prices paid for bananas depend on the type in question. However, prices are market dependent. Service providers in processing are limited and the industry still needs a lot to become beneficial to banana producers in Tanzania. The majority of Tanzanians trade in fresh and dessert bananas which are highly perishable as compared to processed products. Improvement of products and quality control needs to be emphasized by all banana stakeholders in the country. The good news is that there is new planned project on bulk production of banana juice that will use more than 40% of beer bananas produced by farmers.

Small-scale *Musa* processors in Nigeria: their potentials, prospects and challenges

S.O.S. Akinyemi¹, C. Staver², I.O.O. Aiyelaagbe³, A.A. Kintomo¹ and S.O. Babalola¹

¹National Horticultural Research Institute, Ibadan, Nigeria; ²Bioversity International, Parc Scientifique Agropolis, Montpellier, France; ³Department of Horticulture, University of Agriculture, Abeokuta, Nigeria

Scientists have produced many banana and plantain cultivars that are resistant to various pests and diseases. In the next 10-20 years, they could breed many more cultivars with high yielding potentials. While looking forward to this, there is need to know the impact of past efforts on the livelihood of end-users. To this effect, a study was designed to help analyze the challenges of promoting small rural processing enterprises and strengthening the support system which together lead to more value from banana and plantain and greater rural well being. The study revealed that processors have found ways of utilizing most cultivars developed. Processing of spp. into different forms and shape of chips is the most common small agro-processing business in Nigeria. Other products include: flour, soap, dodo-ikire, gin, wine, weaning foods, beer and malt, breakfast cereals and puree. It was further discovered that most small scale processors do not make use of credit facilities available to them. They neither keep record nor think of expansion. There is need for them to come together as cooperatives and take advantage of some facilities and services. Different agencies set up to assist them need more of public awareness. It is obvious that processing businesses in Nigeria have employed many people regardless of sex and age, with chances of absorbing more. It has contributed in many ways to social development. However, with increasing population, producers, processors and scientists still need to stay on the drawing board and be proactive as regards research for development activities on .

A study on the analysis of *Musa* processing businesses and their support environment in Malawi

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The study on the analysis of processing businesses and their support environment in Malawi was carried out in 2005 by a national team with various expertise and experiences. Results revealed that there are several informal -related businesses such as wine, snack, handcraft and paper making, and drying of ripe bananas. The manufacturing industry uses banana as a flavoring ingredient. However, these are being faced with several challenges; hence the need for support from other key players like financial, technology development and training institutions and organizations that supply inputs for production and packaging. The emergence of small-scale processing businesses have seen an improvement in the rural livelihoods as evidenced by the fact that most of the groupings are moving towards being more organized and self sufficient in their operations, by owning/constructing their own buildings and purchasing of modern equipment. Most of the groups/individuals involved in this will attain economic self sufficiency within a short period of time. The study played a very important role in defining follow-up actions whose implementation would provide a quicker break-through to growth of the sector. Proposed actions like the formation of a local banana network, holding of a stakeholders' meeting, scrutinization of the existing policies, and development of more recipes and the improvement of packaging/labeling materials are seen as the most useful actions whose implementation can make a difference to the current status. However, the execution of these has not been easy especially because of limited availability of funds from various partner institutions. In line with the recommendations, various partners who participated in this study have made tremendous progress. The Department of Research has finalized the screening work on identifying suitable cultivars for specific utilization in wine, juice and confectionary making. In collaboration with DEMAT, more groups have been formed and trained in banana wine production. The Department of Research has also worked in close collaboration with the University of Malawi in promoting and developing recipes for different banana based confectionaries.

Posters

Venue: Meister Tent

Time: 1700–1800

Market Segments

M-MS-1

Inter-market and seasonal pricing efficiency for banana marketing in Nigeria

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The study investigated inter-market and seasonal pricing variation and efficiency in banana marketing in Nigeria against the backdrop of exploitative practices of middlemen. Secondary data on average monthly banana retail price in urban and rural markets between 1998 and 2005 were used for the study. Primary data on the average selling price of banana for 2006 were also used. The study described the seasonal pattern of banana, analyzed the inter-market variation in its prices and examined its seasonal price rise and price efficiency. The analytical tools used include descriptive statistics, price index number and regression analysis. The study revealed that the seasonal price rise exceeds storage cost but the difference is minimal. It was further found that with empirical analysis, there was price efficiency in banana marketing in Nigeria during the study period. The effect of kilometer separation between market-pairs on the price differences is significant. Thus if the transport cost reduces the inter-market variation will be reduced and movement of banana between markets will be facilitated.

M-MS-5

Factors affecting utilization of cooking banana among households in Oguta area of Imo State, Nigeria

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The study investigated factors affecting utilization of cooking banana among households in Oguta area of Imo State, Nigeria. Data was collected from 84 randomly selected respondents from six communities in the study area, who were administered structured questionnaires. Data analysis utilized descriptive and inferential statistics. Findings showed that utilization was generally high and respondents indicated reasons such as sweetness, cheapness, alternative source of food, availability. Correlation analysis revealed that gender and age of extension contact showed negative relationship with utilization. Awareness campaign about the importance of cooking banana should be intensified.

M-MS-6

Rural households' perception and preference for selected *Musa* spp. in Niger Delta area of Nigeria

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The importance of spp. to rural households in the Niger Delta area of Nigeria cannot be overemphasized. Several cultivars of the crop exist in the area, as such the area is often known as the home of banana and plantains. In recent years, improved cultivars were introduced, with great implications for increased income. However, the reality of the introduction of improved spp. cultivars is that adoption is generally low, due to various documented reasons. This study therefore is an appraisal of rural households' perception and preference for selected spp. in Niger Delta area of Nigeria, with a view to finding solutions for better adoption.

M-MS-2

Comparative analysis of urban and rural households' preferences for banana and plantain consumption in the Niger delta area of Nigeria

O.M. Adesope¹, A.C. Agumagu¹ and O.A. Angba²

¹Department of Agricultural Economics and Extension, University of Port Harcourt, Rivers State, Nigeria; ²Department of Agricultural Economics and Extension, University of Calabar, Cross River State, Nigeria

Plantain and banana are two common fruits consumed by all and sundry in the Niger delta area of Nigeria. This study compares urban and rural households' preferences for banana and plantain consumption in the Niger delta area of Nigeria. Data for the study was collected through eight focus group discussions. It was found that households in the urban and rural areas have similar preferences in banana and plantain consumption. Based on the findings of the study, policy recommendations were made.

Supply

M-SU-1

Analysis of risk in plantain and banana production in Nigeria

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Risk of pests and vectors especially in the case of black sigatoka disease (*Mycosphaerella fijiensis*) remains a major constraint to plantain and banana production in Nigeria. The management of these diseases in plantain and banana production requires biological, chemical and economic knowledge. The economic aspect which is the basis of this study deals with risk management in plantain and banana production. Therefore this study examines the production risk problems facing plantain and banana farmers in Nigeria. Using the Target- MOTAD model, we determined the set and level of production activities that optimize plantain and banana production returns under

risk in the study area. Our findings revealed that improved hybrid plantain and banana cultivars are less risky than the local cultivars, and that inadequacy of capital is one of the major problems facing plantain and banana farmers in the effort to use improved hybrids generated by IITA.

M-SU-2

Increasing production of banana and plantain among women and the youth in agriculture

L. Sasu

Development Action Association, Ghana

The annual growth rate of banana in Ghana is 7.5% whilst that of plantain is 5%. Ghana has a total land area of 23,854,000 ha, forest area as percentage of land area is 27.8% and a population of 20,471,000 of which 23% are rural. Of the rural population, 60% are farmers, and among the farmers 50% are women. Therefore male to female ratio engaged in agricultural production is 1:18. Plantain and banana are cultivated in the forest agro-ecology zone of the country under rain-fed conditions, mostly by small to medium-scale farmers, using traditional technology for domestic market. Production of plantain is currently about 2 million metric tons per annum and prevailing yield is approximately 7.8 metric tons/ha, close to the potential yield of 10 metric tons/ha. It has been the policy of MOFA to increase production of banana and plantain through planting material multiplication, cultivar, improved farm management and marketing to attract other farmers. Women and youth farmers play an active role in harvesting and marketing of banana and plantain. The big plantain called 'Apentu' is cultivated in the major season i.e. May-June and takes nine months to mature. 'Apen' (small size) is planted during the minor season. This is to withstand the wind in April-May which blows and uproots tall plants. Annual depletion of forest has impact on banana and plantain production in Ghana. Plantain and banana are used for intercropping to nature trees, for medicinal purposes, peels are used to make soap and dry leaves for fermenting cocoa beans.

M-SU-3

Knowledge, attitude and constraints as correlates of post-harvest losses among plantain farmers and wholesalers in southwestern Nigeria

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Post-harvest losses are a constraining factor in plantain production; as such increases in yield due to advances in technology brought about by research do not make any significant impact on the economy of small-scale farmers. This study examined the influence of knowledge, attitude and constraints on post-harvest losses among farmers and wholesalers in southwestern Nigeria. A combination of multi-stage random and snowball sampling techniques were used to select farmers and wholesalers, respectively in Edo, Ondo and Osun states. Primary data was collected through the use of structured questionnaires that were pre-tested and analyzed using frequency counts, percentages and t-test. The results show a significant difference in post-harvest losses between farmers and wholesalers, with the wholesalers having higher losses. Similarly, knowledge and constraints were significantly correlated to post-harvest losses among

farmers and wholesalers, while correlation with attitude was non-significant. The findings presuppose that there is need for knowledge about post-harvest activities among farmers and wholesalers.

M-SU-4

Farmers earn more money when banana and coffee are intercropped

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In Uganda, coffee and banana form the economic base for the majority of small scale farmers. Uganda is the largest banana producer and 2nd largest coffee producer in Africa. Both crops are predominantly grown as monocultures. However, banana-coffee intercropping is frequently observed, especially in highly populated areas. This study characterized banana mono-cropping, coffee mono-cropping and banana-coffee intercropping systems in seven Ugandan districts, in order to assess the profitability of mono-cropping and intercropping systems. Information on resource use (i.e. external inputs, labor, and land) and farm gate prices were obtained through structured farmer interviews in 2006-2007. Crop production, soil fertility, pest and disease pressure, and management practices were quantified at the plot level through field visits. This study showed that banana-coffee intercropping is much more profitable than banana or coffee mono-cropping. In Arabica coffee growing regions (Mt. Elgon area), annual returns/ha averaged USD 3,421, USD 2,092 and USD 1,552 for intercropping, banana mono, and coffee mono systems, respectively. In Robusta coffee growing regions (Masaka, Bushenyi), annual returns per hectare averaged USD 1,576, USD 915 and USD 1,293 for intercropping, banana mono, and coffee mono systems, respectively. In the Mt. Elgon area, the large total revenue was achieved through a 9.1% increase in total/ha Arabica yield (i.e. parchment) when compared to coffee mono-cropping, while banana yields only decreased by 17.4% compared to banana mono-cropping. In western Uganda (Masaka, Bushenyi) the total revenue increase when moving from mono to intercropping systems was less spectacular, because Robusta coffee yields (i.e. kiboko) reduced by 31% and banana yields by 25% per hectare, when compared to mono-cropped systems.

M-SU-5

Plantain cultivation in Nigeria: a review of its production, marketing and research in the last two decades

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Nigeria is one of the largest plantain producing countries in the world. Despite its prominence, the country does not feature among banana/plantain exporting nations. A study was conducted to review its production systems. Findings revealed that the country's output has doubled in the last 20 years. Production, which is concentrated in the southern part of the country, still remains largely in the hands of small-scale farmers who over the years have ingeniously integrated it into various cropping systems. Production is male dominated while women essentially handle marketing. The inadequate knowledge of improved cultural practices of the crop on part of the

farmers, inefficient extension service systems and skewedness of specialization in area of research are some reasons why yield potential per land area of plantain is still low in the country. The contribution of plantain production to the income of rural households in major producing areas in Nigeria has increased tremendously in the last few years. Unlike cassava and some other starchy staples whose demand tends to fall with rising incomes, demand for plantain increases with increase in income. With the potentials for industrial processing of plantain that has recently been taken up, and the increased interest in production by small and large-scale farms in the country, it is believed that the country will continue to be one of the world's highest producers of plantain, however, provision of social amenities, diseases/infestations and seasonal shortages need special attention on the part of the government and scientists, respectively.

M-SU-6

Banana cultivars, uses, production constraints and market opportunities in Malawi: banana baseline survey

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¹ICRAF, Lilongwe, Malawi; ²IITA/SARRNET, Lilongwe, Malawi

Banana (spp.) is one of the major crops in Malawi and plays a very important role in supplying carbohydrates, vitamins and minerals to the local people. The crop is also a very important source of income to small-holder farmers. In 2004, the International Institute of Tropical Agriculture (IITA) in the framework of Regional Centre for Southern Africa/ Rural Livelihood Project with funding from United States Agency for International Development (USAID) carried out a banana baseline study in Nkhata Bay and Mulanje districts in Malawi. The specific objectives were to identify cultivars grown, determine the uses of these cultivars, find out production constraints and market opportunities for banana in Malawi. In Nkhata Bay banana was the second most important crop after cassava while in Mulanje it came third after maize and cassava. Banana farmers in Mulanje were getting almost twice as much income as their counterparts in Nkhata Bay. Cavendish banana cultivars such as 'Williams', 'Mulanje', 'Kafupi' and 'Kabuthu' were major sources of cash to small-holder farmers in the two districts. The farmers used bananas for dessert and cooking. There was little processing and product development. The major constraints to banana production were diseases, pests and technological problems. The major diseases included Fusarium wilt, banana bunchy top virus and black sigatoka, while banana weevils and nematodes were the major pests. In most cases farmers uprooted or cut down their bananas, as they did not know the appropriate pest and disease control technologies. Lack of appropriate banana production technologies was also a major constraint. Market problems such as pricing and transportation were mentioned among the main constraints. Forty percent of farmers in Mulanje ranked low prices as a major production constraint, compared with 30% in Nkhata Bay. Farmers in Nkhata Bay were selling banana at lower prices than in Mulanje. Transportation was also a major constraint in Nkhata Bay, with farmers having poor access to modern methods of transportation, compared with their counterparts in Mulanje. Market opportunities, however, were still there because the markets were not saturated as evidenced by trends in demand and supply. Demand for banana was still increasing. There was high concentration on dessert banana, but demand for cooking banana was increasing. Processing could also open up opportunities to farmers constrained by transport, perishability and low prices. In Nkhata Bay, improvements in transportation were another source of better marketing opportunities.

Farmers could increase their marketing opportunities and profits if they formed marketing associations or increased banana volumes to warrant hiring of vehicles.

M-SU-7

Transaction costs and small-holder farmers' participation in banana markets in Burundi

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Markets and improved market access are of critical and immediate importance to rural poor households as a prerequisite for enhancing agriculture-based economic growth by improving the competitiveness of the farming enterprises and improving rural incomes. Despite this, participation of small-holder rural-based farmers in domestic markets in most developing countries is still low due to a range of constraints. One of the important constraints faced by small-holder farmers is linked to poor market access resulting from high transactions cost and market risks. This study assesses the role of transaction costs in participation of small-holder farmers in banana markets in Burundi. The small-holder farmers' discrete decision of whether to participate in banana markets is separated from the continuous decision of how much to sell or buy conditional on participation. An endogenous switching regression model that corrects for selectivity bias caused by the exclusion of unobservable factors affecting both discrete and continuous decisions has been applied. Results indicate that access to market information, household size and time taken to reach the market (which proxies market access in terms of proximity and quality of road infrastructure) increases the probability of participation by sellers, while land holding size, possession of some means of transport such as a bicycle increases banana quantities transacted, conditional on participation. Access to information is crucial in reducing fixed transaction costs which influence market entry while household characteristics such as size of the household and land holding size are crucial as they comprise productive assets that enable a household to produce marketable surplus large enough to offset transaction costs of trading. In the continued absence of public investments to improve market access in most developing countries, the policy challenge is to identify institutional innovations that reduce a range of transaction costs and increase small-holder farmers' competitiveness in domestic markets.

M-SU-10

***Musa* hybrid technology transfer by Nigerian Agip Oil Company Limited-Green River project (NAOC-GRP) in Niger Delta region, Nigeria**

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Banana and plantain are major food crops in Nigeria. This paper presents tangible efforts and contributions made by multi-national oil company (Nigeria Agip Oil Company Limited-Green River Project NAOC-GRP) to support the development and transfer of banana-plantain- based technologies developed by IITA for the past few

decades. The objective is to establish a sustainable banana and plantain production system through promoting crop management packages that optimize and stabilize the production systems and are compatible with farmers' practices. The geographical area of coverage is within the oil rich Delta region of Nigeria. Key issues under consideration include acquisition, development and dissemination of banana-plantain-based technologies to growers, seed delivery and post harvest services, turning farmers into small- and medium-scale agribusiness folks and market-oriented agricultural advisory services (MOAAS).

M-SU-14

Presidential Initiative for Banana Industrial Development (PIBID): status of banana production, marketing and utilization in Uganda, the case of Bushenyi district

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Presidential Initiative on Banana Industrial Development (PIBID), Kampala, Uganda

The first objective of the PIBID was the establishment of benchmarks for starting a rural based pilot banana processing industry in Bushenyi district. To start with, a rural rapid appraisal (RRA) was conducted, where data was collected using a qualitative participatory approach including focus group discussions and key informant interviews. A case study design was adopted to identify and examine key factors driving rural women's and men's participation (or lack of it) in the export-oriented banana industrialization process. Thereafter a baseline survey was conducted to establish benchmarks in the following categories: socioeconomic status of farming community's households; food security and banana value addition status, banana production with respect to land use, production trends, agronomy, agroforestry and water requirements. Data was collected using a questionnaire consisting of six parts: household characteristics, food security and utilization, banana production, banana marketing and utilization, banana product development and value addition, and microfinance access. A three stage stratified sampling was used according to sub-county, parish and household. Ten out of 56 sub-counties were selected. From each sub-county four parishes were chosen and from each parish 14 households were sampled. The RRA results showed that women's sentiments towards the banana industrialisation initiative were linked to concerns for household food security and increased work burden out of which they feared they may not realize independent dividends. On the contrary men were skeptical due to their distrust for government policies out of previous experiences. The questionnaire tool revealed farmers' dependency on matooke for food security and nutrition, with no other significant food source. The nutrition status of children particularly between 6-12 months was below the recommended standard. The predominant processing activity involved beer cultivars and these included local beer, juice and wine, and some pancakes. Matooke was virtually traded as a fresh commodity. The land tenure in the area is customary or freehold and is predominantly under matooke cultivation. Farmers generally preferred increasing farm productivity to increasing acreage. There was one peak of annual banana production. Over 37 cultivars are grown in Bushenyi, although only five were listed under the most preferred cultivars. Key quality attributes included bunch compactness, tolerance to pests and diseases, size of fingers, taste, bunch size, and the most determining, market preference. Majority of respondents use locally available inputs, with virtually any agrochemicals, where tree planting was practiced, it was limited to eucalyptus (95%), and irrigation was not

practiced. There were many perceived factors affecting marketing of matooke but predominantly lack of value addition and low farm-gate prices, where the farmer received only 44% of the market share, with the rest going to middle men were reported. Over 50% of banana harvested per month is consumed by the respondent households. There was also wide fluctuation in farm-gate prices between the peak and low production season (between 800-4000 U. Shs, for large bunches). Most common (41%) financing of production activities is through local savings and credit co-operative societies, which were the easiest to access. Loans were otherwise only accessed against land or salary. Either way, only about 50% of the loans obtained are used to boost banana production. Therefore PIBID is setting ground to commercialize the production and value addition of a largely food cropping system with poor marketing functions, fragile food security and disenfranchised target beneficiaries of the project with evident gender disparity of access to resources.

M-SU-16

Household income, food availability and commercial plantain production in Nigeria

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Plantain is a very important crop in Nigeria in terms of income generation, food availability and its role as raw material to the food industry. Production is still on small farm holdings of an average of 1ha per farmer. Price per unit of plantain is high relative to other starchy food substitutes. Plantain output data for Nigeria over 15 years was analyzed using regression, correlation and some descriptive statistics. Three functional forms of the regression model were used to examine the impact of six variables on plantain production in Nigeria. The coefficient of determination (R^2) of 0.98 implies that 98.4% of plantain production was explained by unit price, farm size, exchange rate, amount of rainfall, inflation rate and credit availability. This provided the evidence that a combination of all the independent variables had joint impact on plantain output during the years under review. The result further revealed that unit price, amount of rainfall, exchange rate and farm size significantly affected the level of plantain production. Under semi-commercialization of plantain production, increasing plantain production by 100 and 200% over the next five years will increase output to 12 964.2 and 25 1215.2 million metrictons respectively. There will be increased food availability, more raw materials for the food industry and higher income for farmers, marketers and other operators that are dependent on the output of the sector.

Production



Oral Presentations

Plenary: Production

Time: 0830–1030

Venue: Meister Room

Major soil research challenges for *Musa* production in Africa

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Worldwide production amounts to about 100 millions tons per year, from which roughly 27 millions are produced in Africa, which is consumed mostly in the continent. It is associated with production across a wide variety of cropping systems, involving diverse management practices and a patchwork of soil and climate conditions. Three major systems can be roughly identified: (i) dessert banana systems in peri-urban or coastal lowlands areas (e.g. Côte d'Ivoire, Cameroon), (ii) plantain-dominated systems in Central and West Africa, and (iii) highland banana systems in the mid-altitude areas of Eastern Africa. The dessert banana systems mostly target large urban and export markets. These systems are often capital intensive and present the highest opportunities for investment and further intensification. Pest and disease pressure are major production constraints in the lowlands; among them, soil-borne pests and pathogens strongly limit production potential in intensive monocrop stands. The plantain-dominated systems in Central and Western Africa are driven by smallholder farmers with relatively little use of external inputs. Production is very diverse and ranges from homestead gardens in densely populated areas to slash-and-burn in the sparsely populated humid forest zone of central Africa. Consequently, biotic constraints (black Sigatoka, nematodes) and abiotic constraints (soil fertility, drought) vary strongly and often interact. Increasing prices and markets provide some opportunities for investments (e.g. nutrient inputs and healthy planting material), especially in peri-urban areas. The highland banana systems are dominated by smallholder production for home consumption and local markets. Pest and disease pressure is still limited but devastating diseases such as BBTW and Banana *Xanthomonas* Wilt are spreading. Major production constraints are soil borne abiotic stresses (water shortage, nutrient deficiencies). With limited market opportunities and limited available resources (i.e. land, capital), farmers need to improve production by optimizing nutrient cycling within the farm, through labour-intensive management of organic nutrient sources (household residues, crop residues, mulch, and manure management). Banana and plantain are nutrient demanding crops, exporting large quantities of especially potassium and magnesium. Overcoming the current soil biotic and abiotic stresses in the diverse cropping systems, while avoiding large nutrient losses in the long term, is a formidable challenge to sustainable banana production. The present paper discusses the major soil constraints and soil research issues for production in Africa.

Role of biotechnology and transgenics in *Musa* in Africa

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In the more developed countries, genetically engineered crops contribute greatly to agricultural productivity and sustainability. Over the last few years, the largest growth in the adoption of genetically engineered crops has been in developing countries and this trend is expected to continue. The multi-national life sciences companies have been leading the way, but they are focusing primarily on a few crop/trait combinations that have high commercial value and occupy large international markets. Because of the costs and complexity of the issues related to crop biotechnology, many crops and traits of importance to subsistence and resource-poor farmers around the world have been overlooked. The Agricultural Biotechnology Support Project (ABSP II), a Cornell University-led and USAID-funded consortium of public and private sector institutions, provides support for scientists, regulators, extension workers, farmers and the general public in developing countries to make informed decisions about agricultural biotechnology. When possible, ABSP II creates public-private partnerships to help leverage public funds to help absorb development costs and provide broader distribution channels. Since 2005, ABSP II has been working with the National Agricultural Research Organization (NARO) in Uganda to establish safe and cost effective programs for the development and commercialization of East African Highland bananas genetically engineered for black sigatoka and nematode resistance. I will provide a brief description of the work undertaken to date and discuss the ABSP II-based strategy we have adopted to develop and deliver genetically engineered crops for developing countries.

The potential of tissue culture banana technology in Africa: anticipated limitations and constraints

Esther Murugi Kahangi

Jomo Kenyatta University Of Agriculture And Technology

The use of tissue culture (TC) technology to propagate banana plants gives growers several advantages over conventionally propagated material. This technology is an indispensable tool for the facilitation of quick, *en masse* multiplication of adequate disease free planting material of indigenous and exotic banana clones. The technology also rejuvenates the plants resulting in more vigorous growth, higher yields, better quality fruits, earlier fruiting and a more uniform crop than those produced by conventional means. Additionally, banana “seed” corms are bulky and expensive to transport and subject to delay for extended periods for phytosanitary inspection. TC plants are relatively inexpensive to ship and easier to certify by plant inspectors, since they are packaged in a sterile environment. In spite of these advantages TC technology remains little known or under-exploited in Africa due to a number of constraints/limitations. Africa has limited TC production facilities and personnel to operate TC laboratories virus indexing services (TC process does not eliminate viruses), especially for commercial production. A durable system to facilitate the continent to engage in the cross-border business of marketing TC banana plants as planting material is needed to enable improved and more sustainable banana productivity. Using best practice and TC laboratories, workable and practical models for the distribution of TC material within and between countries in Africa face significant challenges. In addition major constraints, which limit

farmer adoption of TC banana technology, persist. These include lack of credit for farmers to purchase the novel planting material and the high inputs required to realize optimum yields, while knowledge on the agronomic practices required for dealing with TC banana remains to be better disseminated and documented. Reliability of markets for harvested fruit is catalytic in promoting production and consumption, which in turn would impact positively on sales of TC planting material. Banana markets in Africa remain rudimentary in most cases, which leads to high postharvest losses, preventing farmers from realizing otherwise profitable incomes and discouraging them from adopting the technology. The future for TC adoption in Africa promises to be bright, but before their benefits can be optimally realized numerous constraints need to be addressed before the African farmer can adopt the technology and change the face of banana production on this continent.

The role of national centers of excellence in banana research and development in eastern, central and southern Africa

W.K. Tushemereirwe¹, M. Byabachwezi², J. Njuguna³, C.K. Nankinga¹, K. Nowakunda¹, D. Ngambeki¹, J. Namaganda¹ and J. Ssemwanga⁴

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Addressing regional issues traditionally leans on the support and direction of regional institutions that have developed programs to promote technologies to resolve problems in the banana industry. However, some national programs have become centers of excellence and increasingly more able to offer expertise on a regional level, which offer new opportunities for augmenting current regional efforts. For instance, the national programs of Kenya provide excellence in sanitary and phytosanitary regulations, while Uganda offer proven expertise in diagnostics, deployment of control interventions and biotechnology in banana research and development (R&D) programs. The current operational frameworks for addressing regional problems need to increasingly consider such national centers for enhanced effectiveness. These centers could champion processes where national institutions initiate R&D strategies to enhance ownership, as opposed to current arrangements where regional organizations lead the formulation of strategies, resulting in reduced national ownership and support. The New Partnership for Africa's Development (NEPAD) has recognized this and has, through the Biosciences for eastern and central Africa, organized the national banana R&D programs in the region into a consortium to offer another option. This should enable pooling of expertise in certain countries to tackle regional issues, such as safe cross border trade and movement of planting material, under one umbrella, but with elevated input and responsibility at the national level. The consortium, the Banana Consortium for Central, Eastern and southern Africa (BACCESA), has recently formulated a strategy and is in the process of mobilizing resources to implement it. This paper highlights the key elements of the strategy and how a national program, such as National Agricultural Research Organisation in Uganda, can provide significant support at a regional level.

The role of NGO's in addressing regional banana problems – creating synergy through partnerships – lessons learned from Catholic Relief Services management of a multi-country and multi-partner banana program in East and Central Africa

Stephen Walsh and Tom Remington

While NGO's have been lauded for their ability to respond quickly to crisis and to work with a variety of actors to address problems in a coordinated manner, they have also been criticized for their lack of technical capacity and the limited sustainability and short term nature of their actions. The NGO mandate differs significantly from the mandate of National Programs or their counterpart International Research Centers. This multi-sectoral orientation on the part of NGO's is driven by the combination of acute funding mandates and oblique program mandates, which is characteristic of the NGO world. With their multi-sectoral orientation, NGO's are less inclined to view sector specific technical capacity as 'in house requirements' than National or International Research Centers but are more inclined to see sector specific technical capacity as 'an external capacity that can be contracted as a service or series of services to be managed over a finite period'. Where research excellence is critical for National and International Research Centers, management and partnership capacity drive NGO success. This paper will argue that the current operational framework for addressing regional banana problems needs to increasingly appreciate the core competencies of NGO's, specifically their capacity to foster and sustain effective networks and partnerships at multiple levels, to administer programs in complex operating environments, and to leverage technical capacity at both the regional and national level in order to address problems at scale in a timely and cost effective manner. The key lessons learned from Catholic Relief Services experience of managing a multi-country banana project in East and Central Africa will be highlighted. Aspects to be covered include building and sustaining partnership networks, administering regional grant funding mechanisms, and managing technical support on a regional and national level.

Parallel Session 1: Plant health

Venue: Meister Room

Time: 1100–1300

Protecting the African banana: prospects and challenges

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In Africa bananas and plantains are staple food crops and sources of income, cultivated as backyard plantings, mixed-crop plantings and in commercial plantations, and consist primarily of cooking type bananas. Continued production is threatened by several important pests and diseases. Nematodes, particularly, are responsible for significant losses across Africa, and the banana weevil (*Cosmopolitus sordidus*) damage both cooking and dessert bananas. Since its introduction onto the continent, black Sigatoka (*Mycosphaerella fijiensis*) has spread to all African tropical banana production areas,

causing immense damage. *Fusarium* wilt (*Fusarium oxysporum* f.sp. *cubense* - *Foc*) is important in dessert banana, while *Xanthomonas* bacterial wilt (*Xanthomonas campestris* pv. *cearum*) has devastated bananas in central and eastern Africa since 2001. Both the banana bunchy top (BBTV) and banana streak virus (BSV) occur on the continent. Because of the limited resources available to backyard and mixed-crop growers, many pests and diseases are only partially controlled or not controlled at all, making banana production highly vulnerable. More importantly, many pests and diseases are indiscreetly disseminated because of limited resources and knowledge. Thus large growing areas have already been forced out of further production. Can Africa do something about this situation, or does the continent, once again, rely on foreign resources to ensure continued production? Even without substantial financial resources, the effect of pests and diseases in Africa can be substantially reduced by promoting the use of clean, healthy planting material, sanitation practices and quarantine regulations to prevent dissemination of existing pathogens and pests and the introduction of important foreign pathogens such as *Foc* tropical race 4 and those causing Moko and blood disease. African scientists have the capacity to accurately identify and map the distribution of important pests and diseases, and the means to determine their dissemination in country and across borders. Africa can further build on innovative disease and pest management technologies already established on the continent, such as plant bio-enhancement, the use of mulches and botanicals, and unconventional plant improvement. Two banana breeding programmes and several facilities for plant biotechnology already exist, and should be more efficiently employed to address the demise of one of our most important staple food crops. Most importantly, national and continental resources should be pooled in order to ensure sustainable banana production in Africa.

Integrated control of *Fusarium* wilt of banana

E.G. Kidane and M.D. Laing

*School of Biochemistry, Genetics, Microbiology and Plant Pathology,
University of KwaZulu-Natal, Pietermaritzburg, South Africa*

The importance of *Fusarium* wilt of banana has been widely documented. The lack of viable control options and its significance to the livelihood of millions of people around the world makes it particularly important. In this study, the integration of biological and agronomic control methods was investigated. Single and combined application of non-pathogenic, endophytic *Fusarium oxysporum* strains, *Trichoderma harzianum* Eco-T[®], silicon and mulching using macadamia husks were tested against *F. oxysporum* f.sp. *cubense* on bananas under greenhouse and field conditions. Tissue culture banana cv. Cavendish Williams were inoculated by dipping them into a suspension of conidia of non-pathogenic *F. oxysporum* Strain N7 or N16. They were fertilized with potassium silicate for 3wk prior to inoculation with *F. oxysporum* f.sp. *cubense*. In order to induce early disease expression, all banana plants were cold stressed for 3wk at 10°C for 1mo post-inoculation with the pathogen. The non-pathogenic *F. oxysporum* Strains N7 and N16 were effective biocontrol agents against *Fusarium* wilt of banana. Amendment with potassium silicate to plants exposed to the non-pathogenic *F. oxysporum* strains improved plant health of cold-stressed banana plants compared to those treated with endophytes only. A field trial was conducted at a KwaZulu-Natal South Coast banana plantation, where *Fusarium* wilt of banana is a serious problem. Banana plantlets were inoculated with the biocontrol agents two weeks before being transplanted into the field. Plants that were treated with combinations of non-pathogenic *F. oxysporum*, *T. harzianum* Eco-T[®], silicon and mulch had significantly better growth than single applications of the treatments. Integration of biocontrol with agronomic practices may improve the efficacy of the biocontrol

organisms and the health of the host plants. This study demonstrated that the combined application of biocontrol organisms, silicon and mulching can provide an effective control option for banana growers dealing with *Fusarium* wilt in their plantations.

Nematode control on banana and plantain suckers (*Musa* spp.) through submergence in boiling water

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Root nematodes, especially *Radopholus similis*, along with other, less important soil and root-borne pests and diseases are a major cause of yield loss to banana and plantain. Farmers are generally unaware of the presence of nematodes, but mostly recognise the distinctive symptoms of toppled plants, which most often lead to total bunch loss. No commonly used method to de-infest planting suckers of nematodes exists. This paper presents a simple, inexpensive, and highly mobile method to treat plantain and banana suckers against pests and diseases attached to the suckers. The purpose of the paper is primarily to show that submerging plantain suckers in boiling water for a limited time (< 60 seconds) does not compromise emergence and crop establishment, but has the potential to significantly increase crop yields. Submerging plantain (genome AAB) suckers of different corm sizes in boiling water for 0 to 60 and east African highland bananas (genome AAA-EA) for between 0 to 40 seconds had no significant effect on the rate of emergence and plant establishment. Exposure times between 20 and 40 seconds appear to be most suitable to attain high crop establishment rates. Exposure was further tested for efficiency of nematode control. No living nematodes were found in corm surface tissue after sucker submergence in boiling water for 30 seconds. Bananas were assessed in halved oil drums only, showing significant reductions in nematode infestations, compared with non-boiling water treated suckers. Boiling water treatment led to significantly higher fresh plantain yields in both Cameroon and Nigeria, than the farmers conventional method (with no treatment), while nematode management was significantly improved on both banana and plantain. The technique requires very little capital investment and only marginal additional labour. It appears suitable as a general technique to reduce both specific and unspecific pests and diseases spread by conventional suckers.

The potential benefits of GIS techniques in disease and pest control: an example based on a regional project in Central Africa

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Bananas support the livelihoods of over 20 million people in the Great Lakes region. Various diseases and pests threaten the livelihoods of these people significantly by reducing banana yield. Geographic Information Systems (GIS) provide valuable tools in monitoring, predicting, managing and fighting the spread of crop diseases and pests. The tools offer opportunities for cost-effective and efficient targeting of interventions and control. In monitoring, GIS can be used to determine the spatial extent of a disease, to identify spatial patterns of the disease and to link the disease to auxiliary spatial data. GIS can also be used to predict the projected spatial spread of

diseases, to provide input for risk assessment models in pest control and in quantifying changing thresholds of pests and diseases due to climate change. In order to lift the described techniques to a broader scale, a protocol for data collection and proper data management is essential. In this paper GIS tools are illustrated with data collected in a project aimed at identifying critical intervention areas to combat the spread and damage of Banana *Xanthomonas* Wilt (BXW) and the Cassava Mosaic Disease (CMD). In a survey covering the Great Lakes region in Central Africa the on-farm incidence and severity of the diseases were monitored, with the precise GPS coordinates of each sampled field recorded. This enabled accurate mapping of the disease and performing the various spatial analyses, permitting an understanding of the geographical breadth of BXW and CMD infection. The survey was repeated during consecutive years to determine an accurate spatial spread of diseases. Data on food security and dependency on banana for rural populations was linked to the BXW severity to target priority areas of interventions and maximize impact.

Crop pests: why pest diagnostics, phytosanitary standards and surveillance is it important and what are our roles and responsibilities

J.J. Smith

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Consumers look for healthy produce at markets, and the market sellers look to procure healthy produce from farmers. And thus, farmers invest much effort and money to deliver on a good product. Plant pests stand between a farmer and satisfied customer. Accordingly, researchers strive to provide for farmers the tools to counter the threat presented by pests through developing improved varieties that are resistant to particular pests or by achieving a better understanding of the life habits of the pest that identify weaknesses to be exploited. And likewise policymakers legislate against pests through setting standards on pests, or their products, within produce and by implementing quarantine against pests not present in the country. Nevertheless, pests are consistently attributed to causing chronic negative impacts and can present a barrier to export trade. Periodically, either a pest mutation or a new pest introduction causes catastrophic losses that seriously threaten food security. To be one step ahead of the pests, as pests adapt and evolve over time, or seek to invade, is to the benefit of all stakeholders of food production. Consumers, market people, farmers, researchers, policymakers and others are all stakeholders in the battle to counter pests. This paper looks at the tiers of knowledge and timescales for a response that are important to the various stakeholders in relation to the outcome they wish to achieve from the actions they take that mitigate against the consequences of pests. It specifically explores the direct and indirect benefits of pest diagnostics, phytosanitary standards and surveillance and the greater need within African society for a precautionary and preventative mindset to counter the threat from catastrophic pest events.

The International Plant Diagnostic Network (IPDN) in Africa: improving capacity for diagnosing diseases of banana and other African crops

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Bananas are subject to a number of diseases of economic importance, which may be difficult to diagnose early in disease development when control measures are most likely to be successful. Further, new diseases that spread rapidly from region to region, such as banana *Xanthomonas* wilt (BXW), present unique diagnostic challenges. Diagnostic capacity is lacking in much of Africa, hindering adoption of appropriate and effective integrated pest management programs and hindering international trade. Surveys conducted in East and West Africa documented the lack of sufficient equipment, supplies, reference materials and training in the majority of plant pathology laboratories charged with disease diagnoses. To begin to address these issues, the International Plant Diagnostic Network (IPDN) was established in two regions in East and West Africa in 2006 through the Integrated Pest Management Collaborative Research Support Program (IPM CRSP). The IPDN is a diagnostic, communication and data network, modeled in part on the U.S. National Plant Diagnostic Network. Software for digital imaging and diagnosis, information management and access to disease management recommendations provides a platform for enhanced diagnosis and communication amongst clinicians and their clientele. Improved diagnostics tools and protocols were also developed and tested, including a PCR assay for BXW. Training programs were conducted in Benin in 2006, and Kenya and USA in 2007 to enhance technical capacity amongst diagnosticians in East and West Africa. Initiatives such as IPDN can benefit by collaboration with other similar internet based initiatives in Africa. One such activity is the East Africa Phytosanitary Information Committee (EAPIC). EAPIC is linked to FAO's International Plant Portal to provide the official national plant protection organization posting of plant pests for each respective country, which now includes Kenya, Tanzania, Uganda, and Zambia. The plant pest list will serve as a foundation from which to develop harmonized border inspection protocols, which in turn support capacity building efforts in plant pest survey, identification and communication systems, such as IPDN.

Parallel Session 2: Post-harvest

Venue: Mandhari Room

Time: 1100–1300

Banana and plantain research at CARBAP: evaluation and post-harvest research for development

K. Tomekpe

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Plantain is one the most popular staple foods in West and Central Africa. In order to boost the production of this important local crop, the governments of six countries in Central Africa created in 2001 the African Research Centre on Banana and Plantain (CARBAP). CARBAP is a base-centre of the West and Central Africa Council for Agricultural Research and Development. The centre hosts and supports the coordination of the West and Central Africa *Musa* network. CARBAP works to contribute to increase plantain and banana productivity through research, training, development and partnership activities at national and regional levels. Research programs focus on five major areas (i) genetic improvement and variety delivery, (ii) agronomy and ecological intensification, (iii) sustainable plant protection, (iv) post-harvest technologies and (v) market chain, innovation and knowledge management. Sustained efforts were made these last years to evaluate the reference collection of CARBAP, in particular for post-harvest characteristics of plantains and cooking banana originating from Papua New Guinea. Evaluation of micronutrient and dry matter content has been particularly targeted, but research is also underway to develop improved banana and plantain-derived products such as flour. In addition, new cultivars including black Sigatoka resistant and dwarf hybrids were obtained by conventional breeding broadening the indigenous plantain diversity and the variability introduced by Papua New Guinea cultivars. Concerted efforts to evaluate the new cultivars in different production systems are ongoing using a participatory approach. Recent advances on cultivar development and on post-harvest characteristics will be presented. Diversified and integrated strategies based on innovative technologies and new approaches will be discussed.

Cooking quality, utilization and consumption pattern of bananas and plantains grown by small-scale farmers in East Africa

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East Africa is endowed with abundant natural and human resources. The Great Lakes region produces the highest volume (20 million tons) of bananas and plantains in the world and also boasts of the highest per capita consumption. Studies and reports indicate that the majority of banana and plantains grown within the region are consumed locally in various forms, with cooking banana being the most popular. Despite this, the cooking quality, utilization and consumption pattern of banana cultivars in East African region has not been rigorously documented. This paper gives information on the types of banana cultivars grown in the region, their cooking quality, utilization and

consumption patterns. Structured questionnaires were administered to 800 farm households, 540 in Uganda and 260 in Tanzania. Results indicated that 95 and 120 banana cultivars are grown by households in Uganda and Tanzania respectively. In Uganda, the most popular cultivar among farmers was 'Sukali ndizi' (AAB group) (exotic consumed as dessert), followed closely by 'Nakitembe' (AAA-EA group) an endemic variety. In Tanzania, the cultivar grown by majority was 'Enshakara' (AAA-EA group). In Uganda, 68% of the cultivars grown were cooking types, among which 'Nakitembe', 'Nakabululu', 'Mbwazirume', 'Musakala' and 'Nakyewogola' had high cooking quality. Cultivar 'Nfuuka' was recorded with the poorest cooking quality. In Tanzania, 56% of the cultivars grown were cooking varieties, with 'Enchoncho', 'Enshakara', 'Entobe' and 'Enyoya' having the best cooking quality. The findings also showed that although farmers sell some of the banana produce, consumption at household level is the highest form of utilization and cooked banana is the most popular way of consuming bananas. Consumption of bananas and plantains was highest between June-August and November-December. Through linear regression analysis, a strong relationship was observed between cooking quality and popularity of cultivar in both Uganda and Tanzania. This information confirms that households in this region depend on banana production mainly for food and prefer cooking bananas with high cooking quality. Therefore enhancing the production and nutrient quality of bananas and plantains will go a long way in reducing food insecurity and enhancing the nutrition and health status of small holder communities in East Africa.

Carriage of bananas in refrigerated ships and containers: pre-shipment and shipboard factors influencing cargo out-turn condition

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Information is obtained during out-turn surveys at destination (on behalf of cargo receivers, underwriters, ship-owners or charterers) or during the study of claims documentation submitted by lawyers acting for one or other of the above parties. There may also be occasion to visit the producer country. Pre-shipment factors influencing cargo quality and out-turn condition include the weather, crop husbandry in relation to leaf-spot diseases, harvesting and handling techniques, post-harvest treatments, method of packaging, schedule of loading, and carriage instructions written by the shipper/exporter. Shipboard factors include design and function of the refrigeration and ventilation equipment, method of stowage, interpretation of carriage instructions, and duration of voyage. For container shipments it is the shipper's responsibility to "stuff" the container in an appropriate manner; the container operator accepts the closed box and undertakes to supply refrigeration/ventilation in accordance with the shipper's carriage instructions. Case studies will be presented, demonstrating that deterioration (such as premature ripening) is often the result of a combination of adverse factors. Particular problems include the difficulty of achieving uniform air circulation through a palletised stow, and the challenge of shipping additional commodities (such as melons or citrus) in the same vessel. Accurate diagnosis of the causes of deterioration can assist in prompt settlement of claims and reduction of losses in the future.

Effect of mode of ripening on ethylene biosynthesis during ripening of diploid banana fruit

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Ripening is the main physiological process that affects the behaviour of fruit quality traits. The progress of this process in banana fruit is different for fruits that ripen on the tree and those that do not, and according to the treatment applied to the fruit after harvest. We investigated the effect of the mode of ripening on ethylene biosynthesis of IDN 110 (*acuminata* AA group) banana fruit ripened *in-planta* (in-Fruit) and *ex-plant* on air (air-Fruit) or after acetylene treatment (ace-Fruit). The levels of ACC and ethylene production and, those of ACC oxidase (*MA-ACO1* and *MA-ACO2*) and ACC Synthase (*MA-ACS1*) mRNA were examined in pulp tissue of each of these fruits. Our result showed that, from the harvesting point (mature green stage), the ripening speed of fruit was not concomitant with ethylene production. Ace-Fruit took 10 days to reach over-ripe stage with a maximum of 22.6 µl/kg/h of ethylene production, whereas Air- and in-Fruit took 27 and 33 days to reach over-ripe stage, respectively, and produced 11.5 and 29.6 µl/kg/h of ethylene, respectively. During ripening, ACC accumulated differentially and, except for in-Fruit, this accumulation was positively correlated with that of *MA-ACS1* mRNA. No correlation was observed between ACC level and ethylene production. In all cases, the level of *MA-ACO1* mRNA was 100-fold more than that of *MA-ACO2*, and both of them increased during fruit ripening. In contrast to *MA-ACO2*, the pattern of *MA-ACO1* gene expression was correlated with that of ethylene production whatever the mode of ripening. The results herein suggested that i) the level of ethylene is not the unique factor that controls the speed of fruit ripening *in-planta*, ii) the level of ripening-ethylene production of the whole fruit is regulated at downstream step of ACC biosynthesis mediated by *MA-ACS1* gene and, in pulp tissue, the product of *MA-ACO2* might be involved in this regulation.

Cultivar difference in peel blackening of banana fruit during low temperature storage

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Banana fruits of cultivars 'Hom Thong' (*acuminata*, AAA group) and 'Namwa' (*x paradisiaca*, ABB group) were stored at 4°C and 12°C (and 85-90% RH). At 4°C, peel blackening was visible on day 2 in 'Hom Thong' but two days later in 'Namwa'. Levels of total free phenolics, thiobarbituric acid (TBA)-reactive compounds, and *in vitro* peroxidase (POD) activity in the peel were not correlated with blackening. A slight increase of *in vitro* catechol oxidase (polyphenol oxidase) activity occurred from day 0 onwards in 'Hom Thong', and could explain blackening in this cultivar, but such an increase was not found to accompany blackening in 'Namwa'. Low temperature storage resulted in a rapid increase of *in vitro* lipoxygenase (LOX) activity in 'Hom Thong', which was correlated with blackening, but the later blackening in 'Namwa' was not accompanied with a rise

in LOX activity. It is concluded that the early peel blackening in low temperature-stored fruit of 'Hom Thong' was correlated with increased LOX activity, which might be close to the cause of the blackening, and increased catechol oxidase activity, which is apparently involved in the blackening reaction. Peel blackening in 'Namwa', in contrast, was not correlated with any of the measured parameters.

Physico-chemical changes during fruit development and ripening of three *Musa* cultivars grown in Cameroon

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Bananas and plantains are staple crops in west and central Africa where they play an important role in the population diet. Some physico-chemical changes during fruit early development and ripening of three types *French sombre* (plantain), *Pelipita* (cooking banana) and *Grande naine* (dessert banana) were determined. Immediately after shooting, samples were respectively collected every 14, 21 and 14 days from the 2nd and 3rd hands of at least 3 'on-plant' bunches. From early development to harvest of these banana and plantain fruits, some Physico-chemical parameters varied significantly ($p < 5\%$). Post harvest maturation of these fruits showed different trends. Pulp to peel ratio, total soluble extract, total acid and peel dry matter content increased considerably while pulp firmness, pH and pulp dry matter content decreased during ripening. These changes differed significantly according to genotypes or sub-groups during the 2 phenomenon investigated.

Parallel Session 3: Agronomy

Venue: Meister Room

Time: 1400–1605

Methodological considerations on banana and plantain yield determinations

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A critical review of literature on plantain and banana research revealed severe shortcomings in the description of methods used to determine and present units used to express yields in numerous publications. This paper points at potential errors in bunch mass determinations, and it proposes (i) uniform yield calculation methods, (ii) universally comparable units of banana and plantain yields, and (iii) procedures to validly compare banana and plantain yields with those of other major staple crops. The major source of error in bunch mass determination, specifically of plantain, appears to be the length of the peduncle retained on the bunch. A standardized cut off point for all plantain and banana cultivars should be used to increase comparability. A major error in yield determination specifically of plantain is caused by a large variation of the proportion of plants that do not produce a bunch within the lifetime of a field. It is proposed to present the fresh bunch yield in the following way: Fresh bunch yield (Mg ha^{-1}) = Plant density (plants ha^{-1}) x percentage of plants that produced an edible bunch x mean bunch mass (kg) / 10,000.

Fresh banana bunches contain about 20-25% edible dry matter. Comparison of plantain yields with other major staples would thus require conversion to dry matter yields. The large between-plant differences of time required from (i) planting to bunch harvest, or from (ii) harvest to harvest between plants from the same mat (but different generations), requires that yields are expressed on a time basis, or that the time from planting until termination of trials is given. To validly compare the productivity of plantain and banana with that of other crops, yields would need to be expressed in Mg edible dry matter ha⁻¹ year⁻¹.

Potential impact of climate change on banana production and bio-constraints in sub-Saharan Africa

K. Sonder

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Banana and plantain ('banana') are important food and cash crops both in the Great Lakes Region of east and central Africa as well as humid West Africa. Africa is expected to be the continent most vulnerable to predicted climate change by the end of this century. The predicted impacts can be both positive and negative. Generally increasing temperatures may allow expansion of current banana cultivation areas towards higher altitudes, but which may also be associated with increased pest and disease pressure. Banana cultivation areas in West Africa may expect reduced rainfall under some climate change models and scenarios, while the banana growing areas in the great lakes region of central and eastern Africa could experience higher rainfall considering averaged predictions according to the Intergovernmental Panel on Climate Change's fourth report. A geographical information system was used with datasets on rainfall and temperature from three global climate models: CSIRO, HADCM3 and CCCMA, and four emission scenarios (1a, 1b, 2a and 2b) to calculate and map predicted changes in banana's suitability for Africa between current average climate conditions and 2080. Associations established between annual rainfall and banana yield for eastern Africa were used to estimate the impact of changes in rainfall patterns on future yield levels. The potential expansion of banana growing areas due to increasing temperatures was also mapped.

Plantain cultivation in Africa: production and research in the recent two decades

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Centre de coopération internationale en recherche agronomique pour le développement, Montpellier, France

Banana and plantain are amongst the major food staples in Africa, where more than 24 million tons are produced, primarily from small family farms, accounting for approximately 25% of global production. However, per capita consumption has continued to fall in urban areas where, in some cases, it has become a luxury product. The discrepancy between demand and production has been reflected in often significant price rises in urban areas. As a consequence, plantain is becoming increasingly less affordable for low income populations. In most African producing countries, production is stagnant if not decreasing. Diverse studies have attributed this situation to land tenure constraints, shortening fallow periods and declining soil fertility, increasing pest and disease pressures, poor access to inputs, marketing chains with many intermediaries and production areas distant from transport. These challenges call for

innovation along the value chain from production to marketing, including the service sector. Starting in the 1980's, in light of the importance of these crops, plantain and banana research and development in Africa has accelerated. WARCOP and IARPCB had pioneering roles, although most research was at that time dedicated to export banana. INIBAP and its two regional networks in Africa contributed to awareness raising and increased collaboration among national programmes and advanced research institutes. New research on pests and production and breeding initiatives were initiated through CARBAP in Cameroon and IITA at Onne, Nigeria and later in Cameroon and Uganda and more recently Ghana. Production and marketing issues faced in Africa have some similarity to Latin America, where in recent decades production has increased in response to increased demand. Lessons can be drawn from such experiences towards addressing problems in Africa. Plantain in Latin America has benefited from technical advances in the export banana sector, more demanding supply chains organized by supermarkets and the proximity of growing export markets in North America. This has resulted in more uniform and healthier planting material, agronomic and cultural practices directed to higher yields and better quality fruits, increased use of irrigation and fertilizers and short marketing chains which pay growers based on weight and quality. South-South cooperation from Latin America could have a stimulating effect on the marketing chain management, intensification process, and innovation management as a whole in Africa.

Agro-ecological intensification in banana and plantain: an approach to developing more sustainable cropping systems for both small-holder farmers and large-scale commercial producers

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Urban centres in Sub-Saharan Africa are generating a growing demand for plantain. Farmers have not responded by increasing supply and this crop has gone from being a food staple to a food consumed on special occasions. Small-holders face numerous difficulties in improving the production and productivity of plantain. New diseases such as black leaf streak and banana bunchy top have spread into new areas, while decreasing fallow periods and declining soil fertility have exacerbated the losses due to nematodes and weevils. Fertilizers and pesticides are difficult to obtain, expensive and not properly evaluated in these cropping systems. High input production has not been applied in plantain production for urban markets. In addition, this high input approach is increasingly questioned due to negative impacts on the environment, on the health of workers and nearby rural communities in some case and due to the increasing cost of energy-intensive inputs. Agro-ecological intensification is a practical, knowledge-based approach with potential to respond both to the needs of small-holders for increased production through more efficient use of local resources and to the demands placed on the high-input export sector for more environmental sustainability. While this approach does not exclude the use of external inputs, the focus is on biological mechanisms for suppressing pests and diseases, strategies for increasing total crop photosynthesis and conversion to yield, and approaches to the management of soil nutrient cycles and crop nutrition. In this approach, management of functional biodiversity serves to reduce losses, optimize crop residue breakdown and symbiotic nitrogen

fixation and promote crop health. Various kinds of research are needed to establish an adequate knowledge base; however, crop and disease modelling can contribute to the effective targeting of research by establishing agro-ecological principles and guiding the choice of crop management options which can then be tested locally with growers in the field. Research results and experiences of different institutions on agro-ecological intensification are reported and future research prospects discussed.

Factors driving fertilizer adoption in banana systems in Uganda

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Highland banana (AAA-EA) yields in Uganda are still far from potential. Soil fertility technologies are being developed to help overcome this yield gap. Technology adoption is influenced by the appropriateness and dissemination methodology of the technology. This study identifies constraints and opportunities to fertilizer adoption in banana systems, by monitoring 179 on-farm demonstration plots in central, south, southwest, and east Uganda. Demonstration plots received on average 71 N, 8 P, 32 K kg ha⁻¹yr⁻¹ (i.e., a generalized 'best-bet' fertilizer rate based on existing literature) and external mulch (53% of the plots), whereas control plots represented farmer practices and subsequently received no fertilizer and little external mulch (13% of the plots). The demonstration plots were used for learning by collaborating farmers groups nearby. Structured and unstructured interviews were conducted to get information on farmer perceptions of demonstrated technologies. Farmers observed that demonstration plots had consistently higher yields than control plots; i.e., yield increases varied from 3.5 t ha⁻¹ yr⁻¹ in Luwero (central Uganda) to 13.1 t ha⁻¹ yr⁻¹ in areas in Masaka (south Uganda). Farmers perceived fertilizer prices as the most important constraint for adoption, despite limited knowledge of actual prices. Other constraints perceived were poor availability, large/costly fertilizer pack sizes (≥ 50 kg), lack of know-how of application methods, and beliefs that fertilizer negatively affected soil and fruit quality. Fertilizer use was highly profitable at sites close to Kampala market, but not at sites far away (>250km). The marginal rates of return exceeded 575% in Wakiso district (central Uganda), but only averaged 10% in Bushenyi (southwest Uganda). Foliar analysis indicates that fertilizer recommendations can become more profitable when targeting site-specific plant nutrient deficiencies. The demonstration plot approach simultaneously allowed participative evaluation, fine-tuning, adoption and adaptation of fertilizer recommendations. This approach, therefore, shortens and strengthens the adoption pathway, provided the process is supported by proper agronomic and economic evaluation of the technologies tested.

Benefits and potential use of arbuscular mycorrhizal fungi in banana and plantain systems in Africa

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Crop plant association with arbuscular mycorrhizal fungi (AMF) often prove beneficial to crop productivity through a number of mechanisms, such as improved access to nutrients and water, pest and disease suppression. Banana and plantain are both mycorrhizal plants, with a number of studies demonstrating the strong stimulatory affect of AMF on plant growth in pots. Application of AMF to newly deflasked tissue culture plants or in nurseries therefore, may improve plant growth and possibly provide healthier plants for sale to farmers. Studies have also shown that plants are also better able to suppress nematodes in pots. However, how this association benefits banana and plantain growth, and consequently yield, under field conditions has yet to be properly determined. Studies are currently underway to determine the mycorrhizal associations of banana and plantain cultivars with AMF in East and Central Africa. Greenhouse studies complement field studies for comparison at the different levels. In West Africa, studies have been conducted to assess the AMF associations and yield impact following inoculation. Data is accumulating, and showing variable composition and abundance of AMF species, with up to a total of 20 AMF species associated with banana plantations in East Africa. Spore abundance, inoculum reservoir that determines colonization, was largely influenced by management practices. However, the data generated to date, is increasingly indicating the importance of the management of banana systems, clearly indicating that banana and plantain are highly dependent on AMF. Some species also appear to be more superior in their effects on banana growth, nutrient uptake and the control of root damage by nematodes. Studies are in progress to screen AMF species and establish trials along different integrated soil fertility management practices. This paper reports on the available data surrounding the potential impact of AMF on banana and plantain in Africa.

Turning unproductive waterways into banana fields

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Likamba village is in northern Tanzania, Arumeru district, Arusha region. Likamba stands on the leeward side of mount Meru and therefore receives little rains. It is endowed with hills and valleys and is residence to pastoralist tribe of Waarusha/Wamaasai. The little rains that fall on the hills concentrate into valleys to form flood waters and before this project, these valleys lay wasted with no beneficial use. Bananas were introduced in Likamba amidst protests from the villagers that bananas cannot perform on the dry area. They were introduced in the waterways which were otherwise unutilized due to the big volumes of water flowing through during the rainy seasons. Seedlings were offered to a few farmers who were willing to try out and were ready to labor for success. The seedlings were planted in holes with a 90 cm x 90 cm x 90 cm dimension. The top soil was mixed with plenty of manure (10-12 twenty kg tins) and was used

to plant the seedlings. Water was fetched from the village dam and used to irrigate the individual seedlings. After the rains, grass was allowed to grow in these fields and only a 120-cm diameter around the seedling was weeded. The rest of the area was covered by grass, with the grass acting as mulch and soil cover to reduce erosion. Within 9 months, the banana crop had developed a canopy, good enough to reduce the erosion and together with contouring controlled erosion. The farms were then weeded and the grass was incorporated in the soils to increase the organic matter. In the midst of a dry area today, Likamba produces bananas and farmers who originally refused to take banana seedlings are now scrambling for seedlings. Food security and income has increased in the village which was originally only dependent on maize for food crop.

Parallel Session 4: Seed Systems

Venue: Peponi Room

Time: 1400–1550

Banana virus indexing in East Africa

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Six viruses, banana bract mosaic virus (BBrMV), banana virus X (BVX), banana bunchy top virus (BBTV), banana streak virus (BSV), banana mild mosaic virus (BanMMV) and cucumber mosaic virus (CMV), are currently known to infect banana worldwide. Of these viruses, BBrMV and BVX have not been detected in East Africa but could be devastating if introduced. BBTV has recently been identified in Rwanda and poses a significant threat to neighbouring countries. BSV is widespread in Uganda and possibly other East African countries, while CMV and BanMMV are likely to be present in East Africa causing small losses. Appropriate diagnostic and control strategies must be implemented across East Africa to minimise the potential impact of these viruses on banana production. Of particular concern is the spread of infected planting material between regions by farmers and, more recently, by the widespread distribution of potentially virus-infected tissue culture (TC) banana plants. TC bananas are increasingly being used for replacement plantings in East Africa. While the propagation and use of virus-indexed TC bananas is encouraged, the increase in laboratories producing TC banana without virus indexing is a concern. It is imperative that TC laboratories provide a source of high quality, disease-free planting material for farmers, especially in future efforts to control virus diseases or for large scale release of new cultivars. The Grand Challenges in Global Health Program is working closely with scientists based in national agricultural institutes in East Africa (NARO in Uganda, MARI in Tanzania and KARI in Kenya) along with Africa Harvest Biotech Foundation to establish virus indexing programs within key TC laboratories. Diagnostic procedures will focus on the use of polymerase chain reaction (PCR) for the detection of viruses during the tissue culture process, including establishing virus-free plots to source plant tissue and quality control of plants for distribution.

Development of a diagnostic protocol for cucumber mosaic virus for screening planting material in Côte d'Ivoire

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Cucumber mosaic virus (CMV) has been shown to be the primary virus affecting commercial banana plantations in Côte d'Ivoire, with the disease also present within nursery systems. A key intervention to reducing infection is through planting virus free material. However, currently no virus indexing of planting material is performed for banana in Côte d'Ivoire. This research attempts to quantify levels CMV detection within banana material. A detection system was developed based on FTA cards, a paper-based system developed to fix and store nucleic acids from infected tissue. Real time-PCR amplification of CMV RNA used an internal control primer designed for banana Ribulose-1,5-biphosphate carboxylase as a quality control measure. Cucumber mosaic virus coat protein fragments were amplified from total RNA templates eluted from FTA discs using TaqMan and conventional RT-PCR. TaqMan assay generated comparable C_T values with either FTA or CTAB derived templates, and was able to detect CMV RNA in plant material containing 1% (W/W) of infected samples. The sensitivity of TaqMan reaction was found to be 10 times more than conventional RT-PCR for CMV detection in banana leaf samples. The use of the Ribulose-1,5-biphosphate carboxylase primer set was confirmed as a robust internal control. Seven hundred fifty seven nucleotide sequences of the CMV CP ORF of 16 Ivorian isolates was analysed and compared to sequences held on GenBank. Nucleotide sequence variability of 0.2 to 2% was observed amongst the Ivorian isolates, with sequence similarity as high as 99.2% observed with CMV occurring outside of Côte d'Ivoire. Phylogenetic analysis revealed that CMV infecting banana plants in the three localities in Côte d'Ivoire belongs to CMV subgroup IA. Research is ongoing to establish the relationship between laboratory end-points of detection with field incidence of CMV.

In planta suppressiveness in banana to nematodes and long term root health stability through biological enhancement- do we need a cocktail?

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It is taken for granted that plants grow in a very complex soil environment harboring high densities of diverse microorganisms and that these plants are constantly exposed to massive numbers of complex biological interactions that either positively or negatively affect root health and growth. Some scientists, however, believe the soil environment is not complex and that biological interactions are rare and seldom affect plant growth significantly. Scientists working in plant pathology usually adhere to the low complexity school of thought and therefore often target their research work to a single pest/disease interaction. Similarly biologists studying microbial based biological control also tend to simplify their approach to a system of one antagonist-one pest, a concept that has been reasonably

successful. For example, the one antagonist-one pest approach has been used effectively for the biological enhancement of banana planting material with endophytic microorganisms. Good control has been attained regardless of the antagonist involved: mutualistic endophytic fungi or bacteria, arbuscular mycorrhizal fungi, plant health promoting rhizobacteria or entomopathogenic fungi. The main reasons for a single antagonist approach are the need for practical application technology at the farm level, economics of production, cost of registration and lack of knowledge of the impact of complex inoculants on control efficacy and environmental health. It is however important to keep one fact in mind, in planta suppressiveness in the field is not an industrial based phenomenon, but is based on unique interrelationships between the microbial community and plants, which result in a healthy root system. Success has been achieved with biological enhancement of plant material for the management of plant parasitic nematodes in . Practical application is no longer a question of if, but a question of when and where. However, a number of questions still confront those working with the biological enhancement concept: 1) can we increase the levels of control presently attained; 2) can we extend the spectrum of target pests affected; and 3) can in planta suppressiveness be established for long term control? Since in planta suppressiveness is clearly related to the activity of microbial communities and not to a single organism, the question that requires answering is - do we need a cocktail?

Combating phytosanitary constraints to banana production: the Kenya example

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Kenya has experienced a decline in banana production during the last two decades. The decline can be attributed mainly to an increase in prevalence of pests and diseases due to the limited practice of effective management. The main pests and diseases of concern are *Fusarium* wilt (*Fusarium oxysporum* f. sp. *cubense*); black and Yellow sigatoka (*Mycosphaerella fijiensis* & *M. musicola* respectively); banana Xanthomonas wilt (*Xanthomonas campestris* pv. *cearum*); banana weevil (*Cosmopolites sordidus*), burrowing nematode (*Radopholus similis*) in addition to pest and disease complexes. Since there is no formal system and standards to regulate planting material, farmers frequently use untreated sword suckers for planting, aggravating the problem. There is need to develop standards and codes of practice that would ensure farmers' access to certified healthy planting materials of improved banana germplasm. Micro-propagation (tissue culture) has gained popularity for rapid production of clean banana planting material. However, updated standards and codes of practice need to guide the application of this method for purposes of quality assurance. Similarly, capacity to use tissue culture to generate clean planting material must be developed in tandem with a virus indexing mechanism for such material, as well as imported material to monitor and restrict movement of viruses of quarantine importance. Rapid detection of pests and diseases during import inspections and certification of nursery propagated materials is essential for prevention of introduction and spread of pests and diseases of quarantine importance. The development of rapid and inexpensive diagnostic kits will facilitate in quick decision-making. In this regard, KEPHIS as a regulatory agency responsible for seed quality and plant quarantine should be a key partner in initiatives to multiply, distribute, import, and export of banana propagation material. This paper provides an overview of regulatory measures necessary for sustainable development of the banana sub-sector of horticulture in Kenya.

Improved banana planting material in Burundi: the case of AgroBiotec

T. Rishirumuhirwa

AgroBiotec, Bujumbura, Burundi

AGROBIOTEC is a private company founded in 1998. It hosts the first private TC laboratory. Its main objective is to increase banana productivity for food security and sustainable farms management by improving banana clean planting material availability. To achieve these goals, AGROBIOTEC has invested in a TC laboratory and in six nurseries, disseminated all over the Burundi. All the banana varieties micro-propagated (more than 40 cultivars) are provided by the INIBAP Transit Centre located at the KU-Leuven within the Tropical Plants Laboratory. ITC also provides documentation and supports the training program. AGROBIOTEC collaborates with the other partners of the seed system among which are the public sector, the research institutes and universities, International organisations, NGOs, government and other donors development projects, local associations and farmers. AGROBIOTEC produces around 250 000 plantlets yearly (+/- 80% of the total banana vitro-plants distributed in Burundi). AGROBIOTEC faces many constraints among which inadequate laboratory infrastructures, unskilled personnel, chemicals and unavailability of spare parts locally, unfavourable investment policy for the private sector and the economic environment of Burundi. AGROBIOTEC has tried to overcome all these constraints. In particular, it is constructing a new laboratory which will be functional by 2009 and the nurseries will be extended to 10 in Burundi and also spread to the neighbouring countries. The annual production will be increased up to 1 000 000 plantlets and also intend to micro-propagate other crops.

Private tissue culture banana production In Uganda

E. Nsubuga

Agro-Genetic Technologies Ltd, Kampala, Uganda

Agro-Genetic Technologies Ltd (AGT) is the first and only private company in Uganda to use tissue culture (TC) techniques for micropropagation of different crops on a commercial basis. Currently the company produces TC plantlets for banana, coffee, pineapple and aloe vera. The company major clients are NGOs and government agricultural organizations. In Uganda, awareness of tissue culture, and biotechnology as a whole, remains limited amongst the public and farmers. As a consequence, to increase the interaction between farmers and the TC supply system, and to facilitate increased TC awareness and training AGT has established 23 banana nurseries and demonstration gardens. Banana currently constitutes 70% of AGT production (approx. 1million per year). However, high production costs, restricted local availability of essential laboratory facilities and materials, inadequate skilled personnel and a lack of an in-house virus indexing mechanism constitute the major constraints to TC production. Improved governmental support for such high-tech crop improvement options and improved networking of TC producers are viewed as important steps for increasing capacity of TC production towards enhanced crop production in the region.

Parallel Session 5: Genetic Improvement

Venue: Mandhari Room

Time: 1400–1600

Overview of banana and plantain improvement in Africa: past and future

J. Lorenzen, A. Tenkouano, R. Bandyopadhyay, B. Vroh, D. Coyne, and L. Tripathi

International Institute of Tropical Agriculture, Kampala, Uganda

Since an unrecorded introduction from Asia in prehistoric times, banana and plantain (commonly called bananas) have become major food and cash crops in Africa. The 4 million ha of bananas in Africa represent nearly a third of global production. Increased movement of plant material in the past century also introduced pests and diseases that became new constraints to banana production in Africa, and have destabilized banana production with susceptible traditional landraces. Biotic challenges to banana production in the region include fungi, bacteria, viruses, nematodes, and insects. Host-plant resistance, whether by conventional breeding or by biotechnology, is the most economical and sustainable means of managing pests and diseases. In recent decades, progress has been made in identifying sources of host-plant resistance, identifying germplasm in other countries most like original progenitors of African landraces, and developing genomic tools to increase the efficiency of developing resistant lines. Major programs for banana breeding in Africa are located in Nigeria (IITA), Cameroon (CARBAP), and Uganda (NARO/IITA). Banana breeding is slow and land-intense compared to annual crops, so increasing breeding efficiency is a valuable objective. Good progress has been made in introgressing resistance to black leaf streak disease, burrowing nematodes, banana weevils, and *Fusarium* in elite selections. There is room for progress in producing high-yielding varieties resistant to multiple biotic threats with similar organoleptic qualities as traditional cultivars.

Biofortification of banana: a grand challenge in global health

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Vitamin A, vitamin E and iron deficiency are major health problems affecting millions of people in developing countries and are responsible for a significant proportion of the sickness and death experienced throughout these regions. Plant sources of provitamin A (β -carotene), vitamin E (α -tocopherol) and iron are a cost effective and sustainable means of supplying these nutrients to large populations, however, many important staple food crops are low in these essential nutrients. The genetic modification of region-specific staple food crops for increased nutrient content will help alleviate these deficiency problems. This project, funded by the Bill and Melinda Gates foundation through the Grand Challenges in Global Health program, aims to improve the nutritional value of bananas. Bananas are an important staple food for millions of people living in East Africa and as such it is an ideal target for genetic engineering to enhance a number of essential nutrients. We have developed an

efficient transformation system for a number of banana varieties and we are using this technology to transfer a number of genes for the synthesis of provitamin A and vitamin E or accumulation of iron, under the control of constitutive or fruit specific promoters, into Cavendish and East African Highland bananas. These banana varieties are currently being regenerated for field trials in Australia and Uganda, respectively. In addition to production of transgenic banana with improved nutritional value, viral threats to banana production are also being investigated to further improve food security. Surveys of bananas throughout East Africa are being undertaken to determine the spread of six currently identified banana viruses and looking for previously unidentified viruses. Robust diagnostic tests are being developed to these viruses and a region wide strategy for implementation of routine testing, particularly for distribution of tissue culture planting material is being developed.

Novel biotechnological approaches for the improvement of East African Highland banana productivity and utilisation

A. Kiggundu, G. Arinaitwe, D. Talengera, B. Namukwaya, C. M. Changa, P. Lamwaka R. Fungo, J. Muchwezi, and W. Tushemereirwe

National Banana Research Programme, National Agricultural Research Organization, Kampala, Uganda

Germplasm improvement of east African highland banana (EAHB), a staple food in the East and central African region, has been on-going at the National Agricultural Research Organisation (NARO) in Uganda for over 10 years, providing considerable success as well as experiencing numerous challenges. Conventional improvement through crossbreeding poses a difficulty for cultivated bananas due to their high inherent sterility, and being parthenocarpic and polyploid. Their vegetative propagation since domestication has resulted in a narrow genetic base with useful genes generally lacking in the gene pool. Modern biotechnology approaches therefore offer high potential to overcome these obstacles, effectively opening more routes towards improving Uganda's most cherished food. In order to compliment conventional breeding, NARO adopted modern biotechnological approaches for the improvement of banana. Scientists at the National Banana Research Programme have, through various projects acquired infrastructure and personnel capacity to develop a novel transformation system for EAHB as a first step towards harnessing such technology. They have also been able to identify, acquire, clone and evaluate novel genes as sources of resistance to biotic and abiotic constraints as well as other productivity and nutritive traits for banana improvement. Through these projects a collaborative consortium of local, regional and international institutions for research, technology transfer and training has also been successfully nurtured. This paper reports on the progress that has been realized from the various projects, such as optimizing and successfully developing transformation systems for EAHB and use of recombinant DNA technology to genetically improve this crop for resistance against black Sigatoka disease, bacterial wilt, nematodes and weevils. Other areas of research and development include virus diagnostics, architectural trait improvement such as early maturity and delayed ripening, as well as bio-fortification. These technologies are at various 'proof of concept' stages in the genetically modified product development pipeline. The most advanced include the use of two rice chitinase genes *Cht-2* and *Cht-3* for the control of black Sigatoka disease, which are currently under field evaluation in the first Confined field trial of transgenic bananas in Africa.

***In vitro* culture and mutagenesis for banana improvement**

S.M. Jain

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Bananas and plantains are important food crops, ranking fourth in the world. They are grown in more than 100 countries with an annual production around 90 million metric tons, can grow in a range of environments and produce fruit year-round. Banana fruit production is threatened by several major diseases and pests such as black sigatoka, Fusarium wilt and burrowing nematodes. The banana breeding program of edible bananas is hampered by high sterility, triploids and lack of seeds. Few diploid banana clones produce viable pollen, but the major problem with germplasm enhancement is its low reproductive fertility and slow propagation rate. Biotechnology and gene technology, together with mutagenesis and conventional propagation methods can assist in overcoming these problems in developing new banana cultivars. *In vitro* propagation of banana is successful and is routinely used for clonal propagation by commercial companies. On average, annually several millions *in vitro* plants can be produced. Somatic embryogenesis of banana has progressed but is not yet commercially exploited due to highly genotypic dependence. Somatic embryogenic cell suspensions are highly suitable for mutation induction and genetic transformation. Protoplasts would be an ideal system for developing asymmetric and symmetric somatic hybrids, especially for partial genome transfer. However, development of banana protoplasts and doubled haploids is very slow. Nuclear techniques have been used for mutation induction in 154 plant species, both seed and vegetative propagated crops, for their genetic improvement. In our Coordinated Research Project on banana at IAEA, Vienna, Austria, several mutants were isolated for traits such as reduced height, tolerance to Fusarium wilt, early flowering, large fruit size and tolerance to black sigatoka (under multi-location field trials). The prospects of application of molecular tools for marker-assisted selection and breeding and TILLING will also be discussed together with an overview of banana biotechnology and mutagenesis.

Chimerism and its implications to the conservation strategies of the East African highland bananas (*Musa*, AAA-EA group)

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Chimerism in bananas has been exploited for selection of favourable traits both for consumption and commercial purposes. The current diversity of the East African highland bananas (EAHB) is believed to have evolved through chimerism. The role of chimerism in the selection and subsequent conservation of banana cultivars by a community is not clearly understood. It is however believed that farmers play important roles in initiating and adjusting the proportions of cultivars on farm, based on different traits. The purpose of this study was to a) initially determine the levels of chimerism in each clone set of the EAHB ex-situ collections b) establish diversity indices for chimeric clone sets in order to understand the conservation potential of each clone set; c) determine the relationship between chimeric traits with diversity indices and d) compare the similarity between cultivar selection criteria and chimeric characters. Correlation and distance coefficients were used to determine accessions that are similar but not identical on the basis of 61

morphological traits of 192 EAHB accessions of ex-situ collections in Uganda. Diversity indices of the five clone sets of the landraces were then determined in three benchmark sites in Uganda and Tanzania. The diversity indices were correlated with overall chimeric characters in the five clone sets and comparisons were made between cultivar selection criteria and chimeric traits. Chimerism was more frequent in 'Nfuuka' and a positive strong correlation between richness and chimeric characters supports this. There was however, a highly negative correlation between chimeric characters and evenness, 'Nfuuka' and beer indicating lower frequency of types, a one prediction of which clone set would maintain diversity overtime. The traits which were more associated with chimerism and selection criteria of farmers were on bunches and fruits an indication of possible role of chimerism in the conservation of banana diversity on farm.

Analysis of genetic diversity and relationships in East African AAB “Apple” and AA “Muraru” dessert bananas using microsatellite markers

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Simple sequence DNA markers were used in this study to assess the genetic diversity and relationships existing in the East African AAB “Apple” and AA “Muraru” dessert banana cultivars. Using 8 nuclear and 4 chloroplast microsatellite loci, a total of 133 banana accessions, including 64 from East Africa, 49 reference accessions from Bioversity International and 20 Polynesian accessions were evaluated at the University of Hawaii, Manoa. The cluster analysis using UPGMA and based on simple matching and Jaccard's similarity coefficients produced major banana clusters that closely corresponded with the genome composition (AAA, AAA-EA, AAB plantain, AAB dessert, AA and AB) and were able to separate the subjective groups on utilization namely cooking and dessert. The analysis further revealed that the SSR markers could also distinguish between individuals at the sub-group level. The AAB “Apple” dessert bananas were grouped into four subclusters. The four AAB dessert banana subclusters constituted: AAB Mysore or the Indian Apple; AAB “Sukari Ndizi” or East African Apple; AAB Prata or Brazilian (Hawaiian) Apple and AAB Silk or “true Apple”. The AB accessions namely Safet Velchi and Kisubi clustered with AAB “Sil”, while AB Kisukari of Zanzibar clustered with Prata and Sukari Ndizi. The AA “Muraru” cultivars also formed their own cluster with a high similarity to AAA Gros Michel and the Cavendish dessert bananas. This suggests the shared ancestry between the AA “Muraru” and the AAA dessert bananas. The Polynesian AAB plantain and African AAB Plantains both formed one clustered separate from the dessert groups. The AAA East African cooking banana reference cultivars also clustered together separately from other banana groups. Microsatellite markers are sensitive enough to distinguish bananas at the group and subgroup level and AAB “Sukari Ndizi” and AA Muraru are unique groups of dessert bananas that need to be treated as such.

Posters

Time: 1630–1730

Venue: Meister Tent

Plant health

P-PH-1

Feasibility of banana bunchy top virus molecular detection in samples collected under field conditions in the Great Lakes region of Central Africa

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Banana bunchy top virus (BBTV) is the most devastating virus disease affecting spp. This pathogen is spread by banana aphids (*Pentalonia nigronervosa*) or through the use of infected planting materials. Control of the disease is based on promoting the use of non-infected planting materials while taking into account epidemiological data specific to a given region. Presently, countries of the Great Lakes Region of Central Africa (Democratic Republic of Congo (DRC), Rwanda and Burundi) are facing important banana production losses due to this disease. Research to assess the spread of BBTV in the region and its control options was initiated by Bioversity International. The present work was carried out to evaluate the feasibility of BBTV detection in banana samples collected under field conditions in the three countries. Banana tissue was collected from different main banana producing zones in eastern DRC, Rwanda and Burundi using the PhytoPASS kit (DNALis sprl). Recovery of the collected materials was carried out by shaking the PhytoPASS abrasive membrane in 1 ml of KAJI extraction buffer. This rapid agitation generated a suspension containing banana tissue fragments which constituted the primary crude extract preparation. The suspension was then diluted 100 times before serving as the target material for PCR reactions aimed at detecting BBTV infections. BBTV was detected in material from all the sampled banana producing regions. More specifically, 100% of the samples collected in Bugarama in Rwanda were infected with BBTV. The preliminary data shows for the first time that banana materials are easily sampled by the PhytoPASS kit from banana producing areas. However, this sampling protocol should be further fine-tuned to reduce the probability of false negative results. BBTV molecular detection can still be carried out in PhytoPASS samples of up to two months old. The PhytoPASS system could thus be used to record epidemiological data and assess prevailing BBTV isolates in countries where BBTV outbreaks have been reported.

P-PH-2

The alarming spread of banana *Xanthomonas* wilt in eastern Democratic Republic of Congo and its impact on food security and income

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Xanthomonas wilt of banana, caused by *Xanthomonas campestris* pv. *cearum* (XW), is an unforgiving disease. Rather than merely reducing yield, as many diseases do, it causes the fruit to ripen prematurely and rot. Eventually the plant dies. In heavily affected areas of Uganda and eastern Democratic Republic of Congo, where it was first observed in 2001 after decades of being confined to Ethiopia, production losses of up to 80% have been observed, mainly on 'Kayinja', a juice banana known elsewhere as 'Pisang Awak'. Since 2001, the disease has spread to several countries in east and central Africa. It was first observed in the territory of Masisi, collectivity of Bashali, locality of Kitchaga, on the Bwerere hills, 72 km northwest from Goma in north Kivu province, Democratic Republic of Congo. In subsequent years, the disease spread at this location at a speed of around 5 km/year, mainly through contaminated farm tools. During a survey conducted in May 2006 under the framework of the USAID-funded Crop Crisis Control Project (C3P), XW was also observed around Aru, Oriental province (north-eastern Democratic Republic of Congo close to the border with Uganda) and in the region between Beni (north Kivu, Democratic Republic of Congo) and Bundibugyo (western Uganda). Here the disease had most likely spread from infected areas across the border in Uganda. It had also spread over an area with a 50 km radius in Kitchanga and Masisi, south Kivu. A survey conducted in May 2008 under the framework of the Belgian-funded project CIALCA, reported that XW was present in south Kivu (Minova, Kalehe territory). In north Kivu the disease is currently present in the territories of Masisi, Rutshuru, Beni and Walikale, and in the Oriental province the disease is currently present around Aru. The disease has thus spread over an area of more than 500 km (north-south axis). At least two million people in eastern Democratic Republic of Congo are affected by this disease which threatens food security and farm income. The most important means of dissemination are infected planting materials, contaminated farm tools and insect vector transmission. Returning refugees contribute to the spread of this disease as diseased banana suckers are often used to establish new banana plantations. Due to insecurity and inaccessibility of large parts of eastern Democratic Republic of Congo, extension efforts to contain the spread of XW are hampered.

P-PH-3

Contribution to banana and plantain disease and pest study in the territories of Beni and Lubero, Democratic Republic of Congo

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We conducted surveys at 4 sites i.e. Munoli (00°7380'N, 029°2206', 1764 masl), Maboya (00°25364'N, 029°3236'E, 1423 masl),

Mangodumu (00°58'049"N 029°32'632", 1026 masl) and Nzenga (00°31'681"N ,029°70'596"E, 1007 masl). Data was collected using PRA and a diagnostic survey. At each site, we chose five random villages and 30 different random fields. The most common diseases observed were black cercosporiose, fusariose, helminthosporiose, cladosporiose, and pseudostem rotting. Severity of black cercosporiose was 30% in Munoli, Maboya and Nzenga sites. Cooking varieties were most susceptible. The incidence of fusariose was 56.1 and 7% in 'Kisubi' and the dessert banana 'Kalole', respectively. Dessert and plantain bananas were most sensitive to Helminthosporiose with severities of 55.8 and 45.5%, respectively. Incidence in medium altitude was observed to be 40%, whereas in Maboya, the disease was less common (21.4%). Pseudostem rotting was observed everywhere with incidences of 2.7% in Munoli and 9.5% in Mangodumu. Plantain and dessert banana plants had a severity of 10%. Pseudostem rotting was not observed in cooking bananas. Nematode incidence was 28% in Mangodumu and 16-19% in other sites. Weevil infestation rates were 8% in Mutwanga, and Mangodumu and below 2.5% in the other sites. It is important to note that banana *Xanthomonas* wilt is a threat to banana and plantain production in the eastern Democratic Republic of Congo. This disease is already present in 3 provinces (southern Kivu, northern Kivu and the Oriental Province).

P-PH-4

Assessing the spread, cultivar response and seasonal influence of banana bunchy top virus and a fruit peel disease in south Kivu, eastern Democratic Republic of Congo

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Baseline studies and subsequent diagnostic surveys carried out in south Kivu, Democratic Republic of Congo by the consortium for improving agriculture-based livelihoods in Central Africa (CIALCA) revealed that banana is severely affected by diseases, especially in Nyangezi and Kamanyola local areas. Banana bunchy top virus (BBTV) and a fruit peel disease are prominent. In-depth studies of the two diseases were carried out by the Université Catholique de Bukavu in order to assess spread, seasonal influence and cultivar response. Preliminary results revealed that both diseases are well known by farmers. Banana bunchy top virus is more prominent at lower elevations (<1,300 masl), while the fruit peel disease is only present at higher elevations (>1,700 masl). The fruit peel disease (locally named Cibojo) has been in the region for over 50 years. The symptoms start on the fruit peel as tiny black spots, which enlarge to diamond-shaped black lesions which eventually cover the whole fruit peel. The symptoms become very severe during the rainy season (and then especially during weeks with heavy rains) and fruits of severely affected bunches become unsuitable for human consumption. Symptoms are limited to small lesions on the peel during the dry season and fruit pulp is unaffected. Although all cultivars are susceptible, the beer banana 'Nakasimbu' (AAA-EA group) is most affected, while 'Gros Michel' (AAA group) is least affected. Infections mainly appear in fields where the disease had been observed during previous years. Farmers do not carry out any control options. It is postulated that insects make the initial damage to the fruit peel and secondary fungal infections colonize these wounds. Peel samples are currently being analyzed at the Global Plant Clinic (GPC), UK. In the Kamanyola local area (1,000 masl) banana is severely affected by BBTV and is disappearing. Although BBTV

attacks all cultivars, the highland beer banana 'Nakasimbu' is least affected. In recent years, farmers have resorted to replanting their infected fields with this cultivar. The first symptoms of reinfection in newly planted fields only appear after 3 years.

P-PH-5

Presence and molecular characterisation of Cucumber mosaic virus in Cote d'Ivoire

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Banana production in Cote d'Ivoire has increased in recent years in response to reduced prices with coffee and cocoa, and now realises an important source of revenue of through local and export markets. One hundred banana leaf samples that exhibited virus-like symptoms were collected from three different localities of Cote d'Ivoire and analysed for CMV using a Real-Time (TaqMan chemistry) reverse transcriptase method (RT-PCR). CMV was detected in about 95% of leaf samples collected from plantation systems and in 42% of samples collected from banana germplasm and nursery sources. These results confirmed the presence of CMV in banana fields and nurseries suggesting that the planting material could be a potential source of CMV spread in the field. Tests for other banana viruses, including Banana mild mosaic virus (BanMMV) and Banana bunchy-top virus (BBTV), was proved negative for all samples. A 657 nucleotide sequences (218 amino acid) of the CMV CP ORF of 16 Ivorian isolates was analysed and compared to sequences held on GenBank. Nucleotide sequence variability of 0.2 to 2% (0.5 to 1.4 with amino acid) was observed amongst the Ivorian isolates, with sequence similarity as high as 99.2% observed with CMV occurring outside of Cote d'Ivoire. Phylogenetic analysis revealed that CMV infecting banana plants in the three localities in Cote d'Ivoire belongs to subgroup IA. This is the first report on the molecular detection (TaqMan) and sequencing of CMV infecting banana in Cote d'Ivoire.

P-PH-6

A farmers' appraisal of banana pests and diseases and their control in Maragua district, Kenya

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Focused group discussions were conducted to assess the major constraints to banana production in Maragua district. The study revealed that pests and diseases are among the first three major constraints to banana production in the district. Build-up of pests and diseases seems to be on a continuous increase leading to a steady decline in banana yield. Banana weevil and Fusarium wilt were rated as the most important pest and disease, respectively. The other pests and diseases that were regarded as economically important were plant parasitic nematodes, banana thrips, yellow sigatoka and cigar-end rot. The farmers were generally not familiar with plant parasitic nematodes but rated them highly when they learnt that toppling of bananas was attributed to their damage. Trapping and application of ash were the most commonly used methods of controlling the banana weevil while replanting was done in response to toppling induced by nematodes. Most of the farmers had replaced the banana cultivar Gros Michel with members of the 'Cavendish' group which are resistant to races 1 and 2 of the Fusarium wilt pathogen that are

present in Kenya. According to the farmers, all the other methods that they had applied were not effective in controlling the disease. Most farmers considered yellow sigatoka to be mild especially if the banana crop is adequately fertilized and vigorously growing. Some farmers attributed severe damage by pests and diseases to lack of adequate water, low soil fertility, and probably to use of infected planting materials. This calls for a multifaceted approach to the search for strategies of arresting the decline in banana production.

P-PH-7

Fusarium wilt disease in Rwanda: a real threat to apple banana market

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The Apple banana (variety: Kamaramasenge, AAB group) is a promising export fruit in Rwanda, covering only 5.6% of total banana acreage. Fruit is marketed fresh or processed into beverages (juice, wine and liqueur). In the last 20 years, however, the Apple banana productivity has been declining due to fusarium wilt disease (*Fusarium oxysporum* f. sp. *cubense*). The disease was first reported early 1980s in South East region of Rwanda (former Kibungo). It has since spread to the Southern Province (former Butare and Gitarama), and by 2001, fusarium wilt was reported in all banana production regions of Rwanda. Incidence varied from 7.1% to 17.7% per region in a country-wide farm survey in 2001. In 2004, the same farmers were re-visited to record farmers' strategies for the control of fusarium wilt. Most farmers had replaced the susceptible cultivars with locally available highland cooking or brewing cultivars (AAA-EA group). Early 2000, ISAR evaluated a range of cultivars and recommended FHIA 17 and FHIA 25 as resistant to the local strain (race 1) of fusarium wilt. These two varieties have high yield but sensory and organoleptic studies demonstrated that they had an inferior taste to that of apple banana. Consequently, development of new varieties of apple banana with resistance and the desired taste is necessary to sustainably exploit the potential of the fresh fruit export market and banana beverage industry.

P-PH-8

Integrated control of Fusarium wilt of banana

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The global importance of Fusarium wilt of banana has been widely documented. The lack of viable control options make it important to the livelihood of millions of people. In the absence of a single effective control method, control efforts are moving towards the integration of multiple control methods. In this study, the integration of biological and agronomic control methods against Fusarium wilt was investigated. Single and combined application of non-pathogenic, endophytic *Fusarium oxysporum* strains, *Trichoderma harzianum* Eco-T[®], silicon and mulching using macadamia husks were tested against *F. oxysporum* f.sp. *cubense* on bananas under greenhouse and field conditions. Tissue culture banana plantlets, of the cv. Cavendish Williams, grown to 50mm in size, were inoculated by dipping them into a suspension of mycelia and conidia of non-

pathogenic *F. oxysporum* Strain N7 or N16, at a concentration of 1×10^7 c.f.u./ml. They were also fertilised with potassium silicate at 1000 mg ℓ^{-1} for 3wk prior to inoculation with *F. oxysporum* f.sp. *cubense*. In order to induce early disease expression, all banana plants were cold stressed for 3wk at 10°C for 1mo post-inoculation with the pathogen. The non-pathogenic *F. oxysporum* Strains N7 and N16 were effective biocontrol agents against Fusarium wilt of banana. Amendment with potassium silicate to plants exposed to the non-pathogenic *F. oxysporum* strains improved plant health of cold-stressed banana plants compared to those treated with endophytes only. A field trial was conducted at a KwaZulu-Natal South Coast banana plantation, where Fusarium wilt of banana is a serious problem. Banana plantlets were inoculated with the biocontrol agents two weeks before being transplanted into the field. Plants that were treated with combinations of non-pathogenic *F. oxysporum*, *T. harzianum* Eco-T®, silicon and mulch had significantly higher number of leaves, stem height and girth size than single applications of the treatments. Mulching increased growth of feeder roots. Integration of biocontrol with agronomic practices may improve the efficacy of the biocontrol organisms and the health of the host plants, which may be sensitive to environmental stress. For instance, mulching encourages growth of feeder roots and creates a conducive microenvironment, increasing beneficial microbial activity in the soil. This study demonstrated that the combined application of biocontrol organisms, silicon and mulching can provide an effective control option for banana growers dealing with Fusarium wilt in their plantations.

P-PH-9

Control of senescent spotting in banana fruit

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Banana is a fruit crop of Thailand, which plays an important role of economics and nutritional values. There are three banana cultivars grown commercially in Thailand namely 'Kluai Hom Thong' (*acuminata*, AAA group), 'Kluai Namwa' (*paradisiaca*, ABB group) and 'Kluai Khai' (*acuminata*, AA group). After reaching maturation, banana fruits will enter the ripening processes, and undergo physiological, chemical and physical changes, resulting in a good eating quality. Senescent spotting develops during the latter phase of ripening when banana fruits are most desired. 'Kluai Hom Thong' and 'Kluai Namwa' do not develop senescent spotting, while 'Kluai Khai' does upon ripening. Senescent spotting is characterized by the appearance of superficial brown spots or flecks. The appearance of senescent spots begins when the peel becomes yellow with a green tip. At this stage, senescent spots are very small, like pins, light brown in color and can be closely seen by the naked eye. The spots gradually increase in size and number, and become dark brown as banana fruits advance in the ripening process. Senescent spotting does not affect eating quality of banana fruits but it reduces the attraction. Many consumers presume that senescent spotting is a pathogenic disease. In fact, it is a physiological disorder that is a non-pathogenic disease. The development of senescent spotting depends on many factors such as ripening stage, cultivar, atmosphere, temperature, relative humidity, etc. Control of senescent spotting can be effectively done by modified atmosphere and temperature management.

P-PH-10

Understanding the distribution and genetic diversity of *Mycosphaerella* spp. in banana and plantain in Nigeria

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Banana and plantain are an important staple food and source of livelihood for resource-limited farmers in many tropical regions in the world. One of the major production constraints is the Sigatoka disease complex caused by three main species *Mycosphaerella fijiensis*, *M. musicola* and *M. eue*. Sigatoka disease can reduce yield up to 75%. Accurate diagnostic tools are necessary to control the disease for more ecologically friendly production of bananas, food security and improved livelihood of farmers. Knowledge of the distribution, identity, genetic structure as well as pathogen-host interactions will help in optimizing diagnostic and disease management protocols. For this purposes, we conducted disease surveys in Nigeria, to develop a map through extensive isolate collections within different geographical zones. Molecular markers of single nucleotide polymorphism (SNP) types revealed the presence of two species (*M. fijiensis* and *M. eue*) and distinguished different strains within each species. The pathogenicity of these strains was assessed. The frequency of *M. eue* (33% of the strains) is higher than what has been reported implying that this species is gaining more importance than what has been reported. There is an intra-specific dissimilarity of *M. eue* (4.6%) greater than that of *M. fijiensis* (2%). This work constitutes the basis for Sigatoka diagnostic tools that will aid in early detection and timely intervention to control the diseases. This will also unravel the population dynamics of the pathogens for better management of the diseases. Finding different strains and assessing their respective level of pathogenicity will help challenge breeding materials with the appropriate fungi diversity for durable resistance/tolerance. This work is being expanded to Ivory Coast, another big producer of banana and plantain in the region to capture a greater amount of genetic diversity of the fungi in West Africa.

P-PH-11

PCR detection of *Xanthomonas vasicola* pv *musacearum* in infected banana: implication for mat management on wilt control

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A wilt disease caused by *Xanthomonas vasicola* pv *cearum* (Xvm) is one of the most devastating disease of bananas in Uganda. This bacterium has rapidly spread across the region with reports confirmed in Burundi, DRC, Kenya, Rwanda and Tanzania. Disease

management has focused on identification of symptoms in the field followed by removal of infected and neighboring plants, at a great cost to the farmers. The movement of infected, asymptomatic plants for macropropagation may be a significant source of pathogen dispersal. A study was carried out to detect the presence of bacteria along the vertical pseudostem axis of banana plants at different levels of infection. The levels were; (i) male bud brackets just starting to shrivel, (ii) drying of rachis, (iii) one cluster ripened, (iv) two or more clusters ripened. Specific polymerase chain reaction (PCR) assay primers were used to detect *Xvm* at the male bud, the top and middle pseudostems, corms and suckers. Three banana cultivars representing very susceptible and moderately susceptible cultivars were used in the study. In all infection categories, bacteria were detected from the top through the middle and down to the corm of the plants and their suckers irrespective of the cultivar. Irrespective of the infection level, 89.2% of the middle samples, 79.7% of the corm samples and 69.0% of the suckers were positive for *Xvm*. These results imply that suckers borne on mats in which some plants are infected are at high risk of having latent infection by the bacterium. It is therefore recommended that such suckers should not be used as planting materials even when they are asymptomatic. Further, the practice of destroying only the infected plant on a mat as a management tool should be avoided. It is recommended that whole mats be destroyed if at least a plant becomes infected with *Xanthomonas* wilt.

P-PH-13

Antibiotic effects of aqueous extract of honeybee propolis against *Xanthomonas vasicola* pv. *musacearum*

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Xanthomonas vasicola pv. *musacearum* (*Xvm*) is the causal agent of banana bacterial wilt which is currently constraining banana production in Eastern Africa. One mode of transmission is by insect vectors and studies in Uganda have shown that drosophilids, honey- and stingless bees are of particular importance. It is not yet known if bee hives may act as pools for *Xvm* multiplication and spread, or if the propolis antimicrobial defense at hives entrance can eliminate *Xvm*. The present study aimed at investigating the presence of antibiotic compounds and/or organisms contained in water extract of propolis that can be effective against *Xvm*. Fresh propolis from hives was soaked in water for 15 d at 37°C and afterwards filtered through a Whatman® filter paper No. 1 (185 mm diameter). Two types of extract solutions were prepared: a) non sterile propolis extract solution (NSP) and b) sterile-filtered extract solution (SP), prepared by filtering again through a Whatman® sterile filter to remove all living organisms (25 mm diameter and 0.2 µm pore size). Each extract was separately mixed with *Xvm* cell suspension (2 x 10⁶ CFU/ml) at a ratio of 1:4 (v/v, extract/*Xvm* suspension) and 100 µl was added to both non-selective medium (YPGA) and selective medium (SM) (containing 5-fluorouracil and Cephalixin) in 9 cm Petri dishes. The control consisted of *Xvm* cell suspension mixed with sterile water in place of the propolis extract. Bacterial growth was evaluated after 72 h using a scale of 0 to 5, based on colony coverage of the medium surface. Growth of *Xvm* on YPGA was not significantly different between the control and sterilized extract (mean growth scores of 4.9 ± 0.1 and 4.8 ± 0.1, respectively). However the non sterile extract completely inhibited the growth of *Xvm* colonies on both YPGA and

SM media. An unidentified, a gram positive bacterium (PB) was obtained from NSP with mean growth scores of 5.0 ± 0.1 on both media. Subsequent studies consisted of growing a pure culture of PB on YPGA media at the same time as *Xvm* with eight spots of *Xvm* (2 mm diameter each) surrounded by nine spots of PB. After 72h, the mean growth scores were 0.1 ± 0.1 and 4.9 ± 0.1 for *Xvm* and PB, respectively. The *Xvm* colonies showed initial convex growth morphologies when adjacent to PB colonies and were then killed. The present results demonstrate the presence of at least one antagonistic bacterial species in the propolis, suggesting possible suppression of *Xvm* on insect body at hive entrance. These findings warrant further studies for possible biocontrol of *Xvm*.

P-PH-14

Comparative importance and epidemiology of BXW transmission through female and male inflorescences

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Insect transmission of the Banana Xanthomonas wilt caused by *Xanthomonas vasicola* pv *musacearum* (Xvc) is an important pathway for the spread of the disease. While the transmission through the banana male bud is well documented, the distinct transmission via the female inflorescence is not yet known. The present study aimed at comparing the epidemiology and importance of BXW transmission through female inflorescence versus the male bud. The experiments were undertaken in an experimental field in isolated area in NAFORRI forest using east African highland banana cv. Kayinja. For the comparison of epidemiology, inoculum was introduced into the fresh wound left by the dehiscing bracts on the (1) male bud and (2) female inflorescence. Each mat was assessed weekly and data on presence of bacterial ooze on rachis and male bud, rotting of male bud, rachis and pulp, fruit premature ripening, leave and sucker wilting were recorded. Epidemiological features of BXW were similar at advanced stages of infection, independent of infection route. However, at early stages, epidemiology features following infection through male and female inflorescences were distinctly separated using various parameters: (1) the position of first ooze on rachis, (2) order and timeframe between first ooze appearance on rachis and first finger premature ripening, (3) the order and time frame between first ooze appearance on rachis and first pulp rotting, (4) the order and timeframe between pulp rotting and male bud wilting, (5) the order and timeframe between pulp rotting and rachis rotting. Based on these parameters, the relative importance of insect transmission through male and female inflorescence was evaluated. Two groups of plants were studied: (1) plants having well formed bunches before artificial inoculation (MB) and (2) plants which flowered after appearance of ooze in the field (YB). These plants were left unprotected to allow natural spread by insects. The first symptoms from this natural spread were recorded 6 weeks after the introduction of inoculum into the field. Within 15 weeks 98.0% and 64.8% of MB and YB respectively were naturally infected. All the MB infected plants were male bud transmitted. However, the YB infections were in 70.2% and 29.8% of the cases through female inflorescence and male bud transmissions respectively. Results show that insect disease transmission through female inflorescence is high, especially when inoculum source is close during early stages of flowering. Any non-debudded infected plants with ooze on rachis are sources of infection even to debudded plants.

P-PH-15

Evaluation of *Xanthomonas* wilt control options on farm in East and Central Africa

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In the framework of Crop Crisis Control Project (C3P), a capacity building subproject was designed and implemented to strengthen farmers' capacity to diagnose and control the *Xanthomonas* wilt epidemic on farm. A training programme was organized to train trainers at the regional, country and district levels. The trained trainers subsequently trained farmers with respect to *Xanthomonas* wilt symptoms, mechanisms of spread of the disease and the options for controlling the disease. The effectiveness of the training approach was evaluated at the farm level in randomly selected sites and farms in two affected districts in the entire project-participating countries. The results compare competences for diagnosis, mechanisms of spread and control options between countries and across the region. In addition the effectiveness of the measures in the study sites was compared with disease incidence on farm. The results indicate that though some control options may be important at specific stages of the epidemic, effective control will require all control options applied in a complementary fashion. The study also revealed that when applied correctly, the recommended measures will control the disease.

P-PH-16

Phytotoxic factors and potassium nutrition in banana *Xanthomonas* wilt development

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Banana production in Uganda is being constrained by several abiotic and biotic factors. In recent years, however, it has been the emergence of Banana *Xanthomonas* Wilt (BXW), caused by the bacterium *Xanthomonas vasicola* *cearum* (*Xvm*) that has posed the greatest threat. Its control has been through debudding and use of non-infected tools and planting material. A preliminary study was undertaken to determine the presence of chemicals produced by *Xvm* that play a role in either its virulence or pathogenicity. The cell-free crude culture filtrate of *Xvm* was used in a detached leaf bioassay to determine presence of a phytotoxic effect using the susceptible cultivar, Yangambi Km 5 (AAA group). The entire leaf margin showed water-soaking symptoms and became chlorotic within a week demonstrating the secretion of phytotoxic factors by *Xvm*. The effect of potassium nutrition on BXW development was also investigated. Plantlets of the highly susceptible, *Pisang awak* (ABB group) and moderately susceptible FHIA 17 (AAAA group) were regenerated in baby food jars (98.5 mm x 59 mm) containing Murashige and Skoog (MS) tissue culture medium supplemented with BAP (2.5 mg/L). The potassium content of the medium was varied (0.1, 0.5, 1 and 2 times the standard MS concentration of 782.608 mg/L). Plantlets were inoculated with 100 µl of 1 x 10⁸ cfu/ml of *Xvm* culture. Wilt incidence for both cultivars was highest in those plantlets regenerated under 0.1 (83%) and 0.5 (100%) times potassium concentration. The significantly lowest wilt incidence was observed on plantlets produced on twice the normal potassium concentration (17% and 33% incidence for FHIA 17 and *Pisang awak*, respectively. Furthermore, the incubation period prior to visible wilt symptoms appearing was

increased when plantlets were regenerated on twice the normal potassium concentration. Based on these results, control measures can be developed that reduce the production of phytotoxicity factors by *Xvm* and that increase the availability of potassium in banana host plants.

P-PH-17

Potential of sunn hemp for management of plant parasitic nematodes in banana production in Uganda

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Root infecting nematodes are one of the major problems limiting banana production in Uganda, causing up to 100% yield losses. Interventions suitable for nematode management in smallholder farming communities are deficient. This study investigated the potential of sunn hemp (*Crotalaria juncea*) for management of banana root infecting nematodes at four smallholder farms. The treatments included no mulch, mulching with sunn hemp, intercropping sunn hemp with banana at planting, farmer practice involving mulching with elephant grass (*Pennisetum purpurium*) and addition of organic manure. One month after planting, each plant was inoculated with 100 g of nematode-infested roots which included *Helicotylenchus multicinctus*, *Radopholus similis*, *Pratylenchus goodeyi* and *Meloidogyne* spp. Mulching was conducted following inoculation, roots were sampled for assessment every three months over 18 months and the plant parameters: plant height, girth at ground level, number of leaves, leaf length and leaf width were measured monthly. Banana plants mulched with sunn hemp had no *Meloidogyne* spp. in their roots while *R. similis* populations were lower than other treatments. Plants inoculated with nematodes were taller than those not inoculated, and also had longer and wider leaves until the 12th month when growth began to subside. The exact pathway by which sunn hemp affects nematodes and the amount of sunn hemp that is necessary for sustainable nematode management in bananas needs to be established. However, sunn hemp offers an alternative control of some banana root infecting nematodes.

P-PH-18

Systemicity of *Xanthomonas vasicola* pv *musacearum* in flower-infected banana plants

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Xanthomonas vasicola pv *cearum* (*Xvm*: previously *Xanthomonas campestris* pv *cearum*) is a bacterium that causes Xanthomonas wilt of banana and onset in East and Central Africa. The disease is primarily spread by insects which visit the male inflorescence parts, infected planting materials and contaminated garden tools. Inflorescence infected banana plants show 4 different disease symptom stages. The first symptom stage is male bud wilting followed by decaying rachis (2nd stage), premature fruit ripening (3rd stage) and rotting bunches (4th stage). A study was conducted to determine the systemicity of this bacterium after flower infection in order to correlate

different disease symptom stages with the movement and location of the bacterium in the plant. Correlating different disease symptoms with the location of the bacterium in the plant would help to select the control option(s). The study was carried out in Luwero district in central Uganda. Banana tissue samples were collected from the corm, true stem and leaf sheaths of flower infected 'Pisang awak' (AABB) mother plants at the 4 different disease symptom stages (30 plants per stage). In addition, samples were also taken from attached lateral shoots. The samples were taken to the laboratory for *Xvm* isolation. In the laboratory, inner tissues of surface sterilised samples were suspended in 1 ml of sterile water for 5 minutes to obtain a bacterial suspension. The suspension was serially diluted and 10µl of each suspension was spread plated on an isolation medium containing; yeast 5 g/L, peptone 5 g/L, Glucose 10 g/L and Agar 14 g/L, incubated for 5 days at 25°C and observed for *Xvm* colonies. Results showed that flower infected mother plants with male bud wilting symptoms (1st stage) had the bacterium restricted to the upper parts of the true stem. The bacterium had however moved down the true stem up to the base and in some plants it had invaded the leaf sheaths, corm and lateral shoots of plants showing a decaying rachis (2nd stage), premature fruit ripening (3rd stage) and rotting bunches (4th stage). These findings suggest that cutting plants with early inflorescence infection symptoms at the pseudostem base can prevent the bacteria from invading the corm and lateral shoots. Uprooting or the use of herbicides is recommended to destroy plants in more advanced stages of disease development as the bacteria most likely already colonised the corm and lateral shoots.

P-PH-19

Relative susceptibility of banana cultivars to *Xanthomonas vasicola* pv. *musacearum*

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The banana *Xanthomonas* wilt (BXW) is the most devastating disease of banana in Great Lakes region of East and Central Africa. The pathogen kills plants quickly and spreads rapidly making the disease one of the most dreaded in banana. The disease affects almost all commonly grown banana cultivars. Ten banana cultivars commonly grown in the Great Lakes region were screened for their susceptibility to *Xanthomonas vasicola* pv. *cearum*. All were evaluated by injecting bacterial inoculum into the pseudostem of *in vitro* plantlets. Following inoculation the plantlets were incubated under normal laboratory conditions. There were significant differences in susceptibility among cultivars. The beer banana 'Pisang Awak' ('Kayinja', ABB group) and dessert bananas (AAA group) 'Dwarf Cavendish' and 'Giant Cavendish' were found to be highly susceptible. East African Highland banana 'Nakitembe' (EA-AAA group) was moderately resistant. The other EAHB cultivars 'Mpologoma', 'Mbwazirume', dessert cultivar 'Sukali Ndiizi' and hybrids 'FHIA 17' and 'FHIA 25' proved susceptible. Diploid parent *balbisiana* (BB group) was found to be resistant. The susceptibility of various cultivars was further tested with artificial inoculation of potted plants and similar results were obtained. This study demonstrates clearly that the banana industry is under threat as the dessert banana cultivar 'Cavendish' (both dwarf and giant) is highly susceptible to BXW. Field observation indicates that 'Nakitembe', which is moderately resistant, also escapes BXW in the field due to flower morphology (persistent bract). This cultivar can be recommended to farmers for growing in BXW infested fields.

P-PH-20

Generation of technologies for bacterial wilt control in Uganda

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Following the outbreak of the Banana bacterial wilt disease, caused by *Xanthomonas campestris* pv *cearum*, in Uganda in 2001, the national banana research team initiated a number of studies in order to assess and generate technologies for its control. A hypodermic needle injection with bacterium into a petiole or pseudostem was found to be an effective inoculation method. *Ensete ventricosum*, *Canna indica*, and wild bananas were also identified as alternative hosts. A semi-selective pathogen isolation medium containing per L: 1 g yeast extract, 1 g glucose, 1 g peptone, 1 g NH₄Cl, 1 g MgSO₄·7H₂O, 3 g K₂HPO₄, 1 g beef extract, 10 g cellobiose, 14 g agar, 40 mg cephalaxin, 10 mg 5-fluorouracil and 120 mg cycloheximide was developed. Stingless bees (*Plebeina denoiti*) and the honey bees (*Apis mellifera*) were found to vector the bacterium through the moist wounds in male buds. The bacterium was found not to survive for more than 45 days in non sterile environments (field soil and debris). Fresh infected banana material in contact with wounded banana plants were found to initiate infection; injection of plants with 20 ml of dilute glyphosate (1:20, herbicide and water respectively) per banana mat was effective in eliminating whole infected plants. Removal of flower infected plants at an early stage (male bud wilting) completely eliminated the pathogen from the mat enabling its survival. These various technologies were formulated into a cultural control package, along with additional disease avoidance elements, such as avoiding introduction of foreign materials into gardens, remove all male buds, destroy all infected plants and clean all garden tools. This strategy was promoted using participatory approaches, which achieved 60-90% control nation-wide. As a long-term measure, the research team also focused on developing host plant resistance using a transgenic approach. This paper reviews the technologies which have been generated and applied for the disease control.

P-PH-21

Evaluation of distant transmission of banana bacterial wilt in Uganda

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The control of banana bacterial wilt disease requires its spread to be understood. The presence of distant and isolated outbreaks suggests transmission by long distance agents. This study was therefore initiated to establish the role of farm tools, bats and birds in transmission. An inventory of bat and bird species associated with banana inflorescence was undertaken. Traps were also set in infected plantations using Japanese mist-nets to capture bats and birds. *Xanthomonas campestris* pv *cearum* was isolated from their bodies at a 12 hr interval in order to determine its carriers and its persistence on them. Following artificial contamination of farm tools with sap from infected plants, the bacterium was also re-isolated at a 12 hr interval in order to determine its persistence on tools. Infectiousness of the pathogen on these tools over time was investigated by using them to cut healthy banana plantlets. The most common birds visiting male flowers were the Eastern gray plantain eater (*Crinifer zonurus*), double toothed barbet (*Lybina bidentatus*),

sun bird (*Nectariniidae* spp.) and village weaverbird (*Ploceidae* spp.). Bats that visited male flowers included *Aidulon helvum*, *Epomophorus labiatus* and *Epomaps franqueti*. The pathogen could be recovered from these birds and bats for up to five days. The bacterium could also be recovered from a stainless steel knife for up to 20 days, but was only infectious for up to 19 days. On the other hand the bacterium could persist on a steel panga for 8 days but was only infectious for up to 6 days. The ability of this bacterium to survive on birds and bats, which are known to travel for distances over 50 km, therefore suggests that they can transmit it over long distances. The long survival of the bacterium on garden tools, which are moved by traders, potentially over long distances, also indicate that they could be responsible for long distant transmission.

P-PH-22

Development of efficient PCR protocol for detection of BSV infecting East African Highland banana (EA-AAA group) germplasm

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Banana streak badnavirus (BSV) constitutes a major threat to banana production. Persistence and spread of BSV is mainly through banana planting material. BSV-free plants are needed as planting material to prevent cycling of diseased material. Investigations to develop an efficient PCR protocol for detection of specific BSV isolates infecting EAHB cultivars are reported. Fifteen primer pairs were designed based on BSV isolate specific nucleotide sequence in public data base domain. Standard PCR analyses for primer sensitivity were performed on total DNA isolated following CTAB procedure from fresh symptomatic banana leaf tissue of 20 EAHB-AAA cultivars. Prior to BSV detection, gel electrophoresis plus housekeeping PCR analyses utilizing banana 18S and actin primers were performed to assess the integrity of DNA for downstream PCR. Housekeeping PCR revealed that DNA from those cultivars was suitable for PCR. However, there was no consistent degenerate PCR detection of BSV from this presumably good quality DNA utilizing primers 1A/4' and BADNA-F/R reported elsewhere. One third of the isolate specific primers evaluated were consistently sensitive for detection of BSV from the symptomatic leaf tissue samples. It was concluded that these primers offer the best option for PCR detection of BSV and identification of BSV-free EAHB-AAA plants.

P-PH-23

A putative Bowman-Birk serine protease inhibitor (*Musa-BBI*) isolated from a weevil-infested resistant banana corm

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The Rapid Amplification of complementary DNA (cDNA) Ends (RACE) procedure with the GeneRacer cDNA kit (Invitrogen, USA) was used to determine the full-length sequence of a putative Bowman-Birk serine protease inhibitor (-BBI) isolated from banana weevil-infested banana corm material of a resistant cultivar Calcutta-04. The -BBI has a characteristic cysteine residue pattern common to all Bowman-Birk

serine protease inhibitors (BBIs). The full-length sequence of the -BBI was successfully sequenced and introduced onto the National Center for Biotechnology Information (NCBI) database under the accession number EF127893.1. A phylogenetic tree was constructed to show the relationship of -BBI to other BBIs from plants and it clustered closest to BBIs from monocots especially those from sugarcane. From the full-length sequence of -BBI a bio-informatics modeling tools were used to predict its 3-dimensional crystal structure. The -BBI sequence codes for a short length protein, which is rich in cysteine residues and has a crystal structure showing one reactive site, a shape common to single headed BBIs. Furthermore, southern blot analysis shows the presence of the -BBI gene in many weevil-resistant East African Highland banana cultivars.

P-PH-24

Expression of Amphipathic protein (SAP1) as a potential source of resistance against banana *Xanthomonas* wilt

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Banana *Xanthomonas* Wilt (BXW) is currently the most destructive emergent disease of banana, causing over 80% plantation losses where no control measures are employed. It attacks all banana cultivars, including East African highland bananas (EAHB) with no resistance yet detected in any banana cultivar. Due to lack of resistant traits in the available improved breeding lines, genetic transformation appears the most feasible way of introducing this trait into banana germplasm. In this study, we report *Agrobacterium*-mediated transformation of embryogenic cell suspensions of two banana cultivars, 'Nakinyika' (AAA-EA group) and 'Sukali ndiizi' (AAB group), with amphipathic protein gene (*SAP1*) that confers resistance against bacterial diseases in many other crops. Transformed cells were selected on kanamycin supplemented medium and regeneration frequencies of 22.5 and 20.7% were observed for 'Nakinyika' and 'Sukali ndiizi' respectively. PCR analysis of eight lines from each cultivar showed the presence of *SAP1* gene. Preliminary *in vitro* screening of 15 randomly selected lines of 'Sukali ndiizi' identified three lines that have enhanced resistance to *Xanthomonas campestris* pv. *cearum*. All regenerants of the two cultivars will be screened and promising candidates will be evaluated in the greenhouse. The results suggest that the *SAP1* gene could provide significant BXW resistance to banana.

P-PH-27

A review, gaps and future prospects of research on enset *Xanthomonas* wilt in Ethiopia

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Enset (*Ensete ventricosum*) is the most important food crop that constitutes a considerable portion of the daily diet for about 20 million of Ethiopia's population. Apart from its food source, it is used for fiber production, as animal forage, construction and wrapping

material, and medicines. It is also known to conserve soil and enrich plant nutrients through its dropped foliage. The area of enset production in the country is estimated to be over 180 000 ha with the productivity of about 10t/ha/yr. Its productivity is highly threatened by *Xanthomonas* wilt caused by *Xanthomonas campestris* pv. *musacearum*, which is rated as the biggest threat to the production of the crop since its report in 1968. The threat continued causing food insecurity and income losses spreading to all enset producing localities of the country. Since the first report of the disease, its symptom characteristics, distribution, biochemical and morphological characteristics, host range, survival and transmission methods have been studied. In preliminary biochemical and molecular studies, it is suggested presence of strain variability among Ethiopian isolates of *Xanthomonas campestris* pv. *musacearum*. Some cultural and sanitary practices have been identified and some what tried to popularize to the farmers. Different enset clones have been collected from different districts of south and southwestern Ethiopia and many of them have been screened for their resistance or tolerance to *Xanthomonas* wilt and the work is still continued. Among the many clones screened, a few of them showed partial resistance/tolerance to the pathogen and currently these clones are under verification stage to push to the farmers. In this paper, we review, analyze gaps and indicate future prospects of research on enset *Xanthomonas* wilt in Ethiopia.

P-PH-28

Histopathological studies of *Fusarium* wilt of ‘Nanjanagud Rasabale’, a unique cultivar of India

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Banana is more vulnerable to diseases of which *Fusarium* wilt or Panama disease caused by *Fusarium oxysporum* f.sp. *cubense* is the most significant vascular wilt disease causing immense loss of crop. The table choice elite cultivar ‘Nanjanagud Rasabale’ (AAB group) of Karnataka, India is in the verge of extinction due to the serious outbreak of this disease in the traditional banana fields of Nanjanagud taluk of Mysore district. The current study is focused on understanding the process of pathogenesis as a prelude to develop accurate disease management practices. An attempt has been made to trace the pathway of the fungal entry from the soil to the roots and its further progress in the host tissue. One set of disease free tissue cultured plants were inoculated in the field condition and microtome sections of roots and rhizome tissues were done periodically at 30 days interval till the death of the plants. At around 30 days after inoculation (DAI) hyphal penetration was observed in the roots. Anastomizing fungal mat developed in the roots, 30 DAI and the accelerated growth of the fungus was noted subsequently. Around 60 DAI, formation of micro-conidia and chlamydospore was observed in the roots followed by cortical distortion. Even though the roots were heavily infected no external symptoms were evident. The external visible symptoms of yellowing and drooping started appearing with the entry of the fungus into the rhizome and its establishment in it. By this time the infection was in an advanced stage and no control measures could check the disease. Initiation of control measures during the early stages of infection of the roots may help to prevent disease progress in this elite cultivar.

P-PH-31

Preliminary field evaluation of *Trichoderma asperellum* for the control of Panama Wilt in Gros Michel bananas

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Trichoderma asperellum is mass produced in Kenya by the Real IPM Company and is currently undergoing Registration as a biopesticide for control of root knot nematode (*Meloidogyne* spp.) in vegetable and flower crops. Isolate RIPM03 has also proved effective against *Fusarium oxysporum* in pea crops. Its combined efficacy against nematodes and *Fusarium* makes it a potentially useful biopesticide for the control of Panama wilt, *Fusarium oxysporum* f.sp. cubense in the susceptible dessert banana cv. Gros Michel. The low cost production systems used to mass produce RIPM03 and its high rhizosphere-competence enhances its cost effectiveness and economic viability as a potentially important crop protection agent for both small-scale farmers and large scale plantations. *In vitro*, dual cultures on PDA plates confirm that RIPM03 will grow twice as fast as *F. oxysporum* f.sp. cubense, inhibiting its growth by more than 50% and completely overgrowing the *Fusarium* within 7 days at 21°C. Preliminary field trials in Meru District, Kenya have demonstrated the possibility of inoculating organic matter on-farm and incubating *Trichoderma* prior to incorporation in the planting holes. Subsequent growth and health of suckers from infected Gros Michel mother plants which were planted into field soils contaminated with Panama wilt were significantly better than untreated plants. Further work is needed to determine the application rates and field protocols needed to provide long term protection against Panama wilt in this very high risk situation. Tissue cultured plantlets of Gros Michel were inoculated with RIPM03 prior to application of *Fusarium* inoculum and subsequent health and vigor compared to untreated plantlets. *Trichoderma* enhanced the growth of plants and increased the root volume compared to untreated controls. Further work is needed to confirm the field use protocols needed to realize the full potential of *Trichoderma* as a biocontrols for Panama wilt.

P-PH-32

Presence of banana *Xanthomonas* wilt (*Xanthomonas vasicola* pv. *musacearum*) in Kenya: way forward

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Xanthomonas campestris pv. *cearum*, the causal agent wilt of enset (*Ensete ventricosum*) in Ethiopia was for the first time reported in banana on a single farm in Mukono district of Uganda in 2001. By 2005, the disease had spread to the Democratic Republic of Congo, Rwanda and Tanzania. The aim of this study was to establish the status of banana *Xanthomonas* wilt (BXW) in banana orchards in western Kenya. A team of scientists from different research institutions undertook the survey in August and September 2006. Wilted bananas (sp.) were observed in Teso, Bungoma and Busia districts. Symptoms were observed on the inflorescence with the male buds wilting and shrivelling, while fingers on the developing bunch ripened prematurely. The pulp of fruits at early stages of

infection appeared discoloured, changing from white to brown. Leaf wilting was the main symptom observed on young suckers that got infected before flowering. A cross section of infected stems revealed abundant yellow ooze typical of *X. campestris* pv. *cearum* now renamed *X. vasicola* pv. *cearum*. The bacterium was isolated on yeast peptone agar and cephalixin cellobiose agar and identified on the basis of colony appearance. To confirm pathogenicity, the isolated bacterial pathogen was inoculated onto 10 three month-old tissue-cultured plants of the susceptible banana 'Pisang Awak'. All inoculated plants expressed symptoms on the leaves similar to those observed in the field and the bacterium was re-isolated from infected stems. The outbreak in western Kenya is significant because this region produces over 60% of bananas in Kenya, and therefore could have serious consequences on food and income security of small-scale banana farmers. This paper describes the adoption of disease management technologies developed and validated in Uganda for disease management in Kenya.

P-PH-33

Indexing of tissue culture derived banana for Banana Streak Virus (BSV) with the aim of establishing a BSV free mother block

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Tissue culture has become an important technology in multiplication and propagation of disease-free planting materials for bananas. The technology is removing the threat of fungi and bacteria pathogens from the planting material, but not viruses. This leads to farmers acquiring tissue culture planting materials that are sometimes infected with various viral diseases, which affects productivity. Due to Kenyan farmers' practice of acquiring vegetatively propagated seedlings from fellow farmers due to inability to acquire them from renowned supplies, if original tissue culture seedlings were infected, the disease will spread across the banana growing regions. A total of 1040 tissue-cultured banana seedling samples were collected and indexed for BSV at KARI-Kabete laboratory. Immuno-capture PCR primers specific to BSV-GF and BSV-Cav were used. Of the 1040 seedlings indexed, 120, 175, 112, 130, 150, 100 and 75 were of cultivar Chinese dwarf, FHIA 18, Solio, Nusu Ng'ombe, Grand Naine, Williams, Chinese Cavendish and Uganda Green respectively. Leaf samples of tissue culture banana seedlings were obtained from KARI/Thika National Horticulture Research Centre, Jomo Kenyatta University of Applied Technology (JKUAT) and Genetics Technologies Limited (GTL).

P-PH-34

Identification of bacterial and fungal pathogens associated with dieback disease of *Musa* spp. in selected locations in West and Central Africa

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Banana dieback disease (BDD) is one of the major diseases of banana and plantain (spp.) widely distributed in West and Central Africa. Disease symptoms are plant decline, unthrifty growth, stunting, wilting and plant death. Etiology of BDD remained inconclusive, although an isometric virus, named banana dieback virus (suspected as a *Nepovirus*), has been isolated from diseased plants but Koch's postulates has not been fulfilled. In addition, studies carried out in Nigeria, South Africa and Australia implicated epiphytes and endophytes in BDD etiology. In this study attempts were made to identify association of fungal and bacteria agents with BDD-affected plants. Leaf, stem or root portions of 10 randomly selected 3-5 months-old 'Cavendish Williams' (CW) banana were collected from Centres des Recherches Agricole (CRA), Cotonou, Republic of Benin; International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and the Western Highlands of Cameroon (WHC). Tissue samples were placed on selective media for isolation of *Fusarium* sp. and on potato dextrose agar and nutrient agar for other fungal and bacterial organisms. Microbial colonies on growth media were serially diluted and pure cultures raised from single colonies were identified based on morphology and biochemical assays. We isolated *Fusarium semitectum*, *F. oxysporum*, *F. lateritium*, *Botryodiplodia theobromae*, *Curvularia lunata* and *Pseudomonas* spp. at 50%, 37%, 21%, 16%, 13% and 13%, respectively, from the 30 BDD-affected plants from three locations. Purified cultures of each of the microorganisms was inoculated singly and in varied combinations onto 1-2 months-old tissue culture CW banana in order to determine any pathogenic effects on banana plants. None of the test plants showed any symptoms or growth abnormalities at 6 months post-inoculation. The five microbial agents were re-isolated from 38.4% of inoculated plants 6 months post-inoculation. It is likely that these organisms infrequently associated with BDD-affected plants may just be secondary saprophytes and of no pathological significance on banana. It is interesting that *F. oxysporum* and *Pseudomonas* sp. isolated from BDD-affected plants appear to be non-pathogenic strains.

P-PH-43

Banana and plantain foliar disease presence in Côte d'Ivoire

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Banana and plantain are among the most important crops in Côte d'Ivoire. Investigations were undertaken for fungi foliar disease identification on the most commonly used cultivars in Côte d'Ivoire i.e. 'Figue Sucrée' (AA group), 'Grande Naine', 'Williams' (AAA group), 'Corne', 'Orishele' (AAB group). Samples were brought back to the laboratory for disease characterization and fungus isolation. Pure colonies were obtained by single spore isolation on potato dextrose agar in the dark at 26-28°C. Conidial suspensions obtained on V8 agar were calibrated according to each identified fungus (*Mycosphaerella fijiensis* var. *difformis* (1 x 10⁵ conidia/ml), *Cladosporium e* (1 x 10⁶ conidia/ml), *Deightonella torulosa* (1 x 10⁵ conidia/ml). Inoculations were performed for pathogenicity tests by spraying conidia on leaf surface. Disease time evolution was estimated for each fungus. Results show symptoms differed according to the cultivar susceptibility and fungus involved. Leaves inoculated showed disease evolution and symptom development similar to those observed under field conditions. *Deightonella torulosa* was observed on all cultivars. Its first symptoms were visible three to five days after inoculation. *Cladosporium e* was observed on all the cultivars and *in vitro* inoculations showed 'Figue Sucrée' was most susceptible, with the first symptoms observed seven to ten days after inoculation on triploid banana. The first symptoms of *M. fijiensis* were observed on plantain 16 to 21 d after inoculation and necrosis appeared five weeks after inoculation. *Mycosphaerella musicola* was observed on dessert cultivars (AAA group) and plantain (*Musa* AAB group). *Cordana e* was observed on necrotic leaves infected with *M. fijiensis*, *M. musicola*, *C. e* and *D. torulosa*. Despite of the occurrence of *M. fijiensis*, banana and plantain leaves were also colonized by other pathogenic fungi contributing to photosynthetic leaf surface reduction. Disease management should consequently be considered according to cultivar and disease.

P-PH-44

Banana bunchy top virus in sub-Saharan Africa: established or emerging problem?

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Banana bunchy top disease (BBTD) caused by Banana bunchy top virus (BBTV; genus, *Babuvirus*) is the most crippling virus disease threatening the production of banana (*Musa* spp.) in several countries around the world. BBTV infection results in narrow, bunched leaves and stunted, fruitless plants, which eventually die. BBTV is spread by the banana aphid, *Pentalonia nigronervosa*, and also through vegetative propagules. The first record of BBTD in Africa was in Egypt in 1901. Although reported from Angola, Burundi, Central

African Republic, Congo-Brazzaville, Democratic Republic of Congo (DRC), Equatorial Guinea, Gabon, Malawi, Mozambique, Rwanda and Zambia, the virus has been positively identified, using nucleic acid/serological methods, only from Angola, Burundi, DRC, Egypt and Malawi. Nucleotide sequence information of the BBTV isolates from Angola, Burundi and Egypt suggests that these isolates are similar to the South Pacific Group. BBTV introduction into continental Africa possibly resulted through virus infected planting materials, through different entry points. Subsequent intra-continental spread may have resulted due to the movement of infected planting material as well as via the banana aphid, which is widespread in Africa. Despite BBTV presence in Africa for several decades, reports of damaging epidemics on the continent are limited. Owing to the characteristic symptoms of bunchy top-affected plants, it is unlikely that severe outbreaks of BBTV would have been missed. This poses a question whether the virus is well established and widespread in Africa, or still emerging? Information available since the mid-1990's from Malawi suggests that BBTV is well established there, where it causing up to 40% annual production loss. More recently, reports of severe BBTV incidence have emerged from Burundi, Mozambique and Zambia. These recent disease dynamics pose new questions as to whether the virus, or more virulent strain(s) of it, was introduced recently into these countries, or are there recent changes in farming systems (cultivars, practices and even climatic factors) that have led to the surge in incidence and severity of the virus. Surveys have been initiated to elucidate answers to these questions by determining the extent of virus spread, its incidence, and its molecular diversity, and any bottlenecks (natural/cultural) restricting virus and vector spread in Africa. Preliminary findings of this study are presented in this poster.

P-PH-45

Biology of the ensete root mealybug *Cataenococcus ensete* and its geographical distribution in Southern Ethiopia

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The ensete root mealybug, *Cataenococcus ensete*, (Homoptera: Pseudococcidae), was first recorded in Wonago, Southern Ethiopia as a pest of ensete. Mealybug specimens collected on ensete roots were sent to the International Institute of Tropical Agriculture (IITA), Benin station where their identities were confirmed as *C. ensete*. *Cataenococcus ensete* has hitherto been referred to as *Paraputo* sp. During 2004-2005, the biology of *C. ensete* was studied in the laboratory of the Southern Agricultural Research Institute, Awassa, Ethiopia. The females are viviparous and produced 253 ± 17.4 nymphs/female. The average duration of the first-, second- and third-instar nymphs was 16.2 ± 0.5 , 18.2 ± 0.7 and 19.8 ± 0.5 d, respectively. The average life span of the adult female was 49.9 ± 0.5 d. The body length and width of the adult female mealybugs ranged from 2.9-4 mm and 2.5-3.5 mm, respectively when measured with wax covering. Adult female mealybugs could not survive more than three weeks in the soil in the absence of plant material (i.e. food). The distribution and importance of the insect was also investigated in 25 districts of Southern Ethiopia from where a total of 163 sites were visited from July-December 2004. *Cataenococcus ensete* was observed between 1054 and 2977 masl. However, its infestation was severe only between 1400 to 2200 masl. The highest infestation (53.6%) was recorded between 1600-1800 masl. Although mealybugs were recorded in Sidama, Gedeo, Gurage, Bench, Kembata Tembaro and Hadyia zones, and Amaro and Yem districts,

the level of infestation was found high only in Amaro, Gedeo, Sidama and Bench, in which 100, 66.7, 61.5 and 57.1% surveyed farms, respectively were infested. The survey revealed that more than 30% of the total surveyed farms were infested. The highest mean number of mealybugs (81 mealybugs/plant) was recorded in Gedeo zone and the lowest (3.3 mealybugs/plant) in Yem district. Knowledge about the biology and distribution of this species has paramount importance in devising proper management strategies.

P-PH-46

Survivorship and development rates of banana weevils reared on different banana cultivars in the laboratory

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Host plant resistance is one of the tools used in management of banana weevil, *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae). Plants of resistant cultivars have smaller populations of larvae and sustain less damage in the field. This is in spite of a lack of female discrimination between plants of resistant and susceptible cultivars for oviposition. These observations suggest that the explanation for low larval numbers on resistant cultivars lies in larval success. This study was carried out to investigate the influence on weevil survivorship, development duration and adult weight of the cultivar that larvae feed on. Larvae were raised on corm pieces of two susceptible, three intermediate, and four resistant cultivars, resistance categories having been determined from a previous field screening trial. Development period was prolonged in resistant cultivars. However, survivorship and adult weight were influenced by the cultivar to a lesser degree. Moreover, the ranking of survivorship did not correlate with resistance levels observed in the field. The implications of these findings for laboratory screening of cultivars for resistance to *C. sordidus* are highlighted.

P-PH-47

Survey of insects visiting banana male buds in eastern Democratic Republic of Congo and their contamination with the bacterium causing wilt

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A survey was carried out in September 2007 in Mutwanga and Kamango districts of eastern Democratic Republic of Congo to identify the insect species on male flower buds of the banana cultivars 'Kisubi' (dehiscent inflorescence) and 'Nguma' (persistent inflorescence). Insects were collected using an entomological net and killed by exposure to chloroform vapour in a glass jar. Wasps and drosophilids were the two most abundant insect species sampled, with 19.3 ± 2.6 and 64.7 ± 11.6 individuals/male bud, respectively, in Mutwanga; and 24.7 ± 5.7 and 5.5 ± 1.6 in Kamango. Drosophilids were found on 97% and 44% of the male buds sampled at Mutwanga and Kamango, respectively, while wasps were found on 97% and 100% of male buds in Mutwanga and Kamango, respectively. There

was no influence of banana cultivar on insect composition and abundance. Site however did influence composition with drosophilids being more frequent in Mutwanga than Kamango. Drosophilids were however present on weeds in all banana fields sampled as were honey and stingless bees which were not sampled from male banana buds. To test reports that insects carry the causal agent of the banana bacterial wilt, the two most abundant insect species in this study (wasps and drosophilids), were assessed for their internal and external contamination (load) of *Xanthomonas vasicola* pv. *cearum* (Xvm). The bacterium was recovered from insects aseptically using a selective artificial media and quantified using a scale varying from 0 to 5, based on colony coverage of the medium surface. Wasps and drosophilids that carried the bacteria did so both internally and externally. The incidence of drosophilids carrying Xvm was 60 and 54% on 'Kisubi' and 'Nguma', respectively; and for wasps 63 and 67% on 'Kisubi' and 'Nguma', respectively, respectively. The load of Xvm for both insect species on 'Kisubi' was greater externally, with a mean external score of 0.6 ± 0.1 compared to an internal score of 0.4 ± 0.1 . On 'Nguma', the internal load (0.5 ± 0.1) was higher than the external one (0.3 ± 0.1). This study presents the first evidence of the involvement of wasps as insect vectors in the spread Xvm, as well as the first evidence of internal contamination of insect vectors of Xvm which has implications for the spread and management of banana bacterial wilt.

P-PH-48

Evaluation of introduced banana germplasm and matooke hybrids for banana weevil resistance

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The experiment to evaluate the resistance of introduced banana (spp.) cultivars to the banana weevil, *Cosmopolites sordidus*, Germar (Curculionidae: Coleoptera) was conducted at Kawanda Agricultural Research Institute starting from 1999 to 2004. The experiment was planted in a field previously under bananas using tissue culture plantlets of 25 banana cultivars which included representatives of FHIA hybrids, IITA hybrids, clone sets of East African highland banana cultivars (EAHB) (AAA-EA group), and resistant and susceptible checks. The plants were planted in a randomised block design with six replicates. *Cosmopolites sordidus* damage on the corms of recently harvested plants was assessed using the cross section method every three months. The percentage of banana mats disappearing was estimated at the end of the experiment. 'Yangambi' (Km 5), 'SABA', 'Pisang Mas' and 'Pisang Ceylan' were highly resistant while FHIA cultivars ('FHIA 01', 'FHIA 03', 'FHIA 17', 'FHIA 23', 'FHIA 25') were moderately resistant to the banana weevil. The EAHBs were found to be susceptible to the banana weevil. In general, there was greater variability in resistance of the clones to *C. sordidus*.

P-PH-49

Effects of banana weevil damage on plant growth and yield of East African *Musa* cultivars

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The banana weevil has been reported as a serious pest affecting banana, an important staple and food crop in the East African region. An experiment was conducted at Makerere University Research Institute Kabanyolo, Uganda to establish the impact of weevil infestation on spp. growth traits during the first crop cycle. Eight spp. comprising the East African highland bananas (spp. AAA-EA group); 'Mpologoma', 'Lwadungu', 'Nakitembe', 'Mbwazirume' and 'Kibuzi'; the dessert banana 'Sukali Ndiizi' (AAB group); the plantain banana 'Gonja' (AAB group) and the beer banana 'Kayinja' (ABB group) were assessed at bunch maturity. Weevil build-up and subsequent damage to the banana corms during the first crop cycle was low, presenting an average cross-sectional corm damage of 1.2%. Consequently, hardly any significant negative effects on yield and growth traits were observed. The results suggest that several ratoon cycles may be required in order to achieve a high weevil population density build-up to cause substantial reduction in yield and plant growth.

P-PH-50

Preliminary evaluation of the effects of commercial *Beauveria bassiana* on banana borer weevils (*Cosmopolites sordidus*) (Coleoptera: Curculionidae) in Cameroon

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Two laboratory experiments were conducted. In experiment 1, weevils were subjected to the following treatments; T1 (no application of *Beauveria bassiana*, which acted as a control), T2 (rice infected with *B. bassiana*), T3 (*B. bassiana* cultured on potato dextrose agar and diluted in water) and T4 (*B. bassiana* diluted directly in water). In experiment 2, an attempt was made to simulate field conditions under the following treatments; T1 (control, as in experiment 1), T2 (*B. bassiana* solution applied only on soil), T3 (*B. bassiana* solution applied only on surfaces of banana corm pieces), and T4 (*B. bassiana* solution applied directly on bodies of weevils). For both experiments 1 and 2, weevil mortality and numbers with *B. bassiana* mycelia were recorded every two days for one month and 15 days after treatment, respectively. A field experiment was also conducted in a banana plantation in Njombe, Cameroon with the following treatments: 6 g of rice with *B. bassiana* mycelia (TA), 2 g of powdered *B. bassiana* placed on disc-on-stump traps (TB), control (T1), 40 ml of *B. bassiana* solution sprayed around corms of harvested stumps (T2) and 40 ml of *B. bassiana* solution applied on traps. In experiment 1, the highest mean percentage of dead weevils was observed in T3 (54.7%) while highest percentage of dead weevils that developed mycelia was recorded in T4 (83.3%). First development of mycelia on dead weevils was recorded one week after treatment in T3. In experiment 2, the highest percentage of dead weevils was recorded from T2 (45%), while the highest percentage of dead weevils showing

mycelia growth was recorded in T4 (80%). First development of mycelia on dead weevils was recorded one week after treatment in T4. For the field study, percentage of dead weevils was relatively higher in TA (75%) and TB (66.7%), while percentages of dead weevils with *B. bassiana* mycelia were higher for TA (100%) and T2 (100%). First development of mycelia was recorded two weeks after treatment. These results indicate that (i) commercial *B. bassiana* (strain GHA) has potential to kill weevils in the field, (ii) effect on adult weevils is enhanced when *B. bassiana* is cultured on substrates such as rice and applied on traps, and (iii) weevil mortality is higher when *B. bassiana* is applied around corms of harvested stumps.

P-PH-53

Endophytic *Beauveria bassiana*: is it a worthy goal against the banana weevil?

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The entomopathogenic fungus, *Beauveria bassiana*, holds a great potential as a tool for the management of banana weevil *Cosmopolites sordidus*, a major constraint to banana production in the sub-Saharan Africa. However, lack of an economic and effective delivery system remains a limiting factor to maximise field effects for this fungus. Application of *B. bassiana* as an artificial endophyte may provide an alternative and cost-effective strategy for managing *C. sordidus*. Previous greenhouse studies conducted to determine the ability of *B. bassiana* to form an endophytic association with banana plants showed that the fungus colonized banana plant roots, rhizome and pseudostem bases of tissue cultured banana plants. Interestingly, the fungus existed as an endophyte inside different banana cultivars for up to 4 months after inoculation, implying that it can offer protection to a variety of banana cultivars. The current study aimed at investigating the efficacy of endophytic *B. bassiana* against *C. sordidus*. *In vitro* bioassay based on conidial germination, production and biological activity revealed that after an endophytic phase inside tissue cultured banana plants, *B. bassiana* retains its morphological characteristics and pathogenicity against *C. sordidus*. Challenging two months-old *B. bassiana*-inoculated tissue cultured banana plants with *C. sordidus* showed that endophytic *B. bassiana* killed between 53.4-57.7% of the pest population and reduced its damage to the plants by 29.1-62.7%, 45 days after infestation. Our findings demonstrate that as an endophyte, *B. bassiana* offers a promising protection strategy against *C. sordidus* because it directly targets the damaging larvae growing inside the rhizome. Furthermore, endophytic *B. bassiana* requires little inoculum and since the fungus is protected from abiotic and biotic factors, which limit its field application, this provides an economically feasible management strategy for the weevil. However, additional research should be conducted to evaluate the efficacy of endophytic *B. bassiana* under field conditions.

P-PH-54

Development of control strategies against banana weevils *Cosmopolites sordidus* and termites *Microtermes* spp. on banana/plantain in Nigeria

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Cost implications and lack of knowledge for ideal pest control practices are among the major factors limiting banana and plantain production in Nigeria. A trial was designed to control the banana weevil *Cosmopolites sordidus* a major insect pest of banana/plantain and occasional termite pests *Microtermes* spp. by affordable methods. The main plot treatments included the use of available cultivars of AAA group, 'TMPX 5295' and 'TMPX 7152-2' and AAB group, 'Agbagba' and 'Red Ogoni'. Mulching with neem *Azadirachta indica* leaves, application of poultry manure, and minimal application of chlorpyrifos insecticide constituted the subplot. The split-plot trial was arranged in randomized complete block design with three replications. Populations of adult weevils and termites were monitored using split pseudostem traps and core soil samples respectively from 2003-2005. In 2004, significantly lower mean populations of weevils were captured in plots treated with chlorpyrifos insecticide (0.9 weevils/plant) compared to the untreated control (2.8 weevils/plant) with or without manure application. However, weevil and termite populations observed in insecticide-treated plots were not significantly lower than those in the mulched plots during the first or ratoon crops. Significantly higher number of weevil larvae were observed in the untreated plants (2.2 larvae/plant) compared to those that received chlorpyrifos + manure or neem mulch applications (maximum 0.4 larvae/plant). The mean number of weevils in cultivars of AAA group and AAB group were not significantly different in 2004. In 2005, however, significantly lower population of adult weevils and larvae were observed in cultivars of AAA group than AAB group. Cultivar has no significant effect on the populations of termites. The interaction of treatments and cultivar significantly reduced weevil population in the crop, but did not reduce that of termites. Significantly higher mean yields (minimum 15 tons/ha) were obtained in the treated plants than the control (maximum 11 tons/ha).

P-PH-56

Evaluation of the effects of the association between banana 'Vétiver' (*Vetiveria zizanioides* L.) and nematode control

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Banana and plantain production in Democratic Republic of Congo is faced with the existence of several pathogens and pests such as phytopathogenic nematodes, which cause important losses and decrease banana and plantain yield in the. Consequently, a study was conducted in the Mvuazi to estimate the effects of the association between banana and plantain, and nematodes on 'FHIA 21' and 'Yangambi' ('Km-5'). The cultivars above were chosen because their roots contain chemical substances which

show pesticide activity i.e. zizanal, épizizanal and nootkatone. The results of these experiments show that root lesions were reduced by 50% and nematode densities were reduced in roots and the soil. Nematodes *Helicotylenchus dihystra* and *Hoplolaimus pararobustus* had high population densities, while *Helicotylenchus multicinctus*, *Rotylenchus reniformis*, *Pratylenchus coffeae*, *Pratylenchus penetrans* and *Radopholus similis* were significantly low.

P-PH-57

Cytoplasmic RNAi silencing of nematode genes for East African Highland banana resistance

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Plant parasitic nematodes constitute a serious pest to most if not all commercial banana cultivars, including East African Highland bananas (EAHB) cultivated in Uganda. Previously we have demonstrated resistance against nematodes in Cavendish desert bananas by applying the RNAi technology against nematodes collagen gene (*col-5*). Double stranded RNA molecules were expressed in bananas to target the *col-5* gene in the reproductive system of nematodes. In the current project we apply the proven cytoplasmic resistance technology to confer resistance against Sukaali Ndiizi, an exotic desert banana (AAB group) and a matooke cooking banana (AAA-EA group). The present research plan, supported by the Rockefeller Foundation, entails collaboration with National Agricultural Research Organisation in Uganda and the Ugandan Nematode Consortium. The *col-5* ortholog was isolated from an East African strain of *Radopholus similis* and the RNAi construct is currently being prepared. Our presentation describes experiments performed on tobacco and Cavendish banana resistance to *R. similis* and the root knot nematode *Meloidogyne javanica*.

P-PH-58

Arbuscular mycorrhizal fungi (AMF) and root nematode damage in banana plantations of Maragua district, of central Kenya

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The survival and establishment of tissue culture (TC) banana plantlets could be enhanced by root endophytes. The occurrence of arbuscular mycorrhizal fungi (AMF) was surveyed in fifty banana farms, comprising of TC and un-improved banana cultivars, in Maragua district of central Kenya. Mycorrhizal colonization, spore abundance, species richness and diversity, root damage by nematodes and number of functional roots were evaluated. Spore abundance, number of functional roots and root damage were significantly different at farm level. Only functional roots were significantly different among banana cultivars. Root damage showed significant negative correlation with spore abundance. Phosphorus, potassium and nitrogen though not significant, had a negative effect on both spore abundance and root colonization. Twenty two AMF

species were distinguished with spores of *Acaulospora* spp. most abundant. Banana cultivars significantly affected spore abundance with spores highest at rhizosphere of sweet banana 'William', hybrids 'Gros michel' and 'Valery', and local banana 'Kiganda', and 'Giant Cavendish'. Four TC banana cultivars had the highest species richness and diversity. Highest spore abundance (≥ 100 spores per 350 g soil), species richness (≥ 10 species) and diversity (1.5-2.0) was in soils with exchangeable P between 13.8 and 47.8 ppm. Variable effects on AMF were also evident in trap cultures with two banana cultivars (cooking and desert), soy beans and sorghum. Soybean had the highest species richness and diversity, sorghum was highest in spore abundance, while 'Giant Cavendish' was second highest. AMF species showed preference for host in both field and in trap cultures.

P-PH-59

Importance of plant nutrition on banana resistance to the root burrowing nematode *Radopholus similis*

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The root burrowing nematode *Radopholus similis* is a notorious endoparasitic pest of banana plants. The nematode exhibits high rates of multiplication in banana roots causing toppling. Control of this pest has been a challenge in most banana growing areas around the world owing to its cryptic nature. Improvement of plant nutrition is a primary strategy in the integrated management of *R. similis*. This study investigated the role of nitrogen, phosphorus and potassium on resistance to nematode in tissue culture bananas. Compared to the control (with all nutrients), N-deficient plants were associated with significant increase in root densities of *R. similis*, while P and K-deficient plants were similar to the control. Nitrogen is therefore necessary for resistance to nematodes by banana plants.

P-PH-60

Effect of dual endophyte inoculations on plant colonization, and control of *Radopholus similis* and the banana weevil

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The root burrowing nematode *Radopholus similis* and the banana weevil *Cosmopolites sordidus* are major pests of banana in the Lake Victoria basin region. An integrated pest management approach that includes habitat management, biological control, host plant resistance and chemical control is currently used to control populations of the two pests. Biological control strategies with potential to control the banana weevil and *R. similis* include the use of entomopathogenic fungi *Beauveria bassiana* and non-pathogenic *Fusarium oxysporum* endophytes of banana. The current study was designed to investigate the effect of dual endophyte inoculations on control of the two pests in 'Nabusa' (spp., AAA-EA group). Endophytic *F. oxysporum* isolate V5w2 known to reduce *R. similis* numbers in screenhouse pot trials was inoculated together with isolate Emb2.4o, known to be effective against the banana weevil. Root and rhizome colonization was higher

in plants where the isolates were inoculated together, compared with plants inoculated with either of the isolates. This effect was achieved when the spore concentration for the dual inoculation was similar to that for isolates inoculated individually. Between the isolates, V5w2 colonized both roots and rhizomes better than isolate Emb2.4o. Dual endophyte inoculation reduced root damage and *R. similis* populations in roots 60 days after nematode infestation. In plants inoculated with both isolates, weevil damage was also noticeably reduced in the corm periphery, and the inner and outer corms. We conclude that dual inoculation of isolates V5w2 and Emb2.4o results in a synergistic effect in both plant colonization and pest control.

P-PH-61

The potential of soil nutrient supplementation on nematode reproduction and damage in east African highland banana

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Mineral nutrition is a factor for plant growth that can be easily modified, and consequently amending soil to alleviate limitations of nutrient availability and/or absorption is common in many agricultural practices. Through affecting changes in plant growth and development, and particularly chemical composition, mineral nutrition may either increase the resistance or decrease tolerance of a plant to pathogens. The potential of soil amendments for management of plant parasitic nematodes infecting east African highland bananas was explored using hydroponic culture nutrient solution, potassium nitrate, chicken manure and sunn hemp (*Crotalaria juncea*). Generally, the amendments provided conducive soil and biological factors necessary for improved plant growth and activating processes that may reduce nematode survival but a “one-size fits all” approach in utilization of soil amendments to control nematodes seems not to work effectively.

P-PH-62

Evaluation of East African Highland banana land races and hybrids for resistance to banana nematodes in semi-arid Uganda

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Radopholus similis, *Helicotylenchus multicinctus* and *Meloidogyne* spp. are among the major nematode pests of banana worldwide. Nematode management through exploitation of genetic sources of resistance is widely encouraged, especially in resource poor countries. A number of hybrids have been developed and assessed for resistance to nematodes under greenhouse conditions and on station. The current study was designed to test the resistance of the genotypes, both land races and hybrid selections that had exhibited some nematode resistance in screening exercises, in a semi-arid location. Peeled and hot water treated suckers of 51 banana genotypes were planted out into the field in Eastern Uganda, (semi-arid ecosystem) where the natural nematode field populations represented the inoculum. The plot management was divided into one of high or low, represented by application of spear grass mulch (~15 cm depth every six months) or no mulch, respectively, which

additionally provided a low and high stress pressure to plants. Nematodes were sampled at 577 days after planting. East African highland bananas had higher nematode population densities, compared with the hybrids. The population densities of the three main nematode species also varied among the genotypes. The diploid hybrids '8817S-1' and '1537K-1' had the greatest population densities of *R. similis*, while triploid hybrid '9750S-13' had the highest population densities of *Meloidogyne* spp. *Helicotylenchus multicinctus* was obtained only from the diploid hybrid '1968-2' among the hybrids. Genotypes 'Nfuuka', 'Entukura', 'Tereza', 'Kazirakwe', 'Cavendish', 'Yangambi Km-5' (AAA group), 'Sukali-ndizi' (AAB group), 'FHIA-21' (AAAB group), and '2409K-3', '9494S-10' (diploids) were all found to be uninfected by nematodes. Management had no effect on nematode infestation. The study showed that the hybrids appear to be more resistant to banana parasitic nematodes than the land races, but which needs to be confirmed with progress of the study. Further study will also assess the impact of management on durability of resistance under sub-optimal water availability conditions.

P-PH-63

A real-time PCR assay for detection and relative quantification of the banana nematode, *Radopholus similis*

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A standard curve based real-time PCR method was developed for the detection and relative quantification of the burrowing nematode *Radopholus similis*, a major pest in banana (spp.) growing regions worldwide. SYBR green dye which binds to double stranded DNA is used to detect PCR products, its fluorescence increasing as the amount of DNA increases. Using a standard curve, precise numbers of nematodes can be estimated by comparing threshold cycle values to the crossing point values of the linear regression line of the standard curve. Primers were designed to amplify a portion of the internal transcribed spacer (ITS2) region of the rDNA and used for optimization of both conventional and real-time PCR. Three standard curves based on three independent DNA extractions from 2000 mixed stages of *R. similis* were generated using ten-fold serial dilutions ranging from 1 to 0.0001. Selected standard curves had correlation coefficients (R^2 values) between 0.98 and 0.99 and acceptable levels of variation based on standard deviation values between and within independent runs. Precise numbers of nematodes were then used to determine the sensitivity and accuracy of the standard curves in estimating nematode numbers. The real time PCR SYBR green method can be used to detect and quantify *R. similis* extracted from root or soil samples on the basis of the number of DNA molecules and thus providing a quick way of estimating nematode numbers in a given sample.

P-PH-64

Use of endophytic fungi for control of nematodes in tissue culture bananas

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A study was carried out at Kenya Plant Health Inspectorate Service, Plant Quarantine Station to evaluate the efficacy of three endophytic

Fusarium oxysporum isolates obtained from Uganda as biocontrol agents of banana nematodes in screen house trials. Endophytes were inoculated into two tissue culture banana varieties Giant Cavendish and Grand Naine two months after weaning. Four weeks after endophyte inoculation, plants were inoculated with 1200 *Pratylenchus* spp. in mixed stages and harvested after twenty weeks. At termination nematode damage expressed as percentage root necrosis and nematode population was determined. Endophyte inoculation into tissue culture bananas significantly reduced nematode damage and population density in inoculated plants when compared to control treatments. Percentage root necrosis in inoculated plants was reduced by 20% while nematode population was reduced 40%. The three isolates did not show variations in their ability to suppress nematode damage and population. From this study the three endophytic isolates offer potential for biological control of banana nematodes.

P-PH-65

Management of banana nematodes using fungal endophytes

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Surveys were conducted to determine the prevalence of nematodes and banana weevils in two banana growing regions in Kenya i.e., Meru district (Altitude: 1050 Masl, 06° 34'S, 037° 46' 23' E) and Mombasa (17 Masl 03° 45' S 0° 03' 40' E). Healthy appearing plants in heavily infested fields were sampled for endophytic fungi isolation. Endophytic fungi were isolated from the plant roots, the corm, pseudostem and the pseudostem base. A total of 2,455 *Fusarium* spp counts were isolated from the two regions. *Fusarium oxysporum* species was the most prevalent endophytic fungi from banana roots and corm. They constituted 15.5% and 44.6% of all fungal isolates from Meru and Mombasa districts respectively. Twelve isolates belonging to *F. oxysporum* spp. were selected for *in vitro* bioassays against two major species of banana parasitic nematodes in the two regions i.e., *Pratylenchus goodeyi* and *Helicotylenchus multicinctus*. The selected species of the endophytic fungi were cultured in Potato Dextrose Broth (PDB) media for seven days. Fungal filtrates from the twelve isolates were obtained after sieving and centrifuging PDB media. One millilitre of the filtrate was used for each treatment consisting of one hundred nematodes suspended in 1 ml of distilled sterile water in sterile 5ml Bjorn bottles. Each treatment was replicated three times and the experiment was laid out in complete randomised design. Mortality and paralysis were recorded after 3, 6 and 24 hours time intervals. Corrected mortalities were calculated using Abbott's formula. The mortality did not significantly vary with the time of exposure. Culture filtrates of *F. oxysporum* isolates significantly differed on their mortality effects to the nematodes. The isolate 2MR23 caused the highest percentage mortality of 90% on *Helicotylenchus multicinctus* after the 24 h exposure. Equally, the isolate V5W2 caused the highest percentage mortality of 71.9% on *Pratylenchus goodeyi*. Endophytic fungi can therefore offer protection against nematodes in tissue cultured bananas.

P-PH-66

Comparative assessment of red *Acalypha* leaf extract, hot water and boiling water treatments on plantain establishment and nematode damage

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An experiment was laid out at the crop section of the Teaching and Research Farm of the Federal University of Technology, Akure to investigate the comparative effect of red *Acalypha* leaf extract, hot water and boiling water rhizome dips on plantain establishment and nematode damage. The treatments were paring, further dipping pared suckers in crude water extract of red *Acalypha* leaf for 5, 10, 15 and 20 min duration, hot water treatment at $52 \pm 2^\circ\text{C}$, boiling water treatment at 100°C and non-pared control. Establishment count data was taken and growth parameters measured at 44, 55, 70, 84, 98 and 111 d after planting. Destructive sampling was carried out 55, 84 and 111 d after planting, respectively. Paring enhanced plant resistance to harsh environmental conditions and dipping of pared rhizomes in red *Acalypha* extracts for 15 min before planting seemed to further confer resistance to harsh environmental conditions on the plant. Only the 20 min dip in extract showed a trace of phytotoxicity on plant emergence and growth. Across the sampling dates, 15 min dip in red *Acalypha* extract and hot water treatment gave the best results in the vegetative performance of the plant in this study. There was inconsistency in the root and rhizome damage results but with an indication that 15 min dip treatment could best reduce these damages and also nematode densities.

P-PH-67

The use of indigenous arbuscular mycorrhizal fungi for improved plantain production and nematode management in Nigeria

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In Nigeria, plantain (AAB-group) is a major staple crop providing ~10% of Nigerian dietary carbohydrates. Among the various production constraints, plant parasitic nematodes pose one of the more serious threats in Nigeria. Nematode management options however, are relatively few or poorly employed in general. While the use of synthetic pesticides can be effective, their application is limited by lack of availability or high cost. The impact of the biocontrol and biofertilizer agent arbuscular mycorrhizal fungi (AMF) was therefore assessed for their potential to improve plantain productivity and reduce nematode damage. A mixture of AMF isolates (*Glomus mosseae*, *G. clarum* and *Glomus* sp.) recovered locally from plantain rhizosphere, were applied at a rate of 240 spores per plant in a field experiment using healthy, pared and hot water treated 'Agbagba' suckers. The effects of 5,000 mixed nematode species inoculation (*Meloidogyne incognita*, *Hoplolaimus pararobustus*, *Helicotylenhus multicinctus*, *Radopholus similis* and *Pratylenchus coffeae*) were investigated, with and without inoculation of AMF, compared with AMF inoculation only and further compared against a nematicide

control (Rugby -10G (cadusafos) applied at a rate of 10 g/plant. The application of AMF to plantain suckers later inoculated with nematodes enhanced crop growth, improving bunch yield per plot, but did not necessarily reduce nematode densities, compared with nematode inoculation only. Plant root weight, length and health were superior and AMF application increased sucker production and reduced the number of days to 50% flowering. Application of nematicide improved growth and yield similar to AMF application. The results indicate the potential for harnessing AMF biodiversity in Africa for improved crop productivity and pest management.

P-PH-69

Evaluation of some low-input options for the management of nematode pests of plantain (*Musa* spp.) in southwestern Nigeria

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An experiment was conducted at the National Horticultural Research Institute's experimental field between July, 2003 and January 2005 to determine the effect of some cultural practices on plant parasitic nematode infestation on the growth and yield of plantain 'Agbagba'. The treatments included corm paring / hot water root dip, *Tithonia diversifolia* leaf mulch and combination of *Tithonia* leaf and hot water root dip. The untreated plantlets served as the control. Results showed that in all the assayed soil and root samples, the control plots recorded the highest populations of nematodes *Meloidogyne incognita*, *Helicotylenchus multicinctus* and *Radopholus similis* while the lowest populations occurred in plots with the treatment combination of hot water root dip and *T. diversifolia* mulch. Hot water and *Tithonia* mulch- treated plantain followed by *Tithonia* mulch and hot water dip treatment significantly enhanced plant height number of leaves and sucker production. It caused early flowering and fruiting and significantly increased bunch weight. This practice is recommended for plantain producers in organic agriculture production system.

P-PH-70

Rehabilitation of *Xanthomonas* wilt destroyed banana farms in Uganda

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Xanthomonas wilt, a non discriminatory disease of banana, caused by *Xanthomonas vasicola* pv. *cearum* was first reported in Kayunga district in Uganda in 2001. The disease causes up to 100% yield losses infected farms. This has threatened food and income security of poor resource farmers who grow the crop. Plant destruction/ removal followed by a fallow period or crop rotation with non-host crops and subsequent replanting with clean planting materials could restore banana plantation. However, knowledge of the duration an appropriate fallow or crop rotation period is not available. Neither did the farmers know the most cost-effective method of destroying infected fields. A study to determine the most appropriate fallow period to avoid re-infestation when re-planting with clean planting materials, and the most effective method of destruction of infected plants was carried in Luwero district in central Uganda. Trials were

carried out at three sites in fields with 68-76% of mats infected at the beginning of the experiment. The fields were divided into three equal plots. In the first plot plants were killed by injecting 2,4-D into pseudostems, in the second plot, plants were manually cut down and their rhizomes dug out, while in third plot, plants were cut down at ground level and sucker re-growth was continuously removed. The banana plant debris was removed from the plots and piled on ridges between the plots. Replanting started one month after clearing the diseased plants and was done monthly up to eight months after the onset of the trials. Tissue culture plantlets of 'Pisang Awak' (AABB group) and 'Mpologoma' (AAA group, East African Highland subgroup) were used. Each row consisted of 10 plantlets of 'Pisang Awak' and 10 of 'Mpologoma' which were randomly planted. An economic viability analysis of the different options to destroy infected plants was carried out. Data on material and labour costs, and farmer's preferences were collected by interviewing farmers using a pre-tested structured questionnaire. Results indicate that plantlets planted after a one-month fallow period had 25% survival rate, while plantlets planted after seven and eight months of fallowing had a 100% survival rate. This suggests that the cleared *Xanthomonas* wilt infected farms need a fallow period of at least six months. Generally more dead plants were recorded with 'Mpologoma' than 'Pisang Awak', suggesting that cultivars may respond differently to *Xanthomonas* wilt soil borne infections. Incidence of re-infection was highest in the continuous cutting plots and lowest in plots where plants had been completely uprooted. This indicates that the bacterium could not survive in the soil free of host tissue for long. In the herbicide-treated plots, the bacterium probably survived in decaying debris from the rhizomes and roots, resulting in intermediate levels of re-infection. Thus complete uprooting of infected plants and removing plant debris onto ridges is the best option for control. However, the economic viability analysis indicated that farmers preferred to use herbicide compared to uprooting because complete uprooting is laborious and expensive. The use of herbicide is hence recommended followed by a 6 month fallow or crop rotation period.

P-PH-71

Garden tool transmission of *Xanthomonas vasicola* pv. *musacearum* on banana and enset in Ethiopia

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Xanthomonas wilt caused by *Xanthomonas vasicola* pv. *cearum* has been an important constraint to enset, *Ensete ventricosum* and banana in Ethiopia. It was postulated that *Xanthomonas* wilt has a similar epidemiology as the other banana bacterial wilts such as Moko, Bugtok disease and banana blood disease which are known to be transmitted by insect vectors and garden tools. A study to determine the role of garden tools in the transmission of *Xanthomonas* wilt was carried out on enset in a greenhouse at SARI, Awassa, Ethiopia and on 'Pisang Awak' (AABB group) in the field at Amaro, Southern Ethiopia. A contaminated knife was used to infect the plants, while the control consisted of cutting plant parts with a clean knife. The treatments in the greenhouse trials comprised: cut green leaves, cut broken green leaves (i.e. break the leaf petiole and cut off the leaf at the leaf lamina side of the point of breakage), cut dry leaves, cut the pseudostem, cut roots. Similar treatments were carried out on the field-grown 'Pisang Awak' plants. However, the treatments de-suckering and de-budding were added. De-budding was done by cutting off the male bud with a contaminated machete,

while the control consisted of breaking off the male bud with a forked stick. In addition, bacterial ooze was smeared on fresh and dry flower and bract scars at the male part of inflorescences. Results indicate that all plants (100%) of enset and banana when cut in the pseudostem with a contaminated machete, and all banana plants (100%) when de-budded with a contaminated machete got infected. Similarly, cutting green leaves and cutting broken green leaves resulted in a high disease transmission of respectively 67% and 62% in banana and 58% and 54% in enset. Similar high transmission rates (90%) were obtained for de-suckering on banana. On the other hand, cutting roots with a contaminated machete resulted in low transmission levels, with 20% in bananas and 25% in enset, suggesting that tool infections mainly occur above ground. This calls for rigorous tool disinfection, while de-suckering and de-leafing in highly infected fields should be avoided. De-budding should be carried out with a forked stick.

P-PH-72

Mycorrhizae inoculation with exotic and indigenous inoculum in two substrates and the growth of the 'Giant Cavendish'

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A comparison is made between two Arbuscular mycorrhizal fungi (AMF) inoculation trials on growth of 'Giant Cavendish'. The first study evaluated the effect of four exotic AMF species (*Glomus etunicatum*, *G. mosseae*, *G. intraradices* and *Gigaspora albida*) in sterile sand substrate, and the second examined the effect of an exotic *G. etunicatum* and mixed inoculum of indigenous AMF species from banana plantations in Kenya, established in sterile sand and conventional nursery media from Jomo Kenyatta University of Agriculture and Technology (JKUAT) banana nursery. The sand in both cases was enriched with Hewitt nutrient solution and the conventional nursery media was treated with furadan and DAP. Inoculation with AMF significantly enhanced plant height, leaf surface area, shoot dry weight, nutrient uptake and to a slight extent number of leaves when 'Giant Cavendish' was inoculated with *Glomus* spp. The effect was however species specific, with *Gigaspora albida* showing no effect on all growth parameters. The effect was more evident at 18 and 22 weeks after planting. In the second experiment, inoculation had significant effects on plant height, leaf width, leaf length and leaf numbers from week 8 to maturity (week 20). This was however substrate dependent. Conventional media inoculated with AMF was better than non-inoculated media. Although sand media was also better than non-inoculated sand substrate, it was slightly better than conventional media. Arbuscular mycorrhizal fungi inoculation also highly enhanced growth of all plant parameters.

P-PH-73

Influence of arbuscular mycorrhizal fungi on growth performance of selected tissue cultured banana cultivars in Kenya

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Banana is a staple food for about 70 to 95% of the total population in regions where it is grown. In Kenya, banana is an important horticultural crop in terms of area and income generation, where an estimated 74,000 hectares is cultivated (~2% of total arable land). In recent years there has been a rapid decline in banana production, due mainly to declining soil fertility, pests and diseases, drought and poor planting materials. However, *in vitro* Tissue Cultured (TC) bananas are increasingly replacing conventional planting material which provide diseases-free quality plants, but which are also free of beneficial microbes such as arbuscular mycorrhizal fungi (AMF). The use of AMF in TC technology may act as an important biological factor contributing to nutrient use efficiency, and has been shown to improve growth and post-transplant performance of several micropropagated species, in addition to suppressing plant parasitic nematode populations. The current study aimed to establish the effects of inoculation with AMF isolates (*Glomus etunicatum*, *Glomus intraradices*, *Glomus mosseae* and *Gigaspora albida*) on the performance of the five most popular TC banana cultivars under greenhouse conditions. Results showed that root colonization with *Glomus* species had beneficial plant growth effects. Banana plantlets inoculated with *Glomus* spp. performed better than those inoculated with *Gi. albida* and non-AMF plants for all parameters measured, irrespective of the cultivar, although variation in cultivar response to AMF was observed. Plant response was more evident at 18 and 22 weeks as opposed to 8 weeks after inoculation. Results indicate that bananas are dependent on AMF and that inoculation at the hardening stage can be effective in enhancing growth of TC banana plants.

P-PH-74

Botanicals for the management of *Radopholus similis* in bananas

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Radopholus similis, the burrowing nematode, which causes major yield losses in banana, is readily managed through the use of synthetic pesticides. However, use of many of these pesticides is becoming discontinued as a result of their environmental side-effects, while in some parts of the world, pesticides are little used. Biologically based methods of control and those locally available are therefore being sought. This study reports on the potential of leaf material (botanicals) of three locally available annuals and pounded neem seed for their efficacy to control *R. similis* on the East African Highland banana 'Mbwazirume'. Leaf material (160 g) from *Tithonia diversifolia* (shrub sunflower), *Tagetes* spp. (African marigold), *Crassocephalum crepidioides* (Crassocephalum) and *Azadirachta indica* (neem) seed cake were applied to the base of planted suckers in 30 litre pots on a two-monthly basis beginning one month after 1000 *R. similis* inoculation, with treatments arranged with or without nematodes in a factorial manner. The experiments were terminated

nine months after planting. Application of all botanicals significantly increased plant height and number of standing leaves compared with treatments with no botanical applied. The number of dead roots and *R. similis* densities were lower where *C. crepidioides*, *Tagetes* spp. and *T. diversifolia* were applied compared with nematode only controls. Live root numbers were higher following botanical application without nematodes and where no botanical or nematodes were applied compared with botanical application together with nematodes, and nematode only treatments. *Azadirachta indica* seed cake application did not significantly affect nematode population densities.

P-PH-75

Enhancing smallholder banana productivity and market access through improved plant health

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Banana production is a major source of livelihood for many farmers in Kenya, majority of who are smallholder farmers. The yields and fruit quality of bananas from these farms are typically low compared to those from commercial plantations due to pressure from diseases, pests, nematodes and low soil fertility. These bananas can not meet the requirements of sophisticated markets and prices offered are therefore low. The cost of production inputs for improvement of soil fertility as well as pest and disease management are beyond the reach of the majority of smallholder banana farmers. The continuous planting of bananas on the same land, due to land limitations, without the use of external inputs further exacerbates these problems. Recent studies show that smallholder banana productivity may be reliably improved through the use of newly developed plant health management options. The use of some organic amendments alone has been shown to suppress populations of parasitic nematodes by between 75-96% in controlled experiments, while contributing substantial amounts of essential nutrients for plant growth and providing suitable substrates for the colonization and proliferation of beneficial microorganisms. The use of *Trichoderma* spp. and solarization has also been shown to significantly inhibit the invasion of *Fusarium oxysporum* f.sp. *cubense* in naturally infected soils. The integrated use of these options together with clean planting materials have the potential to i) reduce the incidence of important banana pests and diseases by up to 100%, ii) improve banana productivity and quality and iii) provide farmers access to better markets, especially the more lucrative organic and export trade.

P-PH-76

Plant health management in Uganda

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In Uganda, bananas once established and properly managed will stay on the farm for a long time. Farmers need all the necessary help they would get in form of sound advice and technical information if all the required management practices are to be put into practice in order to ensure high productivity in bananas. Through National Agricultural Advisory Services (NAADS), farmers are taught practices such as land preparation, proper selection of planting materials, pruning, weeding, proper fertiliser application, proper soil fertility management, and pest and disease control among others. The level

of management determines the health and therefore the performance of the banana crop. The most common pests of bananas are the banana weevil and nematode, and the most serious disease is the banana bacteria wilt. It's important to control these through proper selection of planting materials, use of mulch, liquid manures, and composite manures. These measures help to increase soil organic matter and the plants are able to resist or tolerate pests and diseases.

Another method of pest control is through proper management of harvesting materials whereby after cutting off the pseudo stem, the ground rhizome is covered with a banana leaf sheath. After 2-3 days, the leaf sheath is uncovered and weevils destroyed. During harvesting, all old rhizomes are cut off, but care is taken not to disturb the roots. The splitting out of the rhizomes and pseudo stem with a panga /manually is done. These are then used as mulch. Ash and cow urine has also been used successfully in pest and disease management in bananas. However, the extension agent farmer ratio is still low (1: 2000) resulting into insufficient delivery of the knowledge to all the farmers hence unexpected poor management of bananas still exists in Uganda.

Post-harvest

P-PO-1

Relative contribution of banana and plantain products to the nutritional requirements for iron, zinc and vitamin A of infants and mothers in Cameroon

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Banana and plantain play a substantial role in people's diet in Cameroon. A survey was carried out in 240 households in four localities to determine the daily consumption of banana and plantain-derived foods and the contribution of these foods to iron (Fe), zinc (Zn) and vitamin A intake by children below 5 years of age and mothers. The daily consumption level was assessed by a 24-h dietary recall during three consecutive days. The Fe, Zn and β -carotene (precursor of vitamin A) contents of banana and plantain products were determined and the bioavailability of these micronutrients estimated using the phytate:Fe and phytate:Zn molar ratios. On a dry weight basis, Fe content in banana and plantain-based foods ranged from 0.8-1.3 mg/100 g; Zn content from 0.2-0.4 mg/100 g and β -carotene content from 336-724 mg/100 g. Phytate content was between 0.17 and 1.23 mg/100 g, with phytate:Fe and phytate:Zn molar ratios above the estimated bioavailability thresholds of 10–14 and 15, respectively, for all dishes. The daily quantities consumed by rural and urban subjects were not significantly different. The daily supply of Fe by banana and plantain to children and mothers was 5 and 2%; Zn supply was 3 and 4%, respectively. In contrast, the daily vitamin A supply by banana and plantain foods was relatively significant, reaching 13% on average/day for both children and mothers. In certain cases, this contribution was as high as 20%. Estimated bioavailability of Fe and Zn is low in banana and plantain, therefore banana and plantain poorly contribute to Fe and Zn intake in the households. However, the crops are a good source of β -carotene and can make a substantial contribution to meeting vitamin A requirements of children and their mothers.

P-PO-2

Transformation de la banane plantain en Friandises et valeurs ajoutées

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Dans les recherches sur la banane plantain, nous avons trouvé que la banane plantain est un produit qui s'utilise sous toutes ses formes y compris tous ses éléments avec la banane plantain la pauvreté sera réduite car nous avons découvert que le plantain a des valeurs ajoutées telles que : le sel gemme, le whisky, la farine et bien évidemment les friandises sur lesquelles nous travaillons actuellement et aussi la sève qui coule sur le tronc et sur la peau en est un médicament.

P-PO-3

Influence des stades de maturation sur les polyphénols totaux de quelques cultivars et hybrides de produits au Cameroun

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Les composés phénoliques sont des antioxydants naturels qui interviendraient dans la réduction de certains cancers et de certaines maladies cardiovasculaires. Ils contribuent aux propriétés sensorielles associées à la qualité des fruits et interviendraient dans le changement de la coloration observé pendant le stockage et la maturation des fruits. Les bananes et les plantains sont des cultures essentielles pour la sécurité alimentaire de nombreux pays du sud. Les fruits de bananes dessert sont également très consommés dans les pays du nord. Les teneurs en polyphénols totaux des cultivars et hybrides de ont été déterminées pendant leur mûrissement. Les pulpes de (3 hybrides de type plantain, 13 cultivars de plantain, 5 cultivars de banane à cuire et 10 cultivars de bananes dessert) aux stades 1, 5 et 7 de maturation ont été séchées modérément pendant 48h à 65°C puis broyées. Les polyphénols totaux (PPT) ont été extraits et dosés par spectrophotométrie à 760 nm en utilisant le réactif Folin – Ciocalteu. Les résultats ont été exprimés en µg équivalent acide gallique par rapport à 100g de matière sèche (µg EAG/100g ms). Au cours de la maturation post récolte de la pulpe du *CRBP755* (AAA), les teneurs en PPT évoluent en forme de cloche comparées à celle des 2 autres hybrides de type plantain : *CRBP39* (AAAB) et *FHIA21* (AAAB) ; qui augmentent continuellement. A la récolte, les teneurs en PPT des cultivars de plantains sont inférieures 100µg EAG/100g ms, à l'exception de celles de *Kelong Mekintu* (139,09µg EAG/100g ms). Au cours du mûrissement de ces pulpes, leurs teneurs en PPT augmentent significativement au seuil de $P < 5\%$ et dépassent parfois 540µg ; il en est de même pour les bananes à cuire à l'exception de celles de *Popoulou CMR* qui diminuent entre les stades 5 et 7 de maturation. Au stade 7 de maturation, les teneurs en PPT des bananes dessert diminuent significativement ($p < 5\%$) ; cependant elles restent nettement supérieures aux valeurs observées à la récolte. Les pulpes de quelques cultivars et hybrides de bananiers et plantains étudiés sont donc des sources potentielles des composés phénoliques. Les teneurs en PPT des pulpes de varient significativement pendant le mûrissement en fonction des cultivars. *Kelong Mekintu* et *Popoulou CMR* contiennent les taux les plus élevés de polyphénols totaux au stade 1 de maturation et pourraient fortement être diffusés et recommandés pour une

meilleure valorisation sur le double plan alimentaire et technologique ainsi que de l'amélioration variétale des bananiers. Toutefois, il convient d'évaluer l'effet des traitements de transformation sur cette composition en PPT.

P-PO-4

Comparative study on juice quality and consumer preference for two FHIA hybrids (FHIA-01 and FHIA-25) and Cavendish bananas in Ghana

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A study was conducted to develop and assess the quality of natural fruit drink of two FHIA hybrid bananas and local 'Cavendish' banana in Ghana. Physiologically matured fruits harvested from the banana orchard of the Crops Research Institute at Fumesua near Kumasi were supplied to an industrialist for processing. The sugar content was determined with a refractometer. Sensory evaluation was conducted using untrained panelist. The results showed that (1) the sugar content of FHIA-01 was 20% compared with 10-12% for the local banana ('Cavendish') and FHIA-25. This implied that less amount of commercial sugar was needed for sweetening FHIA-01 juice for acceptability as compared to the local banana, which required higher amount of sucrose. (2) Sedimentation of FHIA-01 was 50% less than that of the local banana; which inferred that FHIA-01 was lighter with fewer residues than the local banana. FHIA-01 was superior to 'Cavendish' and FHIA-25 in terms of flavor. Based on the overall acceptability, results indicated that the two hybrids were excellent for juice production. Correlation analysis of the results showed that though sweetness and color were important for consumers, aroma and taste were the most important factors for the overall acceptance of the juice.

P-PO-5

Problems on harvesting and post-harvesting of banana

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Banana and plantain constitute the fourth important staple crop, with about 90% of worldwide production consumed locally, leaving just 10% for export. Banana growing is generally labor intensive because plants require intensive, individual care in order to obtain the required fruit quality. For the banana growing sector to re-acquire and maintain a good level of competitiveness on the markets, a rationalization of the entire chain of production is needed, which should be particularly focused on harvesting and post-harvesting operations. This would be helpful to maintain and raise qualitative standards of the product while lowering production costs. Bananas are harvested at various stages of maturity, depending upon the purpose for which it is cultivated and distance to the market. Banana bunches generally are harvested using a curved knife when the fruits are fully developed (75% mature). The labor productivity could increase by use of a single-man positioning platform (hydropicker electrically driven) where possible. Banana bunches are hung on tramways and pulled out of plantation by tractors or people. Hands are cut into units of 4-10 fingers, graded for both length and width

and carefully placed in poly-lined boxes. Fruit are usually shipped by boat when green, and ripened by exposure to ethylene gas at their destination, in sealed “banana ripening rooms”. Mechanical damage is one the major causes leading to post-harvest deterioration of banana and plantain. It can occur at any time from the point of harvest to the point of consumption. Mechanical damage can affect the product’s appearance and increase potential for disease infection. It can also result in lower market quality and price. Assessment of fruit susceptibility to mechanical damage is an important post-harvest selection criterion to provide information on the handling and storage potential of the fruit, and in the design of packaging material for the product.

P-PO-6

Post harvest characteristics and qualities of selected local banana cultivars in Oman

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Five local banana cultivars ('Somali', 'Malindi', 'Fard', 'Williams' and 'Negal') were compared at private farm at Al-Swaiq. Yields, fruits morphology, post harvest characteristics and qualities were evaluated. Somali produced the heaviest bunches and there were no significant differences between 'Fard', 'Malindi' and 'Williams'. 'Williams' recorded highest number of hands. No significant differences were recorded between the cultivars in number of fingers except 'Negal' cultivar. Results showed that there were no significant differences between the local cultivars in lightness 'L' level of the fruits peel. 'Williams' cultivar showed poor standard at 'a' scale compared to the remaining cultivars. There were no statistical differences between the cultivars at 'b' scale. In respect of pulp firmness, 'Malindi' had the firmest pulp and 'Negal' had the softest. 'Negal' followed by 'Fard' significantly gave the most acidic taste as compared with the other cultivars. Fard was significantly the sweetest cultivar followed by 'Malindi' and 'Somali'. 'Negal' reduced the lowest TSS / acid ratio as compared with the other cultivars. All the local cultivars (apart from 'Negal') involved in this study had given less than 5 pH% content. The results showed that Somali harvested at $\frac{3}{4}$ full stage had the longest green life with 20 days. As compared to 'Fard', 'Somali' and 'Williams', 'Negal' had shortest shelf life after ripening.

P-PO-7

Optimization of matooke flour, vital gluten and water absorption in matooke/wheat composite bread using response surface methodology

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The objective of this study was to optimise matooke flour, vital gluten and water, with respect to bread-making quality of a matooke/wheat composite. The corresponding hypothesis that was generated was that optimal substitution of matooke and vital gluten into wheat does

not have a significant negative effect on baking quality of the resultant composite flour. A baking test was used for establishing bread baking quality using response surface methodology (RSM). The basic recipe for white bread was adopted. Ingredient levels for optimization of the composite bread were as follows: matooke flour 0-33%, water -2FWA to +2FWA and vital gluten 0-3%. A D-optimal design, consisting of 20 runs (10 minimum model points, 4 points for estimation of lack of fit, 4 replicates and 2 additional centre points), generated by design-expert statistical software (Stat-Ease, Inc., MN, USA; 2003), was used for optimization of the ingredients was studied. The variables under study were *matooke* flour (X_1), vital gluten (X_2) and farinograph water absorption (X_3). Fourteen objectively measured responses (Y_1 - Y_{14}); were modelled. Two responses: baking worth number and volume yield, which generally adequately describe flour baking quality, were used for the optimization process. Desirability function approach (DFA) was used to simultaneously optimize baking worth number and volume yield. Models developed adequately described the relationships and were confirmed by validation studies. Overall, results showed that matooke flour showed the greatest effect on all models, which was negative except for crumb firmness, weight yield; and a^* and b^* colour values in which it was positive. This had a negative effect on the baking performance of composite flour. The optimal baking composite flour formulation was 0.56% matooke flour, 0.33% vital gluten and -1.24 FWA, to give loaves with volume yield of 689 cc/100 g of flour and baking worth number of 247.8. Optimal formulations incorporating both matooke and vital gluten showed better desirability than pure wheat flour, indicating an important interaction between *matooke* flour and vital gluten. Vital gluten alone (without matooke) did not seem to improve baking quality of the wheat flour.

P-PO-8

Effect of cooking banana (matooke) flour and vital gluten on wheat flour physicochemical and dough rheological properties

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Dehydration technologies have been employed to add value to matooke, a triploid East African highland (AAA-EA group) cooking banana. One of the key flours, the raw banana flour has been targeted at the baking industry as the major market entry point. However, efforts to develop matooke/wheat composite bread to date have been wanting due to the lack of gluten in banana. This study therefore sought to optimize levels of substitution of matooke flour into wheat flour with vital gluten to aid improvement of rheological and baking properties. Specifically, the study sought to prove two generated hypothesis: that substitution of matooke flour and vital gluten into wheat flour has a significant impact on dough rheological properties, and secondly that substitution of matooke flour into wheat flour has a significant impact on flour pasting properties. Response surface methodology (RSM) procedures were used to relate ingredients to dough rheological properties. The indicator properties were selected to include pasting and dough rheological properties. The rapid viscoanalyser was applied to determine RVA for matooke/wheat composite flour at 0% 11%, 22% and 33%. D-Optimal Design was applied to study the effect of matooke flour and vital gluten on dough rheology using the Brabender farinograph and Brabender

extensograph. Matooke flour significantly increased the pasting profile of the composite flour, an effect that has been shown to reduce baking performance. Matooke weakened the dough, while vital gluten strengthened it. Water absorption increased with both variables. Dough stability and dough development time (DDT) reduced with addition of matooke flour, but increased with vital gluten. Degree of softening increased with increasing matooke flour, but decreased with vital gluten. The overall effect of increasing the amount of matooke flour in the matooke/wheat composite flour was the yield of dough with poor rheological properties. Vital gluten improved dough rheology, but did not effectively counteract the negative effects of matooke flour, at the levels applied in the study.

P-PO-9

Sensory qualities and acceptability of East African Highland banana derived secondary triploid hybrids

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The East African highland banana (EAHB) is an economically important food crop in the Great Lakes region of East Africa. However, the crop is severely affected by pests and diseases. In Uganda, major diseases include; black sigatoka and bacterial wilt, while the main pests are the banana weevil and nematodes. Breeding for host plant resistance has been identified as the most appropriate intervention for the above constraints. Conventionally, improvement of triploid spp. has been achieved through crossing 3x (triploid) landraces with 2x (diploid) wild or improved diploids to produce 4x (tetraploids) that are generally more male- and female-fertile. Selected tetraploids are then crossed with improved diploids to produce sterile secondary triploids, which are targeted for release. Farmers and consumers are very critical about the sensory attributes of any potential new banana cultivar in comparison with the existing ones. This is very crucial in determining whether the new cultivar will be acceptable or not. Therefore this study was conducted with the objective of determining whether EAHB derived secondary triploid hybrids have acceptable sensory qualities. In this study, 40 secondary triploid hybrids were evaluated for sensory acceptability in comparison with a local check ('Mbwazirume'). Fifteen panelists were requested to score the samples using a 6-point hedonic scale, where a score of 1 represented extreme disapproval and 6 extreme approval. From regression analysis of acceptability on sensory parameters (texture, taste, colour and flavour), it was observed that texture and colour of the cooked product were the most important sensory parameters determining acceptability of cooking bananas. Therefore banana breeders should concentrate on fixing traits for colour and texture in the hybrids so as to increase their chances of sensory acceptability. Two hybrids; '2821k-10' and '12572s-28' from the genotype plus genotype x environment (GGE) bi-plot were identified as having sensory attributes similar to the local check and therefore are highly acceptable.

P-PO-10

Evidence of acidic invertase as a control step of sucrose level during ripening of two diploid banana fruit

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We previously reported that diploid dessert cultivars accumulate more sucrose during ripening on plant than diploid cooking cultivars, and that acid invertase (AIV) might be in this case important by correlating the ratio of sucrose/glucose:fructose of fruits. To investigate the putative mechanisms involved, sucrose phosphate synthase (SPS) and AIV, two enzymes involved in sucrose metabolism were studied in fruits of two diploid AA group dessert ('IDN110') and cooking ('Sowmuk') bananas, during their development and postharvest ripening after acetylene treatment. From the green developmental to late ripening stages, SPS activity increased at comparable levels in both varieties from 107 to 222 $\mu\text{mol glucose/h/g}$ of fruit fresh weight for 'Sowmuk' and from 68 to 168 and then after 106 $\mu\text{mol glucose/h/g}$ of fruit fresh weight for 'IDN110'. Activity of AIV increased slowly in 'IDN110' fruit from 3 to 26 $\mu\text{mol glucose/h/g}$ of fruit fresh weight, and drastically in Sowmuk from 4 to 207 and then after 174 $\mu\text{mol glucose/h/g}$ of fruit fresh weight. At molecular level, the pattern of SPS and Cw-AIV mRNA accumulation was similar in both varieties during fruit development and ripening. SPS mRNA level increased transiently during the green developmental stage while that of Cw-AIV increased with ripening. Interestingly, at equivalent stages, the increase of Cw-AIV mRNA level was approximately 100-fold more in 'Sowmuk' than in 'IDN110', which corroborates with the higher AIV activity measured for 'Sowmuk'. As between the two varieties, no significant changes were observed for neutral invertase activity and for Susy gene expression and activity, our data strongly suggest that AIV activity constitutes a key step that controls the sucrose level during ripening of diploid banana fruit and that Cw-AIV gene contributes to this activity. Thus, Cw-AIV constitutes a target for the identification of molecular markers usable in breeding, and marker-assisted selection to improve quality traits of banana fruit.

P-PO-12

The effect of drying methods on the quality of ripe banana flour

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A study was carried out to investigate the effect of different drying methods on banana flour quality. Five drying methods were used in this study. Two were purely convection (solar and biomass) drying methods. The other three involved a combination of freeze-drying with convection drying, at time intervals of 2, 4 and 6 hours. Colour, taste, odour, texture and overall acceptability quality parameters were determined. Physicochemical parameters like specific gravity, solubility, carotene and sugar content were determined. Biomass dried bananas took the shortest time during convection drying.

Bananas that were dried using a combination of freeze drying for 6 hours with convection drying took 0.5 hours to reach the target moisture content of 10%. Bananas dried using a combination of 4 and 6 hours with convection drying received higher scores for all sensory attributes. Significant differences in carotene content were observed for solar dried bananas with 1138.4 IU while biomass dried bananas had 1070.4 IU. The findings of this study indicate that, drying using a combination of methods reduces drying time but does not significantly improve the quality of the product.

P-PO-13

Optimization of soy incorporation in cooking banana (matooke) flours

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Uganda is the world's largest producer of cooking bananas of which matooke, a triploid *Acuminata*, East African highland cooking banana (AAA-EA) predominates. Matooke is the most common weaning food for children in banana growing regions. However, due to its high bulk/low nutrient density and low Protein Efficiency Ratio (PER), it presents a major nutritional drawback resulting in high levels of malnutrition for under-five-year-olds. Pre-gelatinization techniques (cooking before dehydration and extrusion cooking of raw dried chips) have been successfully performed on matooke in order to reduce the bulk of its flour. Soy on the other hand, is an inexpensive vegetable protein source capable of improving protein efficiency due to its high diversity of essential amino acids. The aim of the study therefore was to establish whether a suitable level of soy in matooke flour was subject to matooke flour processing technique. Soy flour was substituted into three types of matooke flour, namely; raw, cooked and extruded. The three composite flours were then used to make soups and porridges. Quality was evaluated based on consumer acceptability and preference characteristics of the porridges and soups produced. A quadratic surface response model was used to determine optimal soy flour levels. The findings indicated that optimal soy levels were 11.6, 20.7 and 19.5% in soups, and 18.2, 17.8 and 6.9% in porridges for raw, cooked and extruded flours, respectively. Raw and extruded flours produced more nutrient dense porridge and soup, respectively because the flours supported fortification with higher levels of soy.

P-PO-14

Optimization of cooking banana (matooke) flour, vital gluten and water absorption in matooke/wheat composite bread using response surface methodology

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Uganda is the world's leading producer of cooking bananas with the East African Highland cooking cultivars (locally known as matooke), predominating. The crop is bulky and highly perishable thus experiencing high post harvest losses. To add value to the crop, flour has been developed targeting the baking industry (in composite

with wheat flour) as one of the major market entry points. This study, therefore, was carried out to optimize matooke flour, vital gluten and water absorption in composite bread with respect to bread quality parameters (baking worth number, volume yield, specific volume, crumb firmness, crumb color L* value, crumb color a* value, crumb color b* value, crust color L* value, crust color a* value, crust color b* value, baking loss, pore picture, stability to fermentation and weight yield) and cost. Response Surface Methodology (RSM) procedures were used to develop models relating ingredients to composite flour bread-making quality. Matooke flour had the largest effect on all responses; it reduced bread-making quality more than vital gluten improved it. The optimal baking composite flour formulation was 0.56% matooke flour, 0.33% vital gluten and -1.24 FWA. Confirmation baking trial runs to validate the models showed that they could ably predict the response averages 99% of the time. A model developed to relate changes in ingredient levels to cost price showed that formulations with up to 18.6% matooke flour could be cost effective.

P-PO-15

Effect of cooking banana (matooke) flour and vital gluten on wheat flour physicochemical and dough rheological properties

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Uganda is the world's leading producer of cooking bananas with the East African highland cooking cultivars (locally known as matooke) predominating. The crop is bulky and highly perishable thus experiencing high post harvest losses. To add value to the crop, flour has been developed targeting the baking industry as one of the major market entry points. This study, therefore, studied the effect of matooke flour (0-30%) on wheat flour's physicochemical characteristics, and improving effect of vital gluten (0-3%) on rheology of matooke/wheat composite dough. Response surface methodology procedures were used to relate ingredients to dough rheological (farinograph and extensograph) properties. Matooke flour showed higher ash and starch content than wheat flour, but lower protein, fat and reducing sugars. Peak viscosity and break down were higher in matooke flour while wheat flour exhibited higher peak time and pasting temperature. Matooke weakened the dough, while vital gluten strengthened it. Water absorption increased with both variables. Dough stability and Dough development time reduced with addition of matooke flour but increased with vital gluten. Degree of softening increased with increasing matooke flour but decreased with vital gluten. Overall, the effect of matooke was more pronounced than that of vital gluten in the ranges studied.

P-PO-19

Physiochemical properties of starches isolated from plantain ('Agbagba' and cooking banana ('Fougomou') starches in Nigeria

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Plantain and banana are amongst the most important crops cultivated in Nigeria, that contribute to sustainable food security. However, despite this, its utilization remains limited at the subsistence level. This study was conducted to investigate the industrial potential of starches isolated from commonly cultivated plantain and banana in Nigeria. Physico-chemical properties of starches extracted from 'Agbagba' and cooking banana 'Fougomou' was investigated. Starch yield, granule morphology, amylose, water binding capacity, paste clarity, transmittance, syneresis and pasting characteristics of the starches were studied using standard methods. Results showed that the starch yield was between 14-22%, amylose was between 23-25% in both varieties, granule morphology showed that the starch granules were oval and elongated oval shaped, with cooking banana having more elongated oval shaped granules. The granule size ranged between 9-26 µm in plantain starches but between 6-55 µm in cooking bananas. The starches had high peak viscosity, setback and final viscosity indicating they form a gel rather than a viscous paste, resist swelling during pasting and can retrograde during cooling. The least gelation concentration for both starches was 6% indicating a value that is comparable to modified and cross-linked starches. The opaque gel formed after storage in cold temperature revealed a tendency to retrograde, while the syneresis showed that they have reasonably stable freeze-thaw stability. These results indicate that these starches can find wide application for different food products in the food industry, hence its commercial or industrial utilization can be explored.

P-PO-21

Effect of ripening on total polyphenol contents of *Musa* hybrids and cultivars grown in Cameroon

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Bananas and plantains (spp.) are staple food crops in southern provinces of Cameroon and surrounding countries, where they play a significant role in the diet of the population. To enhance the valorisation of some cultivars and the creation as well as the selection of new hybrids in CARBAP, the total polyphenol contents of 32 cultivars and hybrids from the CARBAP germplasm were determined at three ripening stages. The total polyphenol compounds of dried pulverised pulps were determined at 760 nm using an optimised Folin-Ciocalteu method. The results showed significant differences between types according to their genotype. During the ripening process, the concentrations of phenolic compounds varied significantly. The high total polyphenol contents could contribute to their valorisation in Cameroon and the sub-region as well as enhancing their uses in breeding programmes in CARBAP and other research institutes.

P-PO-22

Post-harvest disease: effects of the physiological age of bananas on their susceptibility to wound anthracnose caused by *Colletotrichum musae*

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Wound anthracnose caused by *Colletotrichum e*, and early ripening are the main problems affecting the quality of export bananas from a lot of countries in the world. In the case of Guadeloupe in French West Indies, these problems generally concern bananas grown in lowland plantations during the rainy season. Three experiments were carried out to study the influence of the physiological age of bananas (calculated on the basis of mean daily temperature sums) on their susceptibility to anthracnose. Stressful growing conditions, especially soil flooding, slowed fruit growth but had no direct effect on fruit susceptibility to *C. e* or on the green life. However, fruit that had accumulated lower temperature sums were less susceptible to wound anthracnose. By varying the source-sink ratio, we show that bananas of the same grade but different physiological ages had markedly different susceptibility to *C. e*. Bananas with the same temperature sum accumulation but grown in different soil-climate conditions had different levels of susceptibility. Fruit grown in cooler, highland areas were less susceptible to *C. e* than fruit of the same physiological age from lowland plantations. Our results suggest that temperature sum accumulation rate is a critical factor affecting the susceptibility of bananas to the pathogen.

P-PO-23

Production of ethylene absorber for extending the post-harvest life of Gros Michel banana

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This work was aimed at investigating the process of production of ethylene absorber using marl and potassium permanganate (KMnO₄). The 2:1 (w/w) ratio of marl:water was an appropriate ratio for ethylene absorber production since it resulted in the highest viscosity. Marl solution was then mixed with 1%, 3%, 5% and 7% (w/w) of KMnO₄ solution. The mixtures were subsequently dried at 150, 175, and 200°C using a vacuum dryer or a hot air oven. The drying time of the mixtures decreased as the drying temperature increased. The drying time of samples in the hot air oven was shorter than the drying time in the vacuum dryer. The ethylene absorber with 3% KMnO₄ solution had an absorption rate close to that of the two commercial ethylene absorbers. Ethylene absorber samples dried using the vacuum dryer had faster absorption rates than those dried using the hot air oven. The ethylene absorber was packed in three types of packaging materials i.e. proof, thin mulberry and glassine papers. The ethylene absorber packed in proof paper allowed the highest absorption rate compared to the thin mulberry and glassine papers. The ethylene absorber was then placed in perforated oriented polypropylene (OPP) pouch. The absorption rates of produced ethylene absorber

were compared to those of the two commercial ethylene absorbers. It was found that the produced ethylene absorber achieved the highest absorption rate. The ethylene absorber produced was used to maintain the quality and the storage life of 'Gros Michel' bananas compared to the two commercial ethylene absorbers. The storage life of bananas stored with the produced ethylene absorber was 15 days while bananas stored with the commercial ethylene absorbers were 18 days.

P-PO-25

Changes in concentrations of dopamine in banana after short-term nitrogen gas treatment

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We investigated the effects of nitrogen gas on the dopamine of surface peel banana 'Sucrier'. Mature green bananas were ripened until stage 3 (peel more green than yellow) and then were treated with 99.9% N₂ for 24 h. Short-term nitrogen gas treatment delayed the induction of senescent spotting and the concentration of dopamine was decreased rapidly compared with control banana. The dopamine content did not differ after 500 ppm ethephon following short-term nitrogen gas treatment. The result shows that shelf life was further increased by short-term nitrogen gas treatment together with lower content of dopamine.

P-PO-26

Metabolism of soluble sugars in four cultivars of banana, and activity of associated enzymes

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Changes in amounts of sucrose and hexoses (glucose and fructose), and in activities of sucrose-phosphate synthase (SPS), sucrose synthase (SuSy) (sucrose hydrolytic way), neutral invertase (NIV) and acid invertase (AIV) were studied during development and ripening *in-planta* of banana fruit (2 dessert cultivars: 'IDN 110' and 'Kirun'; and 2 cooking cultivars: 'Galéo' and 'Somwuck' (all the above cultivars belong to *acuminata* AA group)). During ripening, all the cultivars presented the same pattern of total soluble sugar accumulation. The most remarkable result was that, unlike dessert cultivars, cooking banana cultivars did not accumulate sucrose. SPS activity for dessert cultivars increased throughout fruit development and ripening. For cooking cultivars, the activity first decreased during development and increased at the beginning of ripening with, reaching a peak at half-ripe stage. SuSy activity of all cultivars presented the same pattern of changes during development and ripening. Activity was constant at a low level during development; and later becoming extremely low and then remained constant during ripening. NIV activity was extremely low and constant for all cultivars and developmental stages. AIV

activity was low for the two dessert cultivars, with a small increase during ripening. Interestingly, activity increased drastically during the same period for the low sucrose-accumulating cooking cultivars (approximately 6 times more than for dessert varieties). Our results therefore show that: i) even if SPS activity increases concomitantly to soluble sugar accumulation, there is no correlation between its level and the amount of total soluble sugars or sucrose. ii) there is a strong correlation between the level of AIV activity and the ratio of sucrose:hexoses, i.e. the higher the AIV activity, the lower the ratio. This means that AIV could be one of the main determinants of sugar composition of diploid banana fruit, by correlating the ratio of sucrose:hexoses.

P-PO-30

Effects of harvesting stage and smoke ripening on the time to ripening, shelf life and quality of dessert banana

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In the Morogoro district, Tanzania, “Grand Naine” (AAA group) locally known as “Mtwike” is the major dessert banana. Due to absence of ripening rooms, the banana is harvested at a maturity stage equivalent to the “full three quarters” and smoked in special pits on the day of harvest by middlemen traders, before the fruits are transported to urban markets two days later. This study was conducted in order to describe this traditional method of forcing banana ripening, to assess its efficacy and effects on shelf life and quality of banana destined for sale as dessert fruits. Results show that at similar stage of maturity at harvest, smoke ripened fruits did not differ significantly in terms of quality measured as pulp acidity, soluble solids and sugar contents from fruits treated with ethylene or ripened naturally. Major differences observed were that smoking induced rapid ripening, which occurred within two days, leading to development of “green” ripe fruits with relatively shorter shelf life of less than 8 days against that of up to 10 and 16 days for fruits treated with Ethephon and the naturally ripening fruits respectively. It is considered that the heat from the fire producing the smoke raises the temperature in the ripening pit causing the softening of the fruit pulp or high respiration rate that hasten ripening and fruit deterioration. It is concluded that smoking facilitates rapid ripening, has no direct effect on the organoleptic quality, but shortens fruit shelf life. This traditional banana ripening method could be improved through designing of smoking techniques which avoid the development of high temperatures in the ripening pit, such as by facilitating ventilation in the pit, making small fire using material that produce a lot of smoke.

P-PO-31

Post-harvest characteristics of tissue culture banana ratoon crops in nutrient omission trial

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Experiments were conducted to determine to investigate the effects of inorganic fertilizers on yield and postharvest quality attributes of

tissue culture bananas ratoon crop. The bananas were harvested at three-quarter stage of maturity. Three equatorial region hands were obtained from which three fingers per hand were analysed separately in the laboratory. On harvesting, the hands were weighed, washed to remove latex, then packed in crates and transported to JKUAT food science laboratory. Sodium hypochlorite was used to treat against fungal infections. Three hands from each treatment were ripened at $20 \pm 5^\circ\text{C}$ at $90 \pm 5\%$ relative humidity until fully ripe (stage six). The fruits from the different treatments were analyzed for total soluble solids content, total titrable acidity, ascorbic acid content, individual sugars (sucrose, fructose and glucose) levels, ripening, peel colour, peel and pulp ratio, chlorophyll content, mineral content, moisture content, flavor and flesh firmness. Observations on the Shelf life were made. The fruits were assessed every second day during shelf-life. In addition, starch breakdown was visualized by dipping slices of bananas in iodine solution. Sensory analysis on the ripened fruit was also done with 20 panelists for 15 out of the 20 harvests. Fresh weight decreased consistently and slowly between 0 and d6 days. There were no significant differences in objectively measured post-harvest qualities between the first and second ratoon fruit. The results provide information on the potential of in-organic fertilizers in improving the post harvest fruit quality and shelf life thus elimination of poor flavor quality fruits from the market.

P-PO-33

Determination of maturity indices of tissue culture bananas (*Musa* spp.) ‘Williams’ and ‘Grande Naine’

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Growth patterns of ‘Grande Naine’ and ‘Williams’ grown in Maragwa, Central Kenya during 2006 and 2007 were determined with a view to establishing the most suitable maturity indices for determining harvest time. The banana plants were randomly selected from an already existing plantation. The banana bunches were harvested at $\frac{3}{4}$, full $\frac{3}{4}$ and full maturity stages of finger angularity. Bunch characteristics were measured both in field and post-harvest. For both banana cultivars, there was a high positive correlation coefficient (R^2) between bunch age and finger diameter of 0.881 and 0.939 for ‘Grande Naine’ and ‘Williams’, respectively. Also, finger diameter correlated positively with pulp/peel ratio and total soluble solids for ‘Grande Naine’ at 0.941 and 0.997 respectively. A similar trend was observed for ‘Williams’ with a high positive correlation between finger diameter and pulp/peel ratio (0.949) and TSS (0.997). Fruit growth curves for both cultivars followed the pattern for tropical bananas growth. Findings from this study revealed that the best maturity indices for determining the harvest time of ‘Grande Naine’ and ‘Williams’ may be a combination of bunch age and grade as these correlate very well with post-harvest characteristics such as pulp to peel ratio and total soluble solids.

Agronomy

P-AG-1

Effects of fallow age, fertilizer application and sucker treatment on the yield of a local false horn plantain (*Musa* spp., AAB group) cultivar in Cameroon

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Local plantain (spp., AAB group 'Ebang', false horn) suckers were planted in a four year-old bush fallow, an advanced fallow of approximately nine years and a cleared secondary forest (23 years), following treatment with boiling water, or versus traditional planting without boiling water treatment and either with or without fertilizer application. The trial was observed for 32 months after planting (MAP). Plantain establishment was unaffected by fallow age, sucker treatment and fertilizer application. At 32 MAP 44% in the young bush fallow had not reached flowering, significantly more than in the older fallows. Between 78 and 85% of plants in the older fallows flowered versus 47% in young bush. Similarly between 70 and 76% of plants produced an edible bunch, versus 40% in the young bush. Mean bunch mass per producing plant was not affected by any of the treatment factors. Plant crop bunch yield was twice as high in secondary forest than in the young bush, while secondary forest out-yielded the old bush fallow. Soil chemical properties were generally similar in secondary forest and the younger fallows. There were no positive correlations between any of the chemical properties and the edible bunch yield. Root health parameters were positively affected by age of fallow and boiling water treatment, resulting in larger non damaged root indices (NDRI) in secondary forest than old bush and young bush, and a higher NDRI following sucker treatment with boiling water. The Root Necrosis index (RNI) was lower for boiling water treated plants than for traditionally planted ones. Ratoon production was higher in the older fallows than in young bush. Positive effects of the fallow age on root health persisted in the ratoon crops. Fertilizer application had no significant effect on bunch yield. Fertilizer cost exceeded the value of marginal yield. None of the treatment combinations could increase yields in the younger fallows to the level attained in secondary forest.

P-AG-2

Studies on banana plant waste compost

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The compost process of banana wastes and the nutrient contents of raw and compost materials of banana leaves, pseudostem and rhizomes were analyzed. For the compost preparation the experiment was carried out in pits measuring 0.6 x 0.6 x 0.6 m. There were three sets of composts: (1) contained 3 components i.e. leaves, pseudostem and rhizome with bacterial consortium and cow dung, (2) contained 3 components i.e. leaves, pseudostem and rhizome with bacterial consortium and (3) contained 3 components i.e. leaves, pseudostem and rhizome with cow dung. Initially the leaves, pseudostem and rhizome were tested for their chemical characteristics such as nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, zinc and copper. The banana waste has higher potassium content than nitrogen and phosphorus. Among

the three banana wastes, the rhizomes had more nutrients than leaves and pseudostem. The C:N ratio and moisture content are the most important factors to be considered in blending. Materials too dry for good composting and materials too wet for composting were blended in proper proportion with saw dust. The C:N ratio in this work was found to be higher in compost 1. The C:N was 33 in compost 1 and 31 in compost 2. Carbon:Nitrogen ratio is an important factor for any composting process, because when the C:N is less than 30, the composting process gets affected due to decline in microbe populations. The compost was brown to black in color. It was insoluble in water. It contains a larger amount of carbon than do plants, animals and microbial bodies. It contains considerable nitrogen contents about 3% to 6%. In certain cases it may be 0.5% to 0.8%. It contains the elements carbon and nitrogen in proportions, which are close to 10:1. Humus which is rather in a dynamic serves as a source of energy for the development of various groups of microorganisms and it gives off a continuous stream of carbon dioxide and ammonia. Composts 1 and 2 were tested for their nutrient contents. These composts were found to be rich in potassium, phosphates, nitrates and organic matter. Compost 1 had total nitrogen content of 1.5%, total phosphorus content of 2.5% and total potassium content of 6.9%, which were comparatively higher than that of compost 2. From the present study, it is concluded that composting using bacterial consortium and cow dung is faster and results in higher nutrients than other methods studied. The microbes involved in the compost process in the bacterial consortium and fresh cow dung are also discussed. The study revealed that bacterial consortium and the cow dung slurry used in the present studies are much advantageous in term of cost and time taken for the compost.

P-AG-4

Banana fertilizer application and their effects on growth, flowering and production in an on-station trial in Maragua district of central Kenya

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There remains a lack of basic knowledge on the amount of nutrients the banana plant requires, the potential production under well fertilized conditions, the most limiting nutrient to plant growth in different areas, and the amount of fertilizer application needed to achieve the economic optimum for a certain target yield. A nutrient omission trial was therefore established in Maragua, central Kenya to elicit such information. The gross plot size was 7x5 m and net plot of 5x3 m spaced at 3x3 m and planted with four replications per treatment. Tissue culture plants of the banana 'Giant Cavendish' was used throughout the study. Fertilizer was applied as Urea, TSP, Murate of potash; micronutrients (Zinc sulphate, Sodium molybdate, Borax and Magnesium sulphate) and the nematicide furadan applied to all treatments except treatments with all and no fertilizer that were with and without furadan. Lack of application of fertilizer and un-proportional fertilizer application reduced growth (height and girth), delayed flowering and reduced bunch weight. Plants receiving full official recommended fertilizer treatments were largest and had the highest rate of growth when compared with plants not receiving fertilizer or with one mineral omitted. At fifteen months after planting, over 70 plants in treatments with full fertilizer had flowered, 60 in

half rate (half of official recommended rate) of N, 41 in half rate of K, 24 in minus N, 17 in minus micronutrients and fewer than 5 in no fertilizer control. Mean bunch weight from plots receiving full fertilizer and half rate of N equated to 28-33.5 t/ha, plots without K, N, or micronutrients equated to 25-27 t/ha, plots without P were equivalent to 24 tons/ha, while plots without fertilizer yielded <16.8 tons/ha. The effect of omission of at least one mineral was variable, with the negative effects of omission of micronutrients evident at 4 weeks after establishment, while omission of P, K and N effects became more evident as the plant matured.

P-AG-5

Uptake and distribution of silicon by banana plants

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Some plants, especially monocots, take up and accumulate as much silicon as macronutrients such as calcium, magnesium and phosphorus. Different plant organs accumulate different levels of silicon. In this study, total and soluble silicon uptake and distribution was investigated under greenhouse conditions in dessert banana (sp.) plants cv. Cavendish Williams. Plants were fertilized with a wide range of silicon levels, 0 - 4000 mg l⁻¹ wk⁻¹, supplied as potassium silicate. Levels of silicon distributed to different plant organs varied widely, and changed as silicon fertilization levels rose. Initially the plants accumulated silicon in the following order: leaf > root > petiole (midrib) > pseudostem > corm. However, as silicon fertilizer levels rose, silicon accumulated in the root preferentially with levels soon exceeding leaf silicon levels. In contrast, leaf silicon levels saturated quickly and remained steady, regardless of the increase in silicon fertilizer levels. Silicon mapping and EDX analysis using Environmental Scanning Electron Microscopy also revealed that silicon was mainly deposited in the epidermal layer of roots and leaves. The lower surface of banana leaves had higher levels of silicon than the upper surface. Applications of soluble silicon at concentrations beyond 3500 mg l⁻¹ wk⁻¹ reduced plant growth, possibly because of high soil pH. However, total uptake of silicon increased even at this high level of application. The high levels of deposition of silicon in the epidermal layer of roots and the high levels of soluble silicon held in the root cytoplasm have been shown to alleviate biotic stresses, including soil-borne pathogens, such as *Fusarium* wilt, and abiotic stresses, such as cold damage. High levels of silicon in the root also showed that silicon uptake and accumulation is not just a passive process driven by the transpiration stream.

P-AG-6

Bunch quality of tissue culture Giant Cavendish bananas (*Musa* spp.) as influenced by inorganic fertilizers and micronutrients

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In Kenya, banana is a popular crop currently grown in five provinces. The introduction of the tissue culture technology has greatly increased its production. However, fertilizer requirements of tissue culture bananas have not yet been studied and currently a nutrient omission trial has been planted in a popular banana growing area of Maragua for this purpose using the 'Giant Cavendish' as the test variety. The plants were grown in a randomized complete block design and each treatment was replicated four times. Nutrients under investigation were nitrogen at 400 kg/ha, phosphorous (P) at 50 kg/ha, and potassium (K) at 600 kg/ha. Micronutrients were supplied as follows; magnesium at 60 kg/ha, zinc at 6 kg/ha, molybdenum at 0.5 kg/ha and boron at 1 kg/ha. The treatments included all above nutrients applied in combination, each in omission and a control where no nutrients were applied. Fruits from the plant crop were harvested at three quarter maturity and transported to the post-harvest laboratory immediately. Parameters measured were bunch weight, number of hands and fingers. There were significant differences in bunch weights, number of hands and fingers due to the different nutrients applied. The treatment omitting K had the highest mean bunch weight (11.2 kg), number of hands (7) and fingers (85) and was significantly different from the treatment where P was omitted with the lowest mean bunch weight (2.9 kg), number of hands (4) and fingers (36). Findings from this work indicate that P seems to limit bunch weight in the plant crop in this region.

P-AG-7

The effect of farm fertility variability on the efficiency of banana productivity in central Kenya

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The conversion of nutrients to crop yield depends on many factors during the production period of a crop. Soil factors play a major role in influencing the way plants absorb and utilize nutrients hence, the partitioning of dry matter to the various plant parts. Ten banana farmers were randomly selected from Maragua in central Kenya (00°47'S, 037°07'E) during a 14-month on-farm study. The study was carried out to determine key plant growth factors influencing banana yields and determine banana yield variability within farms. The harvest index was significantly higher closest to the homesteads (49.9%), compared with the furthest study point from the homestead (37.9%). Bunch weight and yields were significantly higher closest to the homesteads compared to the furthest sampling point. There was however no variation in total above ground dry matter weights with distance from the homesteads. Soil pH, soil levels of K, and

K/Mg were higher closest to the homesteads compared with the furthest, whereas soil Mg and Ca levels were higher furthest from the homesteads. Foliar K and N content were relatively low in all study farms. Plants furthest from the homestead were more deficient in most nutrients compared to those nearest. Whereas foliar K index continuously decreased with distance from the homestead, the foliar indices of N, Mg and Ca increased. Production efficiency was thus greatest with proximity to the homesteads. The differences in yield are mainly driven by differences in harvest index, which appears to be related to cation nutrient imbalances. Using both the soil and foliar nutrient levels, fertilizer recommendations that enhances higher harvest indices can be formulated. More research efforts should focus on the manipulation of situations to obtain higher harvest indices as a means to improve banana productivity.

P-AG-8

Comparative assessment of mycorrhizal fungi, oil palm bunch refuse and sawdust mulches on banana establishment and nematode damage

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An experiment was conducted at the crop section of the Teaching and Research Farm of the Federal University of Technology, Akure between October 2006 and March 2007 to investigate the ability of mycorrhizal fungi, oil palm bunch refuse and sawdust mulches to modulate banana growth and nematode infection. Seventy two suckers of banana cultivar 'paranta' used for the experiment were collected within the university campus. Growth parameters were measured at four weeks interval from four weeks after planting till 20 weeks after planting. Meanwhile, Twenty four plants were uprooted at 8 weeks interval for root and rhizome damage assessment as well as nematode identification and density count. Root and rhizome damage were assessed as percentage root necrosis, percentage dead roots, feeder root health, and rhizome lesions. These parameters are established indices of damage by plant parasitic nematodes. Plants inoculated with mycorrhizal fungi were significantly taller than other treatments and those mulched with oil palm bunch refuse mulch had significantly thicker pseudostem girths. Plants inoculated with mycorrhizal fungi and the organic mulches had lower root damage compared with the control.

P-AG-17

Changes in leaf lamina shape and size during banana shoot development

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Leaf lamina size assessments of large numbers of peeper, sword sucker, maiden sucker and water sucker leaves of spp. were carried out on plants growing in the ISAR, Rubona, Rwanda on-station germplasm collection, at the IITA Onne research station in Nigeria and at NARO Kawanda in Uganda. Water sucker leaves of all genotypes were observed to have a significantly wider leaf lamina compared to sword sucker leaves with the same leaf length. There

was also a gradual change from sword or lanceolate type leaves to a broader leaf lamina type similar to water sucker leaf shapes. This progressive leaf lamina broadening of the youngest leaves is an indication of the increased independence of the suckers from the mother plant. Water suckers are loosely or not attached to the mother plant and hardly ever rely on the mother plant for the necessary photosynthesis products. They therefore develop broad leaves even when they have the height of large peepers or small sword suckers. Water sucker leaves are similar in shape to those of maiden suckers. Maiden suckers are therefore less dependent on the mother plant suggesting that lateral shoots become less dependent on the mother plants as they increase in size and develop broader leaves. The results from Uganda also indicate that the leaf length: width ratio decreases with an increase in height of the leaf petioles' insertion point on the pseudostem.

P-AG-18

Comparative study of shoot and root development in micropropagated and sucker-derived banana and plantain (*Musa* spp.) plants

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As more and more *in vitro* plants are being used to establish banana fields, we made a comparative study between *in vitro* plants and sucker-derived plants, the latter being the conventional planting material. Eight genotypes were assessed during the first production cycle. Shoot and root traits were measured during the vegetative and the early reproductive phase. During the mid-vegetative phase, sucker-derived plants produced a larger root system, possibly due to the larger corm, which bears the root initiation zone. However, leaf area or pseudostem size, were similar at this stage for both types of propagules. No significant differences were observed at flower emergence between the propagule types for leaf area, corm fresh weight, root traits, height of the tallest sucker and days to flower emergence. Hence the larger amount of roots at planting of *in vitro*-derived plants seems not to have a particular advantage during the first cycle. Few significant correlations between growth traits of *in vitro* and sucker-derived plants of identical genotypes were observed during the vegetative phase. However, significant correlations between both propagule types were observed at flower emergence, for leaf area, plant height, pseudostem circumference, corm weight and corm size, and root dry weight. This indicates that plants originating from different propagules tend to behave similarly at flower emergence. This research suggests that the major advantage to grow *in vitro*-derived plants would be their more homogenous growth, which is particularly important for timing of field practices. Despite their higher phytosanitary status, *in vitro* plants did not display a better growth than sucker-derived plants.

P-AG-19

Root and shoot growth and their relationship during the plant crop and first ratoon in banana and plantain (*Musa* spp.) with implications for perennial cultivation

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Root studies in are limited and mainly devoted to observations during the first months after initial planting. This study assessed the relationships of root and shoot growth within and across two consecutive crop cycles in several widely differing spp. genotypes. A reduction in leaf area, corm weight and root system traits occurred during the reproductive stage of both the plant crop and the first ratoon cycle. First ratoon plants were slightly taller than the parent crop and had a bigger corm resulting in a higher number of cord roots. However, cord root length was reduced for the first ratoon crop. There was a reduction in sucker vigor during the ratoon crop, which may be attributed to the observed high mat and possible soil degradation. This would affect plant anchorage and stability, and limit possibilities for perennial production of bananas and plantains under monocropping conditions on degraded ultisols. Significant positive correlations were observed between plant crop and sucker growth characteristics, mostly within but not across genotypes. Thus, while fast-growing plants may also have better developed suckers, it was unclear that breeding for genotypes with a larger root system would lead to a better suckering.

P-AG-21

Growth and yield response of the plantain hybrid 'FHIA 21' to shading and rooting by *Inga edulis* on a southern Cameroonian ultisol

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Plantain (*Musa* spp. AAB group) is highly susceptible to root nematodes and fungal diseases of the leaves, causing yield losses in the vicinity of 50%. 'FHIA 21' is a plantain hybrid with good tolerance to pests and diseases, excellent palatability and a high level of acceptance by farmers. Plantain production in southern Cameroon is based on slash and burn of relatively old (20-40 years) secondary forest. Forest clearing is labor and cost intensive leading to the retention of large trees, species with hard wood and those of commercial value as well as forest bordering directly on the plantain field. Thus plantains may be shaded to various degrees. This trial determined the growth and yield response of 'FHIA 21' to shade imposed by various levels of canopy cover of *Inga edulis*. Establishment was unaffected by shade with 6% of plants missing at 99 days after planting (DAP). Canopy cover was negatively correlated with growth parameters of 'FHIA 21' plants at 99 DAP. The proportion of plants that failed to produce within 525 DAP was lowest under the lowest level of canopy cover. Failure to produce an edible bunch

caused by uprooting, breaking or premature death were unaffected by shade levels, whereby no effect on pre- and post-flowering failure could be discerned. The proportion of plants that produced an edible bunch and a fresh bunch yield was higher in the low canopy cover area than in high canopy cover areas. Bunch mass per producing plant, although highly variable was not significantly affected by shade level. Root mass of *I. edulis* was weakly, yet positively, significantly correlated with the bunch yield. 'FHIA 21' developed severe symptoms of banana streak virus after phases of low water supply, which were more frequent at higher canopy cover levels. The hybrid appears not to be suitable for systems with high levels of shading from retained trees.

P-AG-25

Association between banana pulp colour hue and β -carotene: nutrition and health implications

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Due to the increasing interest in combating vitamin A deficiency (VAD) by promoting consumption of vitamin A rich bananas among the banana consuming communities of the East and Central Africa, 47 banana cultivars, were analysed for their β -carotene content using the high performance liquid chromatography (HPLC) and their pulp colour intensity using the colour meter. Our results reveal that β -carotene content was registered highest (2416.7 $\mu\text{g}/100\text{ mg}$) in the cultivar 'Dimaemamosi' and least (50.6 $\mu\text{g}/100\text{ mg}$) in the cultivar 'Sukali Ndizi'. On average the β -carotene content of cooking, dessert, juice, roasting and the exotic 'FHIA' cultivars, was 7 times less than that contained in the Papua New Guinea (PNG) bananas. Out of the analysed cultivars, 9 PNG cultivars with carotenoid content above 1200 $\mu\text{g}/100\text{ mg}$ were found to meet the total daily retinol requirement of 200 μg RE for a child aged 2-5 years consuming 250 g daily and 450 μg RE for lactating or pregnant mothers consuming 500 g daily. Color intensity ranged from 6206 in 'Wambo' among the orange pulped banana category to 3266 in 'FHIA 03' among the white-creamy pulped banana category. The regressive analysis revealed that β -carotene content has a significant positive regressive relationship with pulp color intensity. Our results highlight the potential significance of evaluating β -carotene nutritional benefits of bananas on pulp color basis. PNG banana cultivars that are potentially available could play an important role in VAD disease prevention programs in the banana growing regions of East and Central African.

P-AG-27

Performance of plantain (*Musa* spp. AAB group) and cooking banana (*Musa* spp. ABB group) as food crops and shade providers for young cocoa

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The establishment, growth and fresh bunch yield of a local plantain 'Essong' (spp. AAB group) and cooking bananas 'Fougamou' (spp. ABB group) were monitored over 5 years in a trial on cocoa seedling establishment on degraded Ultisol in southern Cameroon. Establishment and survival of cooking bananas was higher than that of plantains. Throughout the trial cooking bananas maintained more living leaves, had taller pseudostems of a larger circumference and a higher number of suckers. The plant-crop fresh bunch yield of cooking banana was 8.26 Mg/ha, significantly more than that of plantain (3.07 Mg/ha). Plantain ratoons produced about 10% of the plant-crop yield while cooking banana ratoons contributed almost the same as the plant-crop, attaining a total yield of 15.75 Mg/ha versus 3.38 Mg/ha for the plantain. Although the flavour of cooking bananas is profoundly different from that of plantain, farmers appreciated the ripe fruit for fresh consumption as sweet banana, and plantains for processing food items and for live stock feed. Cooking banana is an alternative crop for farmers without access to forest, insufficient labour to clear forest and for people seeking raw material for processing. Due to the high yields attained by cooking bananas in degraded (non-forested) land, they may offer an alternative to plantains in products where the flavour is not affected by the type used. This would in the long term reduce pressure on forest resources while increasing profitability.

P-AG-28

Plantain cropping systems of southern Cameroon

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Plantain cropping systems of southern Cameroon can be separated into those based on forest clearing and those based on land already used for cropping. Plantain is a major crop starting the forest clearing cycle. It is more than other food crops grown for commercial reasons. Cultivar choice for auto-consumption is different from that for sales. Nevertheless, farmers prefer to plant mixtures of cultivars. All systems rely on the use of natural resources, with purchased inputs virtually absent. Labour is mainly provided by household members, capital use is limited to specific operations such as felling of trees, digging holes, planting and harvesting. Knowledge on pests and diseases is very limited. Farmers are unaware of infection pathways of nematodes such as *Radopholus similis*. Contrary to that farmers are very aware of the causes of yield loss with an overall realistic assessment of total yield losses, estimated at 50%. The systems could be improved by simple agronomic measures such as regular planting distances to increase densities, separation of cultivars into early producing versus late producing types to reduce weeding labour. Most important appears to be the need to raise awareness

of the major pests and diseases and simple measures to reduce or eliminate nematode and weevil infestation. Research is required to determine fertilizer response curves, response of different plantain cultivars to planting density, response to weeding frequency and other agronomic measures to increase yields and profitability.

P-AG-29

On-farm demonstration, testing and dissemination of boiling-water treatment for plantain sucker sanitation in southern Cameroon

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Plantain is an important staple food and cash crop in West and Central Africa. It is highly susceptible to a complex of root and corm pests, diseases and suffers low yields. Farmers practice virtually no pest or disease control because they are unaware of nematodes, fungi and banana weevil eggs. A simple and inexpensive method to clean suckers of most pests and diseases is submerging suckers in boiling water for 30 seconds. However, with no extension system in place, and with farmers dispersed in forested territory with poor road infrastructure, disseminating this technology poses a problem. Unlike disseminating new germplasm that can be packed in bags or bundled for distribution and multiplication, new technologies need to be taught to farmers, for them to appreciate their positive effects, hence leading to adoption. Here this task was aggravated by the requirement to convince farmers that a treatment, well known to be lethal, was to be administered to a commodity in short supply. The approach was a combination of workshop with hands-on demonstration plot establishment. Once farmers had agreed to participate, technicians visited the village, gave lessons on plantain sucker health, the presence, symptoms and consequences of nematode (*Radopholus similis*) infestation, the concept of transmission of pests and diseases, and the principle of heat treatment. Farmers prepared suckers for treatment and were encouraged to conduct the treatment and time themselves. Treated and untreated (prepared as farmers deemed right) suckers were planted in plots side by side. After one round of workshops adoption ranged from 32 to 47% (mean 39.4%). Follow up at later stages revealed that many demonstration plots had been expanded or abandoned in favor of larger fields planted to boiling water treated suckers. Expansion ranged from 2 to 32 fold for plant number. Negative consequences of introducing boiling water treatment were social conflicts between participants and non-participants of workshops, and farmers who used the technique versus those who continued to plant traditionally prepared suckers. The major reason for abandoning demonstration plots or advanced trials was a shortage of labour.

P-AG-30**Effect of fallow type, cropping frequency and crop density of a groundnut/ maize/ cassava/ plantain intercrop on growth, fruit yield and ratooning of plantain****S. Hauser¹ and F. Gauhl²***¹International Institute of Tropical Agriculture, Humid Forest Ecoregional Centre Mbalmayo, Messa Yaoundé, Cameroon; ²Chiquita bananas, Costa Rica*

This paper reports on effects on plantain yield of: forest versus bush fallow, cropping for two consecutive years versus cropping for one year followed by different fallows, the crop density and the presence of trees for fertility improvement in a typical mixed food crop field from southern Cameroon. Plantains were intercropped with groundnut, maize and cassava for either one or two cropping cycles after clearing forest (>25 years) and young bush (4 years). Performance of plantain on land cleared from forest was significantly better than on bush fallow land. More plants reached flowering (32%) and produced an edible bunch (29%) on forest land than on bush fallow land (11 and 9%, respectively). The fresh mass of individual bunches was not affected by the fallow type, but the fresh bunch (1.0 Mg/ha) and the edible dry matter yield (0.2 Mg/ha) were 4 times higher on forest land than on bush fallow land. Double cropping of groundnut, maize and cassava promoted plantain growth and yield with about twice as many plants reaching flowering (27%) and producing edible bunches (24%) when double cropped, than when the land was returned to fallow in the second year. Individual bunch mass was not affected by the cropping frequency, yet fresh bunch (0.87 Mg/ha) and edible dry matter (0.17 Mg/ha) were twice as high in double cropped plots. Crop density and inclusion of trees had no effect on flowering, bunch production and yield. Survival was higher in double cropped plots and interacted with the crop density and the presence of tree rows: in the single year cropping treatment planted tree fallow reduced the percentage of survivors most severely, followed by the high crop density treatment. In the double cropped plots survival was unaffected. Ratoon crop production was marginal, contributing 2% of the total yield. Soil chemical properties could not be used to explain the yield difference between forest and bush fallow land. Combining plantains with food crops in forest land is an option to generate income, however, compromised by the low plant densities. A higher plantain density would most likely increase income yet there is no information on the effects on the short term intercrops. The low yield in the single cropping cycle treatment indicates that plantains cannot compete with natural or planted fallow. Weeding requirements of plantain have not been investigated in southern Cameroon.

P-AG-31**The importance of banana and plantain in the cultural systems of Beni and Lubero, Congo****L.N. Vigheri, S. Saghasa and K. Sikyolo***Université Catholique du Graben, République Démocratique du Congo*

We conducted surveys at 4 sites: Munoli (00°7380'N, 029°2206', 1764 masl), Maboya (00°25364'N, 029°3236'E, 1423 masl), Mangodomu (00°58049'N 029°32632'E, 1026 masl), Nzenga (00°31681'N, 029°70596'E, 1007 masl). Data was collected using PRA method and a diagnostic survey. At every site, 5 villages and 30 different fields were chosen at random. The average size of banana plantations was found to be 1.5 ha in Nzenga and Mangodomu (low altitude sites), and 0.5 ha at Munoli and Maboya (medium altitude

sites), where bananas occupy 40% and 70% of the cultivated area, respectively. In the low altitude sites, plantation ownership resulting from acquisitions accounted for 64%, while ownership from heritage accounted for 55% in the medium altitude. The average age of banana plantations was found to be 17, 28 and 30 years in Nzenga and Mangodomu, Maboya, and Munoli, respectively. Fields as old as 70 years were found in the medium altitude. Wine banana are cultivated at a high density in medium altitude, with 10 plants/100 m² compared to six plants/100 m² in low altitude. The number of plantain cultivars/100 m² was seven in low altitude, compared with 1.4 in medium altitude. The number of cooking banana cultivars was highest in Mangodomu (12.6), compared to 4.6 in Nzenga ; 6.4 in Munoli and 9.4 in Maboya. Weights of cooking banana bunches varied between 10-25 kg. The big bunches were found in low altitude areas, and there was a negative correlation between the age of banana plantation and the weight of bunches.

P-AG-33

Farmer participatory evaluation and consumer preference of selected tetraploid *Musa* hybrids in Ghana

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Farmer participatory evaluation of three hybrids ('BITA 3' cooking banana, 'FHIA 21' and 'CRBP 39' plantains) was conducted in the two Assin districts in the Central region of Ghana. At harvest consumer acceptability study was carried out on the hybrids for their use as *fufu*, *ampesi* and ripe fried plantain at four locations in the districts. The agronomic results showed that there was no significant difference in the number of leaves at flowering across the locations. The hybrids showed superiority over the local check in terms of number of functional leaves at harvest. All the hybrids ('FHIA 21', 'CRBP 39', 'BITA 3' and 'FHIA 25') exhibited stable performance in yield and growth characteristics across the locations. 'FHIA 25' was however late maturing (18-20 months) whereas 'BITA 3' was early maturing (10-12 months). Nevertheless, the bunch weight (40-50 kg) of 'FHIA 25' could be said to have compensated for the late maturity. 'BITA 3' was robust, sturdy and early maturing carrying an average bunch weight of 25 kg. All the hybrids were resistant to the black Sigatoka disease. These results suggested that under good management practices, farmers would be assured of good yields irrespective of time or season of planting so long as there is adequate moisture. The consumer acceptability results indicated that there were no significant differences between 'FHIA 21' and 'CRBP 39' and the local 'Apantu' across locations, agronomic parameters and recipes assessed. 'FHIA 21' and 'CRBP 39' were the most preferred and compared favourably with the local triploids ('Apantu' and 'Apem'), and 'BITA 3' was the least preferred. The hybrids were accepted for ripe fried plantain at stages 3 and 4 of ripening. Beyond these stages of ripening, the hybrids could only be used for other processed food recipes.

P-AG-34

Integrated weed management in banana

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An experiment was conducted and consisted of the following treatments; i) 2 kg/ha Diuron as pre-emergence herbicide and one time hand weeding at 35 days after planting (DAT) (T_1), ii) 2 kg/ha Alachlor as pre-emergence herbicide and one time hand weeding at 35 DAT (T_2), iii) 2 kg/ha Diuron as pre-emergence herbicide and two times hand weeding at 35 and 70 DAT (T_3), iv) 2 kg/ha Alachlor as pre-emergence herbicide and two times hand weeding at 35 and 70 DAT (T_4), v) 2 kg/ha Diuron and Glyphosate as post-emergence herbicide at 35 DAT (T_5), vi) 2 kg/ha Alachlor and Glyphosate as post-emergence herbicide at 35 DAT (T_6), vii) 2 kg/ha Diuron and Glyphosate as post-emergence herbicide at 35 and 70 DAT (T_7), viii) 2 kg/ha Alachlor and Glyphosate as post-emergence herbicide at 35 and 70 DAT (T_8), ix) Farmer's practice of Hand weeding at 20, 40, 60, 80, 100 and 120 DAT (T_9) and x) no weeding as a control (T_{10}). Data revealed that significantly lower number of weeds (31.7 weeds/m²) and dry weight of weed (46.7 g/m²) were recorded in farmers practice. Among herbicidal treatments T_7 recorded maximum weed count (76.3 weeds/m²) and dry weight (101.6 g/m²). Farmer's practice and chemical control of weeds showed considerable performance as compared to no weed control. Among the herbicidal treatments T_7 produced maximum plant height (146.9 cm), girth of pseudostem (55.8 cm), leaves per plant (14) and also significantly higher fruit yield (77.7 tons/ha), followed by treatment T_8 . Maximum weed control efficiency, minimum growth and yield were recorded in no weed control (T_{10}).

P-AG-35

Sustainable banana production in Tapi basin: Khandeshi farmer's livelihood

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Khandeshi farmers cultivating bananas in Tapi-river basin have to adopt sustainable production practices (SPPs) such as management of natural resources because of the ongoing deterioration of soils, high annual nutrient turn over in banana eco-systems, over-exploited water reservoirs and overall non-remunerative stagnation of banana production to 52 metictons/ha. Among the probable ways to cope with the ever-growing demand of qualitative and quantitative increase in banana production include i) fostering the farmer's co-operative movement in the region, ii) utilizing tissue-culture derived and/or naturally selected high yielding cultivars, iii) irrigation management, iv) preservation of soil health through implementation of eco-friendly technologies and v) increasing plant vitality through application of amino-acid based plant growth regulators. The individual or combined application of a) soil conditioner after its production from voluminous banana orchard waste b) consortium of efficient biofertilisers specially dedicated to banana mycorrhizosphere c) coal-combustion ash as a source of nutrients d) judiciously applied doses and frequencies of chemical fertilisers and irrigation water are the proven practices to sustain banana production with preservation of soil and plant health and productivity in the region. Adoption of these SPPs would help Khandeshi farmers to conserve and recycle the available natural resources, protect their environment, develop profitable farming system and enhance their livelihood. Overall possibilities for fetching sustainability in banana production in the region are discussed.

P-AG-36

Improving automation in banana plantations: Mechanical means for bunch collection and spraying

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The plant size and structure, together with the layout of the plantation, often constitute an obstacle for automation of main cropping operations in banana cultivation. While handling is normally managed quite successfully, other operations, such as harvesting, are still widely conducted manually and others, such as spraying, are long and complex to carry out, with aerial spraying posing a controversial technique. However mechanization of agricultural operations in banana fields not only is, as for other cultivations, one of the principal means of increasing productivity and reducing costs, especially where labour is scarce or expensive, but also contributes in reducing fatigue and hazards for workers. Efforts for developing specific equipment are ongoing but often based on extemporaneous adjustment of existing machinery. The authors provide a critical description of three self-moving implements designed to carry out some important operations in banana plantations and therefore capable of moving easily within the rows with minimum soil compaction: a 97 kW tractor equipped with an extensible arm, pincer and sickle for harvesting of bunches, a small 15 kW tracked carrier with a similar device and an 85 kW atomizer with a two-level distribution apparatus for contemporaneous spraying above and under the canopy. The former two have been tested in the Canary Islands, while the latter remains in the planning stage.

P-AG-37

Characteristics of banana farms and farmers' perceived causes of production decline in Maragua district, central Kenya

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Banana provides the most significant family income and was ranked the second most important crop in Maragua district. Production was allocated to 60% of the farm land with 66% of farms less than 5 ha and 72% of the farms in production for more than 5 years. Soil pH, Ca, K, P and C content were variable, while Mg and total N content were similar across sites. Land preparation was by tillage and planting in pits with 98% farmers applying cattle manure and 22% applying DAP at planting. Banana yield/month averaged 50.8 bunches/month with production ranging between 2 and 400 bunches/month, while bunch weight ranged between 3 -18 kg/plant. Main production constraints included lack of credit, pests and diseases, soil fertility, water stress and scarcity of planting materials. Up to 32% of planting material was tissue culture plantlets; farmer perception of soil fertility was demonstrated by the indicators they gave for declining soil fertility, and they identified the main pests and diseases as slugs, banana beetles, thrips, birds, nematodes, fusarium wilt, yellow sigatoka and cigar end rot. Ranking bananas according to marketability, indicated that 'Gros Michel' occurring at approximately

22.4% in each of the 50 farms, was the most preferred, although 'Cavendish' occurred in more than 80% of the farms. The most preferred local variety, 'Muraru' was of low market value. Farmers sold 25-75% of harvest, depending on their wealth classification. Up to 84% of farmers sold their produce at the farm gate point. The selling prices ranged between USD \$ 0.8-6.1/bunch.

P-AG-38

Farm banana constraints in Rwanda: A farmer's perspective

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A diagnostic survey was conducted between February and May 2007 in five banana growing districts of Rwanda. The objectives of the study were to compare farmers' perceptions of constraints and coping strategies related to banana production, and verify these with field assessments. Banana yields were estimated at 18.4, 38.5, 25.1, 29.4 and 20.1 tons/ha/cycle in Bugesera, Rusizi, Kirehe, Karongi and Ruhango, respectively. Farmer bunch weight estimates were variable with large over estimations in Bugesera (76%) and under estimations of 3, 47, 49, and 63% in Ruhango, Rusizi, Kirehe and Karongi, respectively. Across all sites, farmers reported drought stress (85%) and poor soil fertility (74%) as major constraints to banana productivity, whereas a minority (26%) of farmers mentioned pest and diseases as major constraints. Farmer perceptions are in line with our assessments. Drought stress yield losses based on average rainfall were estimated at 60, 72, 53 and 38% for Bugesera, Kirehe, Ruhango and Kibuye. Banana weevil (*Cosmopolites sordidus*) damage was low (<3%) and root necrosis moderate (16-23%). Fusarium wilt strongly affected exotic banana production (i.e. AB and ABB group beer and dessert bananas) in all sites and 10-67% of plantations. Farmers have therefore resorted to replacing 'Kayinja' (ABB group) with AAA-EA group beer bananas. Farmers' crop management was varied. Banana yield was positively correlated with amount of mulch applied. However, few farmers (22%) applied external mulch. While most farmers interviewed (86%) owned some cattle or small ruminants, only a minority of them (39%) reported application of manure/compost. None of the farmers applied mineral fertilizers. This study shows that farmers correctly perceive abiotic stress factors as the most yield limiting. However, only a minority of farmers seem to adopt technologies (i.e. application of mulch, manure, and compost) to overcome these yield limiting factors. Constraints to technology adoption need to be investigated.

P-AG-39

Resource availability and yield differences between farms in a banana producing valley in Southwest Uganda

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Southwest Uganda is a major banana producing area, supplying much of the matooke consumed in Central Uganda. Bunch yields in much of southwest Uganda (15-30 Mg/ha/year) are still far from

potential (60-90 Mg/ha/year). Moreover, yields show strong spatial variability, which is still poorly understood. Fifty households in a valley near Ntungamo were surveyed in order to identify factors that determine the between-farm yield variability. Farmers were classified into three distinct wealth classes (poor, medium, and rich) based on local wealth criteria that were obtained during a participatory rural appraisal. Of the randomly selected farmers, 10% were in the wealthy, 56% in the medium, and 34% in the poor class. Production resources between the three wealth classes differed significantly. Compared to the medium and poor farmers, wealthy farmers had more livestock units (10.0, versus 7.0 and 5.6), more arable land (0.62, versus 0.53 and 0.37 ha), but a similar proportion under bananas (70%) and similar plant densities (1840 plants ha⁻¹). Bunch weights measured varied from 5 to 60 kg, but average bunch fresh weight (15.7 ± 4.7 kg) did not significantly differ between wealth classes. Due to the larger number of bunches produced; all wealthy farmers were engaged in selling part of the banana production, compared to 78% and 55% for the medium and poor farmers, respectively. Wealthy farmers invested their much larger off- and on-farm income in hiring more permanent full-time laborers (4.9 pers.) compared to medium and poor farmers (≤ 1.0 pers.). Although there were clear differences in resource availability (land, capital, labor) between farms, it appeared difficult to relate these significantly to differences in biophysical (soil fertility, pest and disease pressure) and plant performance parameters. However, within farm variability of plant performance appeared large and studying the within farm variability may give a better clue on what factors contribute to the observed yield gap.

† Mugaaga died on January 28, 2007

P-AG-40

Commonly perceived production levels and constraints in East African highland banana systems do not correspond to field realities

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East African highland bananas cover approximately 25% of the arable land in much of Uganda, Rwanda, Burundi, and parts of East DRC. This highland region is estimated to contribute over 70% of the total banana production in sub-Saharan Africa. Banana is a major food and cash crop for over 30 million people. Despite its importance for smallholder farmers, reliable quantitative data on production levels and the relative importance of major biotic and abiotic cropping constraints is scarce. Over 700 farmers' fields at 25 sites were surveyed during 2006-2007. Banana productivity averaged by site ranged from 11-26, 25-53 and 35-63 Mg/ha/cycle for Uganda, Rwanda, and South Kivu, respectively. With the cycle duration averaging about 1 year, these production levels are much higher than those reported in general by FAO for the region (6-15 Mg/ha/year). Banana pest and disease damage parameters varied markedly between regions, but were strongly negatively related with altitude. Fusarium wilt was widespread limiting productivity of exotic cultivars. Banana Xanthomonas wilt (BXW) severely affected production in certain sites in Central Uganda, Western Rwanda and Eastern DRC, while banana bunchy top virus (BBTV) was observed in the Rusizi

valley. However, BXW and BBTv currently affect a limited geographic area and still have a relatively limited impact on national banana production. Highest productivity was observed near the Albertine rift, where soils are relatively young, rainfall is high, and plant densities are high, compared to much of Central and Southwest Uganda, Eastern and Central Rwanda and Burundi, which have weathered soils, low rainfall, and low plant densities. These findings suggest that much of the current research focus is based on assumptions derived from insufficient data sets, or on inaccurate or flawed datasets. Water stress, which has previously been overlooked, is an important production constraint, while several 'traditional' banana pests and diseases may not be as important as regularly assumed. However, new and emerging diseases such as BBTv, BXW, and Fusarium wilt may need a greater research focus, given their potential threat.

P-AG-43

Implications of banana intercropping in East Africa

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Bananas are very important in Kenya for domestic consumption and export. They are extensively grown where they are mainly intercropped with short term crops. There has been an increase in the grower interest in using intercropping in the development of new cropping systems for their land. Intercropping could reduce management inputs and result in sustainable systems that more effectively use and even potentially replenish natural resources used during crop production for long term management of farmland. While intercropping has been practiced more widely in the developing countries of Central America, Asia and Africa, developed countries have not adopted it well. Some benefits of intercropping to the grower are risk minimization, effective use of available resources, efficient use of labor, increased production per unit area of land, erosion control and food security. This paper discusses the effects of intercropping on pest and disease control, physiology of the crops grown, cultural practices such as date of planting, spacing and plant density, soil fertility and time of planting among other effects.

P-AG-44

Banana production challenges and some research interventions undertaken by KARI-Horticultural Program under the USAID-SO7 Project

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Banana, (*Musa* spp) is the most important fruit crop in Kenya. The banana has recently become an important cash crop for small and medium scale farmers who supply the urban markets in Kenya. The crop covers about 2% of the arable area. The major production areas are Central, Eastern and Western Kenya. Its production is however constrained by various diseases and insect pests. The objective of the USAID Strategic objective seven (SO7)/KARI Horticultural program therefore was to address the constraints using eco-friendly, demand driven and profitable technologies in collaboration with the stakeholders, with the aim of increasing smallholder household incomes. Baseline data collection on production and marketing of banana was conducted in Kiambu and Thika districts and

appropriate technologies disseminated using farmer field school approach. Up-scaling of the tissue culture banana technology was carried out through hardening nurseries established in Bungoma and Nyeri district. The use of bio-pesticides and cultural practices against insect pests and diseases were emphasized as alternatives to chemical pesticides in an integrated pest management (IPM) approach. The most important diseases and pests of banana in Kenya were identified as Sigatoka leaf spot, *Mycosphaerella fijiensis* and *Mycosphaerella musicola*, Panama disease *Fusarium oxysporum* fsp. *cubens*, Cigar end rot *Verticillium theobromae*, banana weevil *Cosmopolites sordidus*, nematodes *Scutellonema* and *Hemicycliophora* spp., *Radopholus similis* and *Pratylenchus goodeyi* and banana thrips *Hercinothrips bicinctus*. Research on entomopathogenic nematodes (EPN) at KARI-Thika reported successful phase recognition of symbiont gram negative bacteria, of the family *Enterobacteriaceae* from infective juveniles of EPN strain, *Steinernema carpocapsae* and from *Galleria* larvae that had been previously infected with *S. carpocapsae* nematodes. Initiatives to establish their efficacy in controlling banana weevil and other crop pests in the field are continuing.

P-AG-45

Developing a simulation model to understand and improve growth of East African Highland Banana (AAA-EAHB, 'Kisansa')

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Highland bananas are a very important starchy food and cash crop in East Africa. Biophysical constraints such as poor soil fertility, moisture stress and pests result in low yields on smallholder farms (5-30 Mg/ha/year). By contrast, exceptionally good yields of 67 Mg/ha/year have been reported from an on-farm trial in southwest Uganda. A crop growth simulation model based on the light use efficiency (LUE) approach is being developed to (i) better understand and estimate how potential yield is attained, and (ii) to quantify water and nutrient limited yield. Our overall aim is to identify opportunities to increase actual yields through improved crop management and to assist breeders with optimum phenotype recommendations. The model will be parameterized using data collected from nutrient omission trials in Kawanda (central Uganda) and Ntungamo (southwest Uganda), using 'Kisansa'. Phenological stages were recorded and plant allometric relationships that describe leaf area and biomass distribution within plants over time were derived through destructive sampling of tissue culture and corm derived plants. Total plant leaf area was estimated as the middle leaf area (MLA) times the number of functional leaves. Middle leaf area was estimated as $MLA (m^2) = 3.85 \cdot 10^{-3} \cdot \text{height (cm)} + 4.16 \cdot 10^{-3} \cdot \text{girth (cm)}$. Perpendicular and parallel transects were used to measure the fraction of photosynthetically active radiation (PAR) intercepted over the day. A light extinction coefficient ($k = 0.7$) was obtained. At four, six and nine months after emergence, the corm, leaves and the pseudostem are the dominant sinks with 43%, 42% and 46% of dry matter, respectively. The allometric relationship between above ground biomass (AGB in kg) and girth (cm) during the vegetative phase follows a power function, $AGB = 0.0001 (\text{girth})^{2.35}$ with $R^2 = 0.99$, but follows an exponential function at flowering, $AGB = 0.32 e^{0.036 (\text{girth})}$ with $R^2 = 0.84$. Using the allometric relationship for biomass estimation, the leaf area model, and the law of Lambert-Beer, radiation use efficiency (RUE) of 3.5 g MJ/PAR was estimated

for highland bananas. Using the first version of the potential growth simulation model, a potential banana bunch production of 72 Mg/ha/year was calculated, which is close to the maximum yield observed in the region thus far. Current research focuses on increasing bunch production on smallholder farms towards the calculated potential for the region.

P-AG-46

Implications of soil and propagule management on plantain yield, root health and disease-pest interaction

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Field experiments were set up between 2005 and 2006 and were monitored till present. In the best performing treatment, two crop cycles have been harvested with about 50% of the plants in the second cycle harvested at the time of data summarization. In 2005, two experiments (short term and long term) were established to assess the effect of paring of sucker rhizome, and the comparative effect of sawdust and oil palm bunch refuse on plantain yield. In the study, plantain root health and the rate of development of plant parasitic nematodes under the different treatments were monitored. In 2006, another experiment was established to investigate the contribution of nursery duration on field establishment of pared suckers and the interactive effect of oil palm bunch refuse on plant growth and yield performance. Effect of treatments on root health and nematode development was also evaluated in this study. Paring enhanced plant establishment and resilience to harsh dry conditions. Pared suckers that were first raised in the nursery established faster than those not raised in the nursery. Plants mulched with oil palm bunch refuse had more luxuriant growth and the best yield. They flowered faster and had shorter cycling rate. For plants established in 2005, high incidence of pseudostem breakage was recorded on mulched plants that flowered towards the end of the rainy season in 2006. In rare cases, symptoms of *Fusarium oxysporum* f.sp. *cubense* (FOC) were observed on mats with broken plants. Between 2007 and 2008, toppling incidence was limited while pseudostem breakage was high in plots established in both 2005 and 2006. Pseudostem trapping revealed the presence of weevils in the plots established in 2005 but rhizomes were not damaged. It is suspected that the collected weevils are banana pseudostem weevils. The oil palm bunch refuse mulch, which gave better yield, also appeared to support strong associations among FOC, plant parasitic nematodes, weevil incidence and pseudostem breakage. This signifies that care should be taken in the use of the oil palm bunch refuse.

P-AG-47

Responding to climate change in Africa: a case study of East Africa

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Since the early 1970s, environmental scientists have expressed concern over the global climatic change due to the disruption of the dynamic equilibrium of the ozone layer. This has resulted into global warming which refers to the progressive increase in the earth's atmospheric temperature as a result of increased levels of carbondioxide that has adverse effects on climate. In Uganda, the

seasons are not as consistent and reliable as before because of this climatic change. This has resulted into unexpected droughts, floods in Eastern region, constant rains among others resulting into unpredictable crop failure. This is a global concern that can be fought at the grass roots through local initiatives like afforestation, proper disposal of wastes and proper management of the climate crop-relations among others. Any agricultural system is a man-made ecosystem that depends on climate to function just like a natural ecosystem. These elements largely determine the global distribution of crops as well as crop yields within a given climatic zone.

P-AG-53

Soil moisture distribution pattern in alfisol under irrigated plantain (*Agbagba, Musa paradisiaca*)

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Plantain suckers (*paradisiaca*) were planted at Agricultural Engineering Experimental Farm at the Federal University of Technology, Akure Nigeria to investigate the soil moisture distribution pattern on a typical sandy clay loam of a tropical soil, alfisol for two years (2006 and 2007). Supplementary water application was by low gravity bucket system of drip irrigation and there were four treatments based on different levels of water regimes: high irrigation (i.e. maintained at near field capacity 100% available water, AW), medium irrigation (maintained at 50% available water), low irrigation (maintained at 25% available water) and the control treatment. All treatments were irrigated to near field capacity during the first month to allow crop establishment. Rain gauges were placed in each plot to measure amount of rainfall. Moisture content was monitored weekly and at intervals of 10-50 cm soil depth using both gravimetric and watermark soil moisture sensors in all field treatments. Results revealed that plantain extracted soil moisture throughout the shallow soil profile, (up to 50 cm). The moisture storage under the medium treatment (50% AW) and high treatment (100% AW) were significantly different at 5% level of significant level. The cumulative soil moisture storage at the 0–50 cm soil depth was 4.5 ± 0.1 cm for the control treatment while for the high treatment it was 9.9 ± 0.3 cm of water at 192 days after planting, which corresponds to the peak of dry season. The corresponding values for low and medium treatments lie between these two extremes at the same period. The soil moisture content at depths 40-50cm was significantly different, owing to the soil property (predominantly clay) at this depth where infiltration is lowered and probably due to hard pan occasioned by pedigree of tractor traffic on the field. The differences in moisture contents between the plots under low irrigation treatment (25% AW) and the control were not significant during the wet seasons.

P-AG-54

Agronomic evaluation of selected Cavendish banana clones from Du Roi laboratory, South Africa in a tropical environment

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Du Roi laboratory a South African-based horticultural company specializing in the production and international export of tissue culture banana plants is involved in an intensive ongoing process to obtain new Cavendish banana clones (selections) with either superior morphological and yield characteristics or disease tolerance or preferably both in the same genotype. This is over and above supplying improved selections of accepted cultivars to international growers. Seven years ago, Du Roi established a collection of superior selections of the main Cavendish cultivars ('Grade Naine', 'Williams' and 'Chinese Cavendish'). The best of these selections were multiplied by tissue culture and established in a central foundation block. In three cropping cycles, it was shown that considerable productivity differences exist between selections of the same cultivar. The objective of this trial was to determine if the superior, high-yielding Cavendish banana clones selected in a sub-tropical environment produce the same uniformity and high yielding characteristics when evaluated in a tropical environment. Individual plants were selected on performance and multiplied as single clones. The multiplication was done by suckers to retain 100% of the genetic improvement in the single clone. These single clones were then multiplied by tissue culture and plantlets submitted to CARBAP for field evaluation. Field evaluation took place in Njombe, Cameroon. Nine selections were evaluated over two cropping cycles based on a randomized complete block design with four replications. Observations were essentially on agronomic and yield parameters. Field maintenance and farm management operations were carried out following standard practices on commercial farms. Results obtained indicate significant yield differences between the selections compared. Some selections show considerably higher yields compared to those obtained on commercial plantations. Selection C49 showed a strikingly shorter growth cycle duration. Interesting differences were equally obtained with bunch and finger conformation, packing friendliness as well as the cartoon yield.

Production

P-AG-55

On-farm demonstration, testing and dissemination of a simple sucker sanitation method in southern Cameroon

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Plantain is an important staple food and cash crop in West and Central Africa. Due to its high susceptibility to a complex of root and corm pests and diseases yields are low. Farmers practice virtually no pest or disease control because they are unaware of nematodes, fungi and banana weevil eggs. A simple inexpensive method to clean suckers of most pests and diseases attached is submerging suckers in boiling water for 30 seconds. However, with no extension system in place and farmers dispersed in forested territory, with poor road infrastructure, disseminating the technology poses a problem. Unlike disseminating new germplasm that can be packed in bags or

bundled for distribution and multiplication, new technologies need to be demonstrated and farmers sensitized to their positive effects, who then need to accept possible changes in labor allocation in order to adopt. Here, this task was aggravated by the requirement to convince farmers that a treatment, well known to be lethal, was to be administered to a commodity in short supply. The approach chosen was a combination of workshop with hands on demonstration plot establishment. Farmers willing to test the technology were invited to discuss requirements for successful implementation. Once a group of farmers had agreed to participate, a team of technicians visited the village, gave extensive lessons on plantain sucker health, the presence, symptoms and consequences of nematode (*Radopholus similis*) infestation, the concept of transmission of pests and diseases and the principle of heat treatment. Then suckers were prepared for treatment and farmers were encouraged to conduct the treatment by themselves while others would do the timing. After treatment the group planted the treated and a set of untreated (treated as farmers deemed right) suckers in a field previously prepared with a minimum of 25 treated (5 x 5 pattern) and 25 untreated suckers. Following two series of workshops, adoption ranged from 32 to 47% (mean 39.4%). Follow up at later stages revealed that many demonstration plots had been abandoned in favor of expanding to larger fields planted to boiling water treated suckers. The lowest level of field expansion was a doubling in field size (plant number) and the largest expansion was 32-fold, being a 1ha field. Negative consequences of the introduction of boiling water treatment were social conflicts arising between participants and non-participants of workshops and those who used the technique for plantain establishment versus those who continued to plant traditionally prepared suckers.

P-AG-56

Survival and yield of the plantain cultivar 'Ebang' (*Musa* spp. AAB group) produced from corm fragment initiated plants and conventional suckers after hot-water treatment in southern Cameroon

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Plantain (*Musa* spp. AAB group) is the most important food and cash crop in Southern Cameroon. Farmers suffer yield losses due to pest and disease infestation of suckers planted without any measure taken to remove pests and diseases. This paper reports on the first trial conducted under farmers' condition on the performance of hot-water treated conventional suckers versus plants produced from corm fragments (CFP). Both techniques are used to provide planting material free of nematodes and disease propagules. After field planting the plantains were monitored for 50 months. Pre-flowering losses, mainly due to death for unidentified reasons were highest in CFP material. Toppling and pseudostem breakages were not different between CFP material, hot-water treated and untreated conventional suckers. Bunch weight was highest in CFP material, yet due to the high plant losses bunch yield of the plant-crop was lower than after hot-water treatment of conventional suckers and not different from traditionally prepared suckers. Root number and root health in CFP plants were better than in both conventional sucker treatments. None of these advantages was carried over to the first ratoon crop. CFP plants have a high potential to increase yields yet the weakness of high plant losses in the early stages of growth need to be overcome to make the technique adoptable.

P-AG-57**Comparative study on the field performance of 'FHIA 01' (hybrid dessert banana) propagated from tissue culture and conventional sucker in Ghana****B.M. Dzomeku, M. Quain, R. Bam, and A.A. Ankomah***Crops Research Institute, Council for Scientific and Industrial Research, Kumasi, Ghana*

Micro-propagated plants of 'FHIA 01' (exotic hybrid dessert banana) from Honduras were grown and their shoot-tip cultures were produced following standard method. Suckers were taken from the same plants as with the shoot-tip culture samples. The trial was planted at Fumesua in 2001, a semi-deciduous forest zone of Ghana in a random complete block design. The plant density was 1667 plants/ha. Plants were fertilized at the rate of 40 tons/ha poultry manure per year split over 3 equal applications. The field performance of *in vitro* propagated (tissue culture) tetraploid banana ('FHIA 01') plants was compared with that of sucker-derived plants. *In vitro*-propagated plants established and grew faster, taller (240 cm) and bigger than the conventional sucker-derived plants. The former produced heavier bunches (39.1 tons/ha) and were harvested earlier. They however produced smaller number of fingers than the conventional sucker-derived plants. Significant differences were observed between the plant height and plant girth (48.6cm) at harvest. No significant difference was observed in bunch weight, number of hands, number of fingers and the number of leaves at harvest. The nutrient used in the Tissue culture medium may be playing a significant role in the growth vigour of 'FHIA 01'. It may also be having an influence on the performance of the hybrid. This influence may improve the yield of the crop thus improving the economy of farmers.

P-AG-58**Evaluation of different banana genotypes under the local conditions of Oman****S. Al-Hosni, K. Al-Farsi, M. Al-Jabri, K. Al-Busaidi and H. Al-Azri***Directorate General of Plant and Livestock Research, Ministry of Agriculture, Sultanate of Oman*

Banana tissue culture plantlets of seven different banana hybrids were received from INIBAP for introduction and evaluation under the local conditions of Oman. The trial established at Sohar research farm started in 2004. The hybrids were laid in a randomized complete block design with four replications. The exotic hybrids showed significantly taller pseudostem than the local clone, whereas 'FHIA 25' got significantly the wider plant girth. In respect of the number of leaves at flowering, the local clone produced intermediary number of leaves as compared to the introduced hybrids. 'FHIA 21' significantly surpassed the other cultivars in leaf length, whereas the local clone significantly gave the least leaf length in comparison with the exotic hybrids. It was concluded that the exotic hybrids showed extra vigor and vegetative growth compared to the local clone. Compared to 'FHIA 25', 'Williams' had smaller bunch sizes with fewer hands per bunch particularly in the second growth cycle. 'Williams' bunches had fewer number of fingers in the second season compared with 'FHIA-25', yet there were no significant differences between 'Williams' and 'FHIA 25' in the first production cycle for the number of fingers. Mean fruit weight was higher in 'FHIA 18', 'FHIA 21', 'FHIA 25' and 'FHIA 03', followed by the local clone without significant differences. 'FHIA 21' had statistically greater fruit lengths as compared to the other hybrids

and the local clone. There was a tendency of enhancement and augmentation in the parameters in the second season in particular fruit weight and fruit length.

P-AG-61

Low cost tissue culture gelling agents and support matrices for initiation of bananas

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Different solid support matrices and gelling agents were used in the initiation of bananas from meristematic stem cuttings as explants. The highest survivability was achieved from liquid media with glass beads and marble as the solid matrix, which had results comparable to using Gelrite. Explants cultured on this kind of media were best propagated by splitting them and transferring them to the multiplication media. Up to 20 shoots were recovered from one explant initiated in the marble/glass bead initiation media, compared to less than 6 from the agar and Gelrite media. The possibility of initiating bananas in liquid media with reusable solid support matrix would help reduce the cost of banana tissue culture.

P-AG-62

Evaluation of banana cultivars and production technologies for the semi-arid areas of Nakuru district, Rift Valley province

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Farmers in Nakuru district have settled in the agroecological zone (IV-VI) and subsequently introduced banana cultivars and technologies from their original homes. These agro-ecological zones lack conditions required for adequate banana production. The areas are characterized by low and erratic rainfall and soils are depleted of nutrients and organic matter required for banana production. Two trials were set up in these transitional and semi arid areas of Nakuru district to evaluate the adaptability of banana cultivars and planting methods. In one trial 30 cultivars used were obtained from banana growing areas of Kisii, Kamiti, Thika and from several farmers in Nakuru. These cultivars were established in a mother block observation trial considered as cycle 0 in holes measuring 120 x 120 x 120 cm in April 1998 at KARI-Njoro. Based on the ability to flower and fruit 12 elite cultivars ('Kisii', 'Bogoya', 'FHIA 01', 'FHIA 02', 'William hybrid', 'Chinese dwarf', 'Uganda green', 'Uganda white', 'Lacatan', 'Giant Cavendish', 'Grand Naine' and 'Apple banana') were selected for cycle 1 to form the basic cultivars for further evaluation on expanded sites at Njoro and the farmers fields at Rongai-Mang'u, Molo-Baraka, Belbur-Kang'out, and Naishi-Lare. The cultivars were planted in trenches measuring 1.2 m wide, 1.2 m deep and 36 m long at a spacing of 3 m between plants within the trench and 4 m between trenches. The experimental design was an RCBD with three replicates. Data on stem height and girth, days to flowering, bunch weight, finger length and finger circumference were used as selection criteria. Results indicated that 'Kisii' had the highest bunch weight (15.6 kg) and cumulative index of 3.7 and was best adapted. 'Dwarf Cavendish' had a bunch weight of 5.5 kg with a cumulative index of 1.6 and low adaptability. The performance of these cultivars depended on method of establishment in large planting holes or trenches. Generally, cultivars showed more tolerance to drought

conditions when planted in trenches. On the contrary, weak stalks, drying of the plants, rapid change in phenology during dry months were more frequent amongst bananas planted in holes as compared to those planted in trenches. Bananas in trenches yielded on average 15 kg per plant as compared to 9.2 kg per plant for those in planted in holes reflecting a 53.3 % advantage associated with improved soil conservation and water harvesting in trench environments. Based on these preliminary results, farmers in Nakuru are advised to grow recommended cultivars using the trench technology to be able to establish and maintain bananas successfully.

P-AG-63

Comparison of the *in vitro* culture conditions of banana genotypes in Kenya

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Banana is one of the most important food crops in Kenya. The cost of controlled culture conditions generally limits production in developing countries. Establishment of a low cost efficient *in vitro* regeneration system will significantly boost the availability of the planting materials. There is therefore an urgent need to assess the possibility of *in vitro* culturing of bananas under natural conditions to make the technology closer to the farmers. The objective of the present study was to compare the regenerative response of bananas under different culture conditions of light, temperature and concentrations of sugar. Bananas were regenerated from shoot meristem explants using MS medium supplemented with 4 mg/L BAP and different concentrations of sugar. Increase in the concentration of sugar significantly increased the regenerative frequency of banana genotypes tested. The regenerative response of the banana explant when grown under natural environmental conditions compared to that under controlled culture conditions was not significantly different. Giant Cavendish had the best response in culture. The use of local sugar as a carbon source instead of sucrose reduced the cost of tissue culture of bananas in the present study. It can be concluded from the present study that natural culture conditions can be used for the *in vitro* culture of bananas and this can help to reduce the cost of production.

P-AG-64

Clonal propagation of *Musa sapientum* genotype 'BARI-1'

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This abstract describes methods of clonal propagation for one of the elite genotypes of banana developed by Bangladesh Agriculture Research Institute (BARI). The principal characters of this genotype (BARI-1) are its sweetness, good smell and high yield which has made this particular genotype popular in Bangladesh. *In vitro* cormlets were formed within 2-3 weeks when meristems were carefully isolated from field-grown plants, and after proper sterilization implanted in semisolid Murashige and Skoog (MS) media fortified with 2 mg/L 6-benzyleaminopurine (BAP). Regeneration of cormlets was geared up when MS was enriched with 1.0 mg/l BAP and 1 mg/L Kinetin. Rate of shoot proliferation increased considerably with the synergistic effect of BAP and Kinetin. With the increase of sub-culture (up to 9th maximum), frequency of shoot proliferation was enhanced. Addition of 0.1 mg/L Indole-3-acetic acid and 10% coconut water to the medium increased noticeably shoot elongation and stimulated

growth of the shoots, respectively. The micro shoots rooted well within 2 weeks in ½ MS supplemented with 0.5 mg/L Indole-3-butyric acid and in few cases auto-root induction was observed when the number of sub-culture was beyond five. Rooting percentage and their growth were much better in liquid media, compared with semisolid media. Elimination of agar from root induction media reduced cost of production significantly. After proper acclimatization, rooted plantlets were transferred to polythene bags containing garden soil and humus (1:1). After 2 weeks of transplantation, 98% plants survived and flushed new leaves. No morphological variants were observed during the passage of micropropagation.

P-AG-66

Field performance of tissue-cultured banana (*Musa acuminata*) cultivars 'Ambon' and 'Rathambala' (AAA group)

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'Ambon' and 'Rathambala' are two most expensive banana (*Musa* spp.) cultivars, offering a high potential for commercial cultivation in Sri Lanka. This necessitates their rapid multiplication to meet planting material requirements. Tissue culture technology offers a great opportunity for rapid multiplication but lack of information on the comparative performance of tissue-cultured 'Ambon' and 'Rathambala' against conventional suckers hinders commercial application of the technology. Hence, field performance of tissue-cultured 'Ambon' and 'Rathambala' was compared with conventional propagules of the same cultivars at the Horticultural Research Unit 2, Gannoruwa, Peradeniya between 2004 and 2006, aiming at comparing morphological characteristics and yield. Tissue-cultured plants were produced *in vitro* by micropropagation via shoot-tip culture technique and the conventional suckers were obtained from superior mother plants selected for favorable bunch characters. Plant height and girth, emergence of suckers, color of the pseudostem and young leaves, total number of leaves at the time of emergence of inflorescence (shooting), time taken for shooting and bunch characters were recorded. Tissue-cultured plants established in the field faster than conventional suckers, were taller and produced greater number of leaves at shooting and more number of suckers irrespective of cultivar. No morphological variations were detected in both varieties but tissue-cultured 'Ambon' suckers developed a red pigmentation on leaves, which disappeared 3-4 months after planting. Bunch emergence occurred simultaneously in both types. Results showed that the tissue-cultured plants perform similarly as conventional plants in the field in all-important characteristics. Mean number of suckers produced by tissue-cultured plants was more and they could be used as planting material. Thus, the tissue culture technique is a useful tool for rapid multiplication of cultivars 'Ambon' and 'Rathambala'. Other management practices such as plant nutrition and soil moisture management might be helpful in improving yields of tissue-cultured 'Ambon' and 'Rathambala' banana.

Seed systems

P-SS-1

On-farm performance of East African Highland banana hybrids in Uganda

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East African highland bananas are a major food and cash crop in the Great Lakes region. The crop has a narrow genetic base that makes it susceptible to diseases and pests, including black sigatoka, banana bacterial wilt, various nematode species and banana weevils. Breeding for host plant resistance was identified as the most appropriate means of managing these constraints. Four hybrids namely; TMH3 x9750S-13, TMH3 x7798S-2, TMH3 x9187S-8 and TMH3 x8386S-19, developed by the International Institute of Tropical Agriculture (IITA) in collaboration with the National Agricultural Research Organization (NARO) were selected on-station according to their black sigatoka resistance, maturity period, high yield and pulp color. These were planted on farmers' fields in four districts of Uganda: Masaka, Mukono, Mpigi and Rakai. Additionally, the two NARO lines TMH3 x2729k-1 and TMH3 x2625k-1 were planted in Rakai and Mpigi. Ten farmers per district were selected and provided with 15 plants/genotype to plant in a completely randomized design and compared with the local check 'Mbwazirume'. The performance of plants was monitored and data for yield and sensory acceptability were collected. Yield was obtained by measuring bunch weights, number of hands per bunch and number of fingers on the third hand from the top of the bunch. Acceptability by farmers was rated on a 1-6 point hedonic scale for the characters pulp color, pulp texture, food aroma, taste and general acceptability in comparison to 'Mbwazirume'. Although data collection is still in process, most hybrids produced higher yields than 'Mbwazirume'. Sensory evaluations by farmers of steamed banana revealed that the hybrids TMH3 x9750S-13 and TMH3 x9187S-8 were acceptably close to 'Mbwazirume' and therefore highly promising. However, an ideal ideotype of a multiple-disease resistant, high yielding genotype with superior consumer acceptability is yet to be achieved, and remains a key objective.

P-SS-2

Innovations for producing clean banana planting materials by macro-propagation in Uganda

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Macro-propagation is a technique that involves manipulation of the buds on a corm to increase number and rate of sucker production. It involves uprooting and paring a maiden sucker, followed by removal of sheaths to expose buds. Apical and lateral buds are then cut (to suppress apical dominance and increase shoot number) and the corm placed in a sterilized medium in the propagation chamber. Up

to 35 plantlets can be produced from a single corm over a period of 10–18 weeks. On emergence, plantlets are detached from mother corms and planted in soil in potting bags and kept in a shade, where they develop roots and are hardened prior to field planting. Currently, the International Institute of Tropical Agriculture (IITA) is promoting this technique as an efficient means of propagating healthy and robust planting material, with relatively uniform growth characteristics. The technique is simple, inexpensive, and suitable for on-farm adoption. However, adoption of any technology requires sensitisation, access and acceptability. As a result, eight propagation/training sites were developed in the four Ugandan districts of Masaka, Rakai, Mpigi and Mukono. These acted as training centers for farmers from surrounding areas. This being a new technology, it was also important to determine the perceptions of stakeholders regarding macro-propagation. Therefore, a survey was conducted in areas where the technology was being promoted. A total of 372 people were interviewed, including farmers, business persons, extension workers/teachers, NGO representatives and students. The majority of the respondents preferred that macro propagation services be provided by farmer groups. A reasonable price for plantlets was indicated in the price range of 500 to 1000 Uganda shillings (USD \$0.29-0.58). Generally, responses across districts were similar, however, in Masaka and Rakai, where older plantations are common, the level of adoption was much lower than in Mpigi and Mukono, where new field establishments are on-going due to recent losses caused by banana bacterial wilt.

P-SS-3

A new generation of dwarf plantain hybrids with resistance to Black Sigatoka and high yield

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Plantains are important food and cash crop in the humid forest zones of West and Central Africa where they are especially cultivated by smallholders. In Cameroon, it is estimated that more than 600,000 smallholders are involved in the plantain production. Banana and plantains productions are threatened by several pests and diseases and wind damage severely affects the yield. Since the smallholders cannot afford pesticide use, resistant and vigorous varieties appear as the appropriated and environment friendly solution for sustainable yield improvement. The African Research Centre on Banana and Plantain (CARBAP) is managing in Cameroon a project focusing on dwarf plantain breeding using advanced cooking diploid male parents. Significant achievements are several triploid hybrids with dwarf stature and resistance to Black Sigatoka. Selected hybrids look similar to plantain cultivar and exhibit earlier flowering and big bunch with parthenocarpic fruits and orange flesh. Evaluation of post-harvest characters shows that organoleptic traits of some hybrids are comparable with those of the plantain cultivar. Although the acceptability of the first generation of dwarf hybrids is good, their cooking features have to be improved in order to broaden their use and increase their market value. To insure that, superior plantain-like diploid parental lines are using and a few hybrids have already been obtained. Superior dwarf hybrids have been planted on a medium scale under high pressure of black sigatoka on research station as well as in small-scale farmer system. Results of these evaluations are presented.

P-SS-4

Participative evaluation of banana hybrids in rural areas in the southwestern Democratic Republic of Congo

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In the Democratic Republic of Congo banana and plantain production is jeopardized by several factors, among which is the black sigatoka disease. The tolerance of local banana and plantain hybrids ('FHIA 01', 'FHIA 03', 'FHIA 21', 'FHIA 23', 'FHIA 25', 'Bita 3', 'Cardaba', 'Saba', 'SH 3640', 'Orishele', 'Bubi', 'Diyimba' and 'Gros Michel') was evaluated in three districts in Bas Congo province between January 2002 and October 2005. Significant differences were observed between cultivars and sites in plant height and girth, bunch weight, number of hands per bunch, number of fingers per hand, number of green leaves at harvest, and days to harvest. Most hybrids had good vegetative growth and size (between 260 cm and 300 cm), that provided a good lodging resistance. In general, most introduced cultivars showed good tolerance to black sigatoka, except 'Orishele' which was quite susceptible (had an average of three leaves/plant only). Average days to harvest was 500 for the hybrids and 573 for the local cultivars. Organoleptic evaluations showed that the local plantain 'Bubi' and 'Diyimba' and the dessert type 'Gros Michel' are more appreciated by degustators, compared with local cultivars. 'FHIA 01', 'FHIA 21', 'SH 3640', and 'Bita 3' were most preferred by farmers. 'FHIA 25' was not liked despite its big bunch size and huge pseudostem. The dislike of this cultivar is because of the presence of seeds in fingers of the first hand.

P-SS-5

Molecular marker aided analysis of genetic diversity and detection of dwarf somaclonal variation in Indian banana cultivars

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India is considered as one of the important centres of diversity for banana, and there are a number of banana cultivars, ranging in diversity from delicate diploid *acuminata* (AA group) types to hardy hybrid triploid (AAA, AAB, ABB groups) types. Although characterization based on morphological and agronomic traits or isozymes has been reported to distinguish and classify accessions, their effectiveness has become debatable as these are subjected to environmental influences. Considerable attempts have been made on the basis of molecular markers such as RAPD, AFLP, SSR, IRAP and 5S rDNA. Markers like RAPD are neutral to environment effects and management practices and are more suitable and ubiquitous to most of the living organisms. Another complementary dominant marker system is inter-retrotransposon amplified polymorphism (IRAP). As they insert themselves into the genome, retro elements act as mutagenic agent thereby providing putative sources of biodiversity. As 5S rDNA is a conserved region of the eukaryotic genome, the chance of variation in this sequence is mainly in terms of point mutation that occurs in the non-translated intergeneric spacer region.

The objectives of the current study were to i) characterize some of the important clones of banana (AAA, BB, AB, AAB, ABB groups) using different markers including a retrotransposon based marker method to identify the genomes in banana cultivars and, ii) detect dwarf off types, at an early age, by using the sequence characterized amplified region (SCAR) marker among somaclones regenerated through somatic embryogenesis of banana cultivars. As the dwarf off types among somaclonal population are a major problem affecting micropropagation of the banana cultivars, their detection at an early stage in growth assumes significance. The use of different molecular markers is useful in analyzing the genetic diversity existing within a sample of banana cultivars, from different or same genomic constitution, used for cultivation in different parts of India.

P-SS-6

Morphological and molecular characterization of *Musa* germplasm in Sri Lanka and selection of superior genotypes

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Banana (spp.) is the most important fruit crop in Sri Lanka and is identified as a species for genetic improvement. Genetic variability present in spp. in the country is rich and needs characterization for its use in banana improvement. Characterization or estimation of genetic diversity at molecular level, using Simple Sequence Repeats (SSR) is a rapid and accurate technique complementary to morphological characterization.

In this research, 27 germplasm (*M. acuminata*, *M. balbisiana*, polyploids and interspecific hybrids), were characterized using SSRs and morphological characters. Morphological characterization of generated useful information for clustering the germplasm. However, difficulties were faced in scoring morphological data as some character states were not discrete. Therefore, specific SSR regions of were amplified by PCR, using SSR primers (AGMI and MaSSR). PCR products were separated by PAGE and the bands were detected by both autoradiography and silver staining. Characterization by SSR gave a better picture of the genetic relationship between cultivars and wild species in Sri Lanka. SSR primers MaSSR 20 a/b, MaSSR 18 a/b, MaSSR 22 a/b MaSSR 24 a/b, MaSSR 7 a/b and AGMI 95/96 are useful for characterization of distantly related *Musa* spp. in Sri Lanka. spp. used in analysis showed a great extent of SSR diversity, which reflects a rich genetic diversity among them. Therefore, the gemplasm used in this research is recommended for conservation in the field and *in vitro*. MaSSR 24 a/b can be used to differentiate inter-specific cultivars (AAB or ABB) from AA or AAA genotypes. SSR markers were greatly useful to identify 'Unela' (AA group), 'Navarat' (AA group), 'Bahua' (ABB group), 'Mondan' (ABB group) and 'Etikesel' (BB group) which are useful in cultivar identification and breeding. In the molecular dendrogram 3 major groups viz. dessert and wild types, 'Embul' (Mysore) and cooking types were identified. The dessert cultivar 'Embul' (Mysore) is extremely diverse from the rest of dessert cultivars. In contrast to wild spp. 'Etikesel' (*M. balbisiana* colla), 'Unel' (*M. acuminata* colla, AA group) is also diverse from the rest of the genotypes which reflects the possibility of contributing genes of 'Unel' into Sri Lankan cultivars is rather low in contrast to the 'Etikesel'. Ambon was morphologically classified

under the 'Gros Michel' group but it was substantially distant from 'Gros Michel' type 'Anamalu'. Fertile diploids viz. 'Unel', 'Etikesel' and 'Navari' are distinct genotypes useful for genetic mapping and breeding. 'Muwanethikesel' (no male bud) is a possible mutant of 'Walsuwandel'. 'Alukesel' and 'Etamuru' which produce seeds occasionally are also unique genotypes useful in banana improvement. 'Puwalu' and 'Seenikesel' are superior genotypes with respect to bunch, fruit and yield characters. 'Kolambaseeni' is also a potential variety for commercial cultivation.

P-SS-7

Effect of dark and light regimes on *in vitro* banana micro-propagation in Petri dishes

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Light and darkness treatments were compared for *in vitro* micro-propagation of bananas. Aseptic 3 cm³ shoot-tip cubes of banana 'Nfuuka' (East African highland banana, AAA group) and 'Sukalindiizi' (AAB group) were inoculated on a medium containing Murashige and Skoog mineral nutrients supplemented with (mg/L): 0.5 nicotinic acid, 0.5 pyridoxine, 1.0 glycine, 0.4 thiamine-HCl, 10.0 my-inositol, 10.0 ascorbic acid, 4.5 BAP and 30 000.0 sucrose. Six g/L of agar were used to solidify the medium. Culturing was undertaken in the dark and light at 25-27°C in 10 cm diameter Petri dishes containing 25mls of medium at three density levels of 9, 13 and 20 shoot tips per Petri dish. For half of the Petri-dishes, three replications per density level were maintained in complete darkness while the others were maintained in 16 h light intensity of 1173 ± 42 lux and 8 h dark cycles. Shoots proliferated in small axials and more shoots were observed in the dark than in light incubated shoots at inoculation levels of 13 and 20 shoots. Compared to use of culture tubes where normally one shoot-tip cube is used, the method used here requires less media per explant, and more explants can be stacked per unit area. Culturing in the dark also reduces light requirement and thus saves electricity. Therefore, culturing in the dark and in Petri dishes provides a more economical means of rapid banana micro-propagation other than manipulating auxin/cytokinin balances to achieve adventitious organogenesis.

P-SS-8

Fast-track release of black sigatoka resistant banana and plantain hybrids and related technologies to farmers in Cameroon: a strategy to enhance food security

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Beginning 2001, IITA-Cameroon launched a systematic effort for deployment of resistant banana and plantain hybrids in collaboration with the plant health regulatory services of Nigeria and Cameroon. These hybrids were field established at the Mbalmayo (3° 25N latitude, 11° 28E longitude and 640 masl) research farm of IITA for evaluation of their agronomic and post-harvest compliance. Data were collected for three production cycles on disease response, phenology, yield, and fruit quality. Twenty-one hybrids were evaluated in comparison with the most popular indigenous

landraces ('Assang-Da', 'Ebang', 'Elat', and 'Essong'). Of these, three triploid hybrids ('PITA 21', 'PITA 23' and 'FHIA 25') and four tetraploid hybrids ('PITA 14', 'PITA 17', 'BITA 3' and 'FHIA 23') were selected with input from farmers, exhibiting higher levels of resistance to black leaf streak (BLS), shorter growth cycle, higher bunch yield, relatively to the landraces. When grown in mixtures with the landraces, the hybrids mitigate the intra-field propagation of BLS between susceptible plants, thereby enhancing the performance of the landraces under natural BLS infection. This constitutes an attractive scheme for deployment of the improved hybrids through on-farm participatory evaluation in Cameroon. In 2003, we initiated an outreach program with non-governmental organizations (NGOs) and farmer associations (Common Initiative Groups, CIG) aiming to foster a fast-track cultivar testing and dissemination scheme coupled with hands-on training in healthy sucker production and post-harvest processing options to overcome scarcity of planting material and to cater for the anticipated excesses. This scheme fits within and complements programs of the Cameroonian government for banana and plantain (Programme de Relance de la Filière Plantain, (PRFP) and Programme de Reconversion Economique de la Filière Banane Plantain, (PREBAP) with the objectives to increase the productivity of banana and plantain in Cameroon, enhance food security and develop trade opportunities.

P-SS-9

HIV/AIDS-related constraints to adoption of tissue culture technology in banana farming in Kenya

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Adoption of appropriate agricultural technologies is key to increasing productivity and rural household income. Yet several factors influence the adoption of agricultural technologies, which may constrain the technology's potential contribution to development and poverty reduction. This study investigated HIV/AIDS-related constraints to the adoption of tissue culture technology in affected and non-affected banana farming households in rural Kenya. The sample population was stratified on the basis of use or non-use of tissue-cultured banana. The study adapted the sustainable livelihood approach and used a mixed-method approach incorporating quantitative and qualitative data collection. Using logistic regression analysis two stages of adoption were analysed: initial adoption and continued use of tissue-cultured banana. Qualitative data was manually analysed. The results showed that the HIV/AIDS status of the household had no significant influence on the initial adoption of tissue-cultured banana. However, a significantly higher proportion of HIV/AIDS-affected households had reduced amount of inputs and level of management practices in banana plots, while some households had altogether abandoned their plots due to lack of labour, time, cash, skills and knowledge on de-suckering and pruning. The death of an adult household member negatively influenced continued use of tissue-cultured banana. Regardless of the HIV/AIDS status, adoption was found to be related to financial capital (savings) physical capital (farm equipment) and natural capital (security of land tenure). Continued use of tissue-cultured banana was positively related to off-farm livelihood activities and contact with extension agents. It was also found that the government extension service is faced with challenges in providing appropriate technology for HIV/AIDS-affected households.

P-SS-11

On-farm participatory evaluation of East African Highland banana 'matooke' hybrids

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The East African highland bananas 'matooke' are unique in terms of utilisation, taste and their cultural attachment to the people in the East Africa region. Research efforts have been directed towards improving these bananas for disease and pest resistance, and higher yields while keeping their unique taste and other culinary qualities. This paper presents results of an on-farm participatory evaluation study of 18 conventionally bred hybrids selected from an early evaluation trial at Kawanda Agricultural Research Institute. The 18 conventionally bred 'matooke' hybrids and a local variety 'Mbwazirume' were planted in farmers' fields in Kasangombe sub-county, Nakaseke district in central Uganda. The hybrids were evaluated for consumer acceptability, black sSigatoka resistance, agronomic performance and weevil damage. The 'matooke' hybrids 'M2', 'M9', 'M14' and 'M17' were selected as the most acceptable hybrids and found to be resistant to black sigatoka. The selected 'matooke' hybrids had significantly higher bunch weights than the local variety 'Mbwazirume' and were less affected by weevils in comparison with the local check.

Genetic improvement

P-GI-1

Over-expression of anti-apoptosis genes as a novel molecular strategy for protecting banana from fungal diseases and abiotic stresses

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The expression of mammalian anti-apoptosis genes in plants, such as tobacco, has been shown to provide varying levels of resistance against several necrotrophic fungi and abiotic stresses. We have been investigating whether these genes can be similarly exploited to generate transgenic bananas with resistance to the devastating fungal diseases, Black and Yellow Sigatoka and Fusarium wilt, as well as abiotic stress. A large number of transgenic banana plants (both Cavendish and Lady Finger) expressing different mammalian anti-apoptosis genes (Bcl-2, Bcl-xL, and CED-9) have been generated by Agrobacterium-mediated transformation and these have been fully characterised. Previous studies in our laboratory have shown that banana cells exposed to the soil pathogen, *Agrobacterium tumefaciens* exhibit features associated with mammalian apoptosis including DNA laddering, fragmentation, and the development of apoptotic bodies. Interestingly, these features were absent in our transgenic banana plants expressing the anti-apoptosis genes, suggesting that the gene products were functional. We have commenced glasshouse trials to challenge a selection of transgenic bananas lines with the fungal pathogens causing Yellow Sigatoka and

Fusarium wilt. We will also examine whether the transgenic bananas show enhanced resistance to abiotic stresses such as heat, cold, salinity and drought.

P-GI-2

Defining the molecular basis for increased carotenoid levels in high provitamin A bananas

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Vitamin A deficiency (VAD) causes approximately 8 million deaths per year in developing countries. Although preventable, VAD is a major health issue mainly due to low provitamin A (pVA) levels in staple food crops and limited access to alternative pVA containing foods. The East African Highland banana (EAHB), a staple food crop of the Ugandan people, is low in pVA (approx 0.21 µg/g) while some banana varieties endemic to the Asia Pacific region contain high pVA levels (up to 27.8 µg/g). The development of EAHB with increased pVA is of significant value. This project aims to identify the molecular basis for the differential production of pVA in high and low pVA bananas. Such insights will facilitate the production of high pVA bananas via genetic modification, as reported previously for tomato, oilseed rape and rice. The gene encoding phytoene synthase (PSY) which catalyses an important rate limiting step in the biosynthesis of carotenoids, was the first selected for characterisation of banana pVA accumulation. Phylogenetic analysis of part of the PSY coding region from a range of banana cultivars identified three different PSY genes (psy1, psy2a and psy2b) in banana. The genomic and mRNA sequences of each of these genes from 'Asupina' (high pVA) and 'Cavendish' (low pVA) bananas have been determined and the coding sequences transformed into rice callus to compare the relative activity of each psy gene. Expression profiles for these genes is being investigated by quantitative Real-Time PCR to determine the relative abundance of RNA transcripts in both leaf and fruit and by transient expression of the GUS reporter gene under the control of each of the putative promoter regions in banana tissues. The potential role of these genes in mediating differences in pVA levels is presented.

P-GI-3

Promoters for biofortification of banana

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Nutritional deficiency is a major problem affecting millions of people in developing countries and is responsible for a significant proportion of the sickness and death. Dietary deficiency in vitamin A, vitamin E and iron are common in Africa and are a primary focus of nutritional enhancement programs. Plant sources of provitamin A, vitamin E and iron are cost effective and sustainable means of supplying these nutrients to large populations. Unfortunately, many important staple food crops contain low levels of these nutrients. The genetic modification of region-specific staple food crops for increased nutrient content will help alleviate these deficiencies. Bananas are a staple food for millions of people living in East African countries such as Uganda, and have been identified as an ideal target for genetic modification to enhance essential nutrients. Many genes for the

synthesis of provitamin A and vitamin E, and accumulation of iron, have been described from a variety of eukaryotic and prokaryotic sources. We are using this information for the manipulation of provitamin A, vitamin E and iron content in banana. The key to this improvement in nutrient levels is the combination of appropriate promoters with highly active genes in banana fruit at the correct developmental stage. A number of genes are available for the improvement of provitamin A, vitamin E, and iron levels; however, there is limited information about promoters which will drive transgene expression in banana fruit. We have identified a number of constitutive promoters, as well as fruit specific/preferentially expressed promoters, and have conducted a preliminary evaluation of their ability to express reporter genes in banana fruit sections. Transgenic banana plants are currently being produced to validate these results in whole banana plants. Concurrently, these promoters are being used for expression of provitamin A, vitamin E and iron accumulation genes in transgenic banana fruits.

P-GI-4

Banana and plantain germplasm study in the territories of Beni and Lubero, Democratic Republic of Congo

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We conducted surveys at 4 sites: Munoli (00°7380'N, 029°2206', 1764 masl), Maboya (00°25364'N, 029°3236'E, 1423 masl), Mangodomu (00°58049'N 029°32632'E, 1026 masl), Nzenga (00°31681'N, 029°70596'E, 1007 masl). Data was collected using PRA method and a diagnostic survey. At each site, we chose 5 random villages and 30 different random fields. In medium altitude sites (Munoli and Maboya), wine varieties were the most common (47%), compared with cooking bananas (34%). Plantains are more often cultivated in low altitudes, making 39% of cultivars, compared with 23% at the middle altitude. Cooking bananas accounted for 45% of cultivars grown at Mangodomu and 24.4% at Nzenga. Dessert bananas were not common at all sites. Cultivars grown include 'Nguma' (plantain), 'Kitoke', 'Vulambya' and 'Mudjuva' (cooking type), and 'Mukingiro', 'Kisubi Musa', 'Kisubi Mangango' and 'Tundu' for wine banana. 'Musilongo' (plantain), 'Pakuma' and 'Nyaghenge' (cooking banana) are reported to have the best taste. 'Kitoke', 'Kitwavwira' and 'Nziravahima' (cooking type), 'Nguma', 'Vuhindi' and 'Kikotina' (plantain), and 'Kitika Sukari Kikui' (Dwarf Cavendish dessert) have persistent bracts for BXW prevention. 'Nziravahima' and 'Vulambya' are genetically unstable, due to mutations. In the study area, the border between the Congolese basin and East Africa highlands (plantain secondary diversification area and AAA-EA group, respectively) was found to have a high genetic diversity of banana and plantain. Some plantains from the Congolese basin are suitable for growth at altitudes of below 1000 masl.

P-GI-5

EST-derived genomic resources for *Musa*

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Two normalized *Musa* cDNA libraries comprising 1 root, and 2 leaf and stem tissue (including shoot meristem) were sequenced from the 5-T end. The libraries comprised cDNAs from drought-stressed and irrigated plants of the lines 'Sukari Ndizi' (apple banana, AAB group),

'Pisang Awak' ('Kayinja', ABB group) and 'Mpologoma' (*Musakala* clone set AAA-EA group). 'Sukari Ndizi' is a cultivar which is reported to have a good physiological adaptation to drought. 'Pisang Awak' is generally considered to be a cultivar that can withstand abiotic stresses (drought, poor soil). 'Mpologoma' has a high yield potential and harvest index, but is considered (by farmers) to be sensitive to abiotic stresses (drought, fertility) and is one of the most drought-sensitive cultivars within the highland banana group. Some 5494 good quality sequences were generated. Assembly and clustering into contiguous sequences yielded 4190 unigenes comprising 820 contigs (mean size 855 bp) and 3370 singletons (mean size 656 bp). This data has been combined for analysis with the Global Genomics Consortium's EST repository data. The final combined assembly contains a set of 32,649 unique sequences comprising 8320 contigs (mean size 712 bp) and 24329 singletons (mean size 472 bp). SSR and putative SNP-Ts could be identified in both this EST set and the combined data set. Some 4089 potential markers have been identified from this EST data set (3692 putative SNPs and 397 SSRs), while 30752 putative markers were identified in the combined data set (28815 SNPs and 1937 SSRs). Validation of these markers is underway and results will be presented. The output from this project increases the marker resource available for dramatically and will significantly improve our capabilities for diversity studies, targeted trait selection and gene expression experimentation.

P-GI-6

***Agrobacterium*-mediated transformation of banana cultivar 'Rastali' (AAB group) with chitinase gene**

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A rice chitinase gene (*RCC2*) multiplied in *Agrobacterium* strain (EHA 101), was simultaneously introduced into single buds of *in vitro* grown banana cultivar, 'Rastali' (AAB group). Plasmid pBI333-EN4-*RCC2* contained a hygromycin phosphotransferase gene (*hpt11*) as the selectable marker and *gusA* gene as a reporter marker to identify the transformants. Treatment A contained hygromycin at 25 mg/L and treatment B contained hygromycin at 50 mg/L in both MS medium supplemented with 5 mg/L of BAP together with 2.7 g of gelrite agar. Single buds derived from multiple bud clumps (Mbcs), were the target explants for transformation. An assay was performed to identify the minimum concentration required for the two antibiotics (carbenicillin and cefotaxime) that is most effective against *Agrobacterium* strain, EHA 101 and the effect on tissue regeneration capacity. Even though the transformation frequency based on hygromycin selection medium (treatment A) was higher, no transformant could be confirmed based on PCR and Southern blot analyses, compared with 50 mg/L hygromycin selection medium. Stable *gusA* gene expression was detectable in transformed single buds, multiple bud clumps, shoots, leaves and roots derived from treatment B. Assay of protein extract from the transgenic plantlets showed an increase in chitinase enzyme activity compared with the untransformed plantlets. *Agrobacterium*-mediated transformation, as reported here is suitable for using tiny meristem tissues to obtain fungal disease tolerant or resistant banana through genetic engineering.

P-GI-9

Bridging the technology gap in banana improvement: the case of biotechnology adoption by developing countries

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Banana (spp.) constitutes an important staple food and a major source of revenue in local and international markets. The crops are also a cheap source of protein, fat, vitamins A, B (thiamine, niacin, riboflavin) and C and the minerals (iron, sodium and potassium). In Kenya, banana cultivation, which in the past was largely for subsistence, is rapidly becoming an important economic activity among small-scale farmers. Black and Yellow Sigatoka diseases caused by the Ascomycetes fungi *Mycosphaerella fijiensis* (Morelet) and *Mycosphaerella musicola* (Leach) are reportedly on the increase, contributing to declining yields of the preferred cooking and dessert varieties. Fungicide control though effective on commercial plantations elsewhere in the world is hardly applied in Kenya. Besides being expensive the intervention is environmentally unsafe and impractical for backyard small-scale production. The use of clean planting material and host resistance is a more sustainable strategy. Through public-private partnerships involving among others, the Kenya Agricultural Research Institute (KARI, Thika), Jomo Kenyatta University of Agriculture (JKUAT), the International Service for the Acquisition of Agribiotech Applications (ISAAA), Africa Harvest and commercial laboratories the banana tissue culture technology has been successfully introduced in the major banana growing areas resulting in enhanced productivity (from 20 to 45 tons/ha). However, there is still the risk of Sigatoka disease infestation in farmers' fields. At the global level, conventional breeding attempts have yielded limited genetic variability, necessary for Sigatoka host resistance improvement. Breeding for resistance using biotechnological tools is, therefore, a promising alternative. Initial successes have relied upon a combination of conventional methods and tissue culture-based techniques. Efforts are currently geared towards adopting emerging biotechnologies such as genetic engineering and molecular marker-assisted selection. However, developing countries have not fully adopted the more advanced biotechnological techniques due to infrastructure and training constraints. Besides, the application of genetic engineering is riddled with controversies regarding the potential risks and benefits, and requires strict government regulations, which are lacking in many developing countries. To bridge this technology gap it is necessary to adopt the simpler, affordable techniques of banana improvement. Integration of *in vitro* culture methods and induced mutations into conventional banana breeding is one such strategy for creating genetic variability in *Musa*. This paper reports on the use of this approach to improve three dessert cultivars popular in Kenya. Data on protocols for micropropagation, *in vitro* mutation induction and screening for host response to the Sigatoka diseases will be presented.

P-GI-11

Pollen fertility in *Musa*: viability of synthetic diploid hybrids in improving East African Highland bananas for the market

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Male fertility is a major limitation in the genetic improvement of bananas for markets. Both wild and cultivated diploid bananas are used as male parents in banana breeding programmes to generate genotypes with host plant resistance to pests and diseases, which are the major biotic constraints to banana production in the great lakes region of East Africa. Synthetic diploid hybrids derived from East African highland bananas (EAHB) (spp. AAA-EA group) provide an opportunity for germplasm enhancement at the diploid level and are a source of the highly desired 'matooke' cooking alleles in the banana breeding. Quantity and quality of pollen grains are important attributes to be considered in the selection of male parents for banana breeding. This study therefore aimed at assessing the potential of utilizing the synthetic diploid hybrids as male parents in breeding programmes. Twenty four synthetic diploid banana hybrids recovered from 2x-2x, 3x-2x and 4x-2x crosses in the improvement of EAHB in Uganda, were evaluated for pollen output, stainability and *in vitro* germination. The results showed that pollen output did not significantly depend on the node from which the anthers were excised in the synthetic diploid genotypes. Pollen stainability values were significantly correlated to pollen germination although there was no consistent relationship between the stainability and germinability values. Ten genotypes namely '3550K 1', '861S 1', 'OPP1 861', '3146K 3', '12506S 29', '2866K 4', 'OPP2 861', '3162K 3', '3162K 1', '3162K 5' and '3146K-' show sufficient pollen germination, stainability and pollen rating to be considered male fertile for introgressing genes for their desirable traits in improving bananas.

P-GI-12

***Agrobacterium*-mediated transformation of EA-AAA banana (*Musa* spp.) previously categorized as recalcitrant**

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East African Highland bananas (AAA-EA group) constitute a staple food crops for the East and Central African region. In Uganda, cooking bananas (matooke) provide food for over 80% of the population. Despite their importance, the crops are greatly threatened by pests and diseases. Resistance to pests and diseases is lacking in edible cultivars and conventional breeding is hindered by the crop's biology and genetics. Genetic engineering, with genes that have potential resistance against diseases, has been reported mainly in plantains and desserts. Due to recalcitrance of AAA-EA banana to somatic embryogenesis, their genetic transformation remained complicated. Recently, we developed high quality Embryogenic Cell Suspensions (ECSs) of a few AAA-EA cultivars. To obtain stable expression of a foreign gene, genetic transformation of AAA-EA cultivars was optimized. *Agrobacterium tumefaciens* strains EHA105 and/or AGL1 containing the binary vector, pCambia1305.1

or pFAJ3000, were used in this study. Vector pCambia1305.1 contained *hpt* gene as a selectable marker and *Gusplus* as a reporter gene; whereas pFAJ3000 contained *nptII* and *gusA* respectively. Regenerated lines were transgenic, based on PCR analyses. Southern blot analysis confirmed that *gusA* gene is integrated in the genome with various integration patterns. Observed transformation frequencies and regeneration were compared with results obtained from transformation of 'Sukali Ndizi' (AAB group) and 'Gros Michel' (AAA group), used as model cultivars in our transformation system. These results open new avenues for genetic improvement of AAA-EA bananas through genetic engineering and show the wide application of *Agrobacterium* based gene transfer in bananas of different genome types.

P-GI-16

Banana transformation for nutritional enhancement

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The vast majority of bananas grown today are selections and have not undergone any process of continuous improvement through conventional breeding. The major reason for this is that most cultivars are essentially sterile. A very appropriate alternate strategy is to improve current cultivars through genetic modification. We have developed efficient *Agrobacterium* mediated transformation protocols for a number of banana cultivars as well as transgene expression tools for bananas. Our banana improvement program has two major targets, disease resistance and biofortification. We have transformed bananas using a number of different experimental disease resistance strategies and potential disease resistance genes, including R gene from *accuminata malaccensis* which was segregating for resistance to *Fusarium oxysporum* f.sp. *cubense* (*Foc*). This gene has been transformed into both 'Cavendish' and 'Lady Finger'. We have transformed 'Cavendish' and 'Lady Finger' with a range of anti-apoptosis genes to establish their potential to generate resistance to *Mycosphaerella* spp. and *Foc*. Surprisingly, the constitutive expression of these genes resulted in a spectacular increase in *A. tumefaciens* transformation efficiency. Our biofortification program is centred on improving the micronutrient content of East African highland bananas (EAHB) in Uganda. The two major micronutrient targets are pro-vitamin A and iron. For pro-vitamin A enhancement, phytoene synthase genes from both high pro-vitamin A banana cultivars and maize have been isolated and have been inserted into 'Cavendish' in Australia and EAHB in Uganda under the control of both fruit specific and constitutive promoters. Potential genes to drive accumulation of iron in banana fruit are being isolated and characterised.

P-GI-17

Genetic engineering of Hill banana ecotypes against BBTv

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Two Hill bananas cultivars 'Virupakshi' and 'Sirumalai' known for their special flavour and long shelf life, are unique to the state of

Tamil Nadu, India. Hill bananas are perennial in nature and are the ruling crop of the Lower Pulneys hill range, Sirumalai and Kolli hills of Tamil Nadu from 1940 through 1975 while coffee and pepper also formed part of a multitier system. Hill bananas prefer an altitude of 2000 to 5000 masl and a well distributed annual rainfall of 1250-1500 mm. Like other bananas, hill bananas are also susceptible to banana bunchy top virus (BBTV). BBTV has been the sole cause for reduction in hill banana cultivation from 18,000 ha in 1970s to a mere 2,000 ha at present. None of the strategies now available are able to completely protect hill bananas against the virus. The improvement of this crop through conventional breeding has not been successful. This presentation reports on the efforts made at the Centre for Plant Molecular Biology, TNAU with a view to engineering resistance in hill banana cultivar, Virupakshi against the BBTV. Immature male flower buds of 'Virupakshi' were used as explants. Among five different media composition tested for callus induction, a Murashige and Skoog callus induction medium (MS-CIM) containing 2, 4-D (4 mg/L), IAA (1 mg/L), NAA (1 mg/L), biotin (50 mg/L), proline (150 mg/L), MS vitamins, Sucrose (30 g/L) and Phytigel (3g/L) was found to be the most suitable for callus induction and proliferation. Putative embryogenic calli were obtained in 4 to 6 months and were used for initiating embryogenic cell suspension cultures in MS embryogenic cell suspension medium (MS-ECS) containing 2, 4-D (4 mg/L), IAA (1 mg/L), NAA (1 mg/L), with sucrose (45 g/L) and coconut water (10%). Homogenous embryogenic cell suspensions were obtained in 2 to 3 months. Such embryogenic cell suspensions were used for the induction of somatic embryos in SH medium (Schenk and Hildebrandt, 1972) containing IAA (1 mg/l), NAA (1.5 mg/l) and 2-ip (0.2 mg/L), MAs vitamins (Ma, 1991), sucrose (45 g/L) and phytigel (2 g/L). Putative somatic embryos were induced after two months of incubation. Such somatic embryos were then transferred to a maturation medium containing half strength MS basal salts, NAA (1 mg/L), coconut water (10%), charcoal (1%), MW vitamins (Morel and Wetmore, 1951), sucrose (30 g/L) and phytigel (3 g/L). Mature somatic embryos were obtained after 1-2 months incubation. These mature somatic embryos were transferred to the regeneration medium containing half strength MS medium, BAP (2.5 mg/L), TDZ (2.5 mg/L), sucrose (30 g/L) and Gelrite (2.5 g/L). Two month-old regenerated plants were rooted in rooting medium containing a half strength MS medium, charcoal (1%), sucrose (30 g/L) and Gelrite (2.5 g/L). We isolated a full length, 850 bp Replicase gene of BBTV from infected hill banana. The isolated sequence showed 98% homology to the already reported BBTV Replicase gene sequences from India available in NCBI databases.

P-GI-18

Role of biotechnology in banana: Indian scenario

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Banana is a globally important fruit crop grown over an area of 8.25 Million ha with an annual production of 97.35 Mt. India is the largest producer and consumer of banana contributing 19.7% of the world production with a total production of 19.2 metric tons from an area of 0.6 million ha. India can immensely contribute to the world banana trade with cutting edge technology through biotechnology, hi-tech cultivation, and post harvest practices, fruit processing and value added products. Tissue culture technique in banana has been gaining wide acceptance in India and abroad as a tool to obtain virus free, high yielding and superior quality planting material. To support the growth and development of Indian banana, the plant tissue culture

division of Reliance Life sciences (RLS) provides cutting edge services in micro propagation of plants, mass multiplication of elite varieties and contract production of client specific plant varieties. RLS has established modern state-of-art plant tissue culture facility and hardening centers across the country. Apart from producing and supplying high quality, virus free tissue culture plants, RLS is also offering advisory services, package of practices, farmers training, post harvest technology etc. to obtain highest returns for farmers through high tech cultivation. In addition, our group concern Reliance Retail is buying back banana fruits from growers and after scientifically ripening, the fruits are being distributed to retailers and consumers through a chain of retail stores. In addition efforts are being made to export of fruits, fruit processing and value added products in banana. Thus, biotechnological application is playing a vital role in banana through high tech production, cultivation, post harvest, and marketing technology to bring about a rural transformation in India.

P-GI-19

Tetraploid banana breeding: a novel breeding technique for developing new banana cultivars

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Successful and efficient artificial hybridization is an import aspect of plant breeding. The most important constraint in breeding cultivated bananas is triploidy ($2n = 3x = 33$ chromosomes) that contributes to the sterility and limits the use of hybridization in banana improvement. The development of disease resistant banana hybrids with consumer characteristics that match the traditional grown cultivars is still the major challenge to banana breeders. The objective of this study was to develop tetraploid bananas from $3x \times 2x$ crosses and use the resulting tetraploids in generating new hybrids in $4x \times 4x$ crosses. The $4x \times 4x$ crosses were made at the Namulonge Research Station in Uganda in 2003 and 2004. In this study we evaluated progeny resulting from the $4x-4x$ crosses to ascertain the inheritance of characteristics from the female grandparent. One of the striking features of the progenies obtained from the $4x-4x$ crosses as compared to progenies obtained from other breeding strategies ($3x-2x$, $4x-2x$) is their marked resemblance in morphology, bunch characteristics and palatability to their female grandparents. The $4x-4x$ breeding scheme thus provides opportunities for new genetic recombinations that were previously not practical. The tetraploid hybrids inherit 75% of their genes from the triploid landrace gene pool, assuming that there is nuclear restitution, and 25% from the diploid parent sources. Tetraploid hybrids are therefore expected to have more traits in common with landraces. Progeny derived from $4x-4x$ crosses could potentially have 50% of their genes donated by each parent, assuming normal meiosis, and are more likely to inherit favorable alleles from the parents.

P-GI-21

Control of banana *Xanthomonas* wilt disease using genetic engineering

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The banana *Xanthomonas* wilt (BXW) disease caused by the bacterium *Xanthomonas campestris* pv. *cearum* (*Xcm*) has threatened the livelihoods of millions of farmers in the Great Lakes region of East and Central Africa. The disease was first identified in Uganda in 2001 and now has also been reported in eastern Democratic Republic of Congo, Rwanda, Kenya, Tanzania and Burundi. The pathogen kills plants quickly and spreads rapidly over a large area in a short time, making the disease one of the most dreaded in banana. The development of disease resistant banana cultivars remains a high priority since farmers are reluctant to employ labor-intensive disease control measures. Prospects of developing varieties with resistance to BXW through conventional breeding are limited, as no source of germplasm exhibiting resistance against *Xcm* has been identified. Transgenic technologies for banana may provide a timely and cost-effective alternative solution to the BXW pandemic. The ferredoxin-like amphipathic protein (*pflp*), isolated from *Capsicum annuum* is a novel protein that can intensify the harpinPSS-mediated hypersensitive response. The International Institute of Tropical Agriculture (IITA) has negotiated royalty free license from Academia Sinica, Taiwan, patent holder, through the African Agricultural Technology Foundation for access of technology for bacterial wilt resistance. The genetic transformation of banana with construct having *pflp* gene is in progress at IITA in collaboration with National Agriculture Research Organization, Uganda. Several transgenic lines of banana cultivars have been generated and are currently under screening for disease resistance in laboratory conditions. Most promising lines will be evaluated for efficacy against *Xcm* in the field.

P-GI-22

Transforming banana with *APETALA1* gene for initiation of early flowering

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The East African Highland bananas grow to as high as 5-8 m, which increases susceptibility to breakage of pseudostems. This height is associated with a long vegetative phase of the plants. Limitations in banana conventional breeding hamper the introgression of dwarfism in banana germplasm. Therefore, genetic engineering to shorten the vegetative phase through over-expressing flowering genes that induce early flowering was sought. We report genetic transformation 'Sukali ndiizi' (AAB group) with the gene *APETALA1* (*AP1*), which is reported to reduce plant height in several plant species. Immature male flowers were used to initiate embryogenic cell suspensions of 'Sukali ndiizi'. Cells from a highly embryogenic cell suspension line were transformed by *Agrobacterium tumefaciens* containing modified pCambia1302 binary vector. Transformed cells were selected by hygromycin selection, and clusters of transformants regenerated into shoots. A regeneration frequency of 26% was observed. Polymerase chain reaction of *hygromycin phosphotransferase* (*hpt*) selectable marker and *AP1* gene analysis confirmed 10 positive lines out of the

17 regenerated lines. Plants are being multiplied *in vitro* to generate materials for green house evaluation and Southern blot analysis.

P-GI-23

Engineering banana cell cycle with *cyclin D* gene for increased growth rates and reduced maturity time

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The East African highland bananas (spp.), which constitute a staple for millions of people in the Great Lakes region are characterized by a long growth cycle. Such long cropping cycles affect banana productivity per unit time, which, if reduced can provide higher yields over time. However, limitations of conventional banana genetic improvement still challenge breeding for early maturity. In this study, we undertook a genetic transformation strategy of over-expressing *Cylin D* type genes that are responsible for shortening the cell cycle duration with eventual increased growth rates in model plant species. A full-length cDNA *cyclin D* was isolated from East African highland banana and transformed into embryogenic cell suspension of 'Sukali ndiizi' (AAB group) via the *Agrobacterium* system. Polymerase chain reaction after three cycles of *in vitro* multiplication of the regenerants indicated the presence of the transgene, whereas Southern blotting analysis confirmed its integration in the genome. Cyclin expression levels of the different transgenic lines will be correlated with plant development and growth characteristics.

P-GI-24

Biofortification of Ugandan banana (*Musa* spp.) cultivars for enhanced provitamin A and iron contents in edible fruit pulp

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Micronutrient deficiency is the major cause of child mortality in Africa and seriously constrains human development and survival. In Uganda, micronutrient deficiencies are responsible for high rates of mortality and morbidity in children and adult populations. Two micronutrient deficiencies that are highly prevalent are vitamin A deficiency (VAD) and iron deficiency anaemia (IDA). Such micronutrient deficiencies are intensified by over dependency on banana that contains insignificant quantities of provitamin A and iron. This is indicated by higher rates of VAD and IDA in banana growing areas of western and southwestern Uganda. Biofortification of staple crops is regarded as the most effective strategy for reducing micronutrient deficiencies. In the current study, we report on the genetic modification of Ugandan banana cultivars with genes that have potential to increase provitamin A and iron in edible banana fruit pulp. Using *Agrobacterium tumefaciens* strain AGL1, transgenes involved in provitamin A biosynthetic pathway (*Apsy2a*, *PSYB73*, and *CrtI*) and iron uptake (*IrtI*) and storage (soy *Fro2*) were introduced into embryogenic cells of 'Sukali Ndizi' (AAB group) and 'Nakasabira' (AAA-EA group). A wide range of plantlets were regenerated for each

transgene and numerous shoots remain under the regeneration process. Preliminary screening, so far conducted with PCR, showed the presence of these transgenes. Detailed molecular analyses of these genes will be undertaken as plants grow and their activity will be evaluated in the field.

P-GI-25

Application of cytoplasmic and nuclear DNA based marker systems for elucidation of phylogenetic relationship of *M. acuminata* and *M. balbisiana*, and their hybrids

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(*Musaceae*) is one of the most important staple crops widely cultivated in the tropics and sub-tropics. The present day edible bananas originate mostly from the diploid species ($2n = 22$) *acuminata* and *M. balbisiana*. The diploid or polyploid cultivated banana varieties are sterile intra- or inter-specific hybrids of these two species and have been fixed through hundreds of years of human selection. Therefore, knowledge on the putative fertile ancestors would be beneficial for breeding programs. In the present work cytoplasmic (chloroplast and mitochondria) as well as nuclear genome based marker systems (rDNA and DaRT) were applied for the identification of putative ancestor gene-pools of banana in a model study based on a mini core collection of 52 genotypes including ten *M. acuminata* and eight *M. balbisiana* wild types, along with ten AAA group, ten AAB group and eight ABB group triploid hybrids. The collection also contained three AA group and two AB group diploids, and a single tetraploid cultivar. The results provide information, which may be considered in future breeding programs, revealing the origin of hybrid genomes related to the wild types.

P-GI-27

Horizontal gene flow from transgenic bananas (*Musa* spp.) to microorganisms

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Recent advances in plant biotechnology, especially genetic engineering have heightened promises for mitigating biotic and abiotic constraints. However, the use of biotechnology to mitigate biotic constraints has raised several biosafety concerns, mainly gene flow. Of interest is gene flow to rhizosphere and phyllosphere microorganisms. In this study, transgenic banana plantlets having the hygromycin resistance (*hpt*) gene as selectable marker and beta-glucuronidase (*gusA*) gene as reporter gene were used to investigate the potential of gene flow to fungal endophytes (*Fusarium oxysporum*) and microorganisms of the rhizosphere. The first batch of transgenic plants was grown in soil and microorganisms were isolated from rhizosphere on selective media supplemented with hygromycin. The second batch of transgenic plants was transferred to soil after inoculation with endophytes (*F. oxysporum*). After colonization, the fungal endophyte was re-isolated from transgenic plants on a selective medium. The DNA was extracted from bacteria and fungal

organisms growing on selective media. The DNA was amplified using *hpt* and *gusA* specific primers to confirm putative gene flow from transgenic plants. Results indicated that the microorganisms did not take up the transgenes from transgenic plants. This implies that horizontal gene transfer from transgenic plants to microorganisms did not occur. The implications of horizontal gene flow are discussed in the context of biosafety considerations of transgenic bananas.

Innovation Systems



Oral Presentations

Plenary: Innovation Systems

Venue: Meister Room

Time: 0830–1030

Bananas and new thinking about pathways for science impact

N. Röling

Wageningen University, Wageningen, Netherlands

In terms of genetic diversity, bananas are not promising. Traditional breeding and diffusion of high yielding or resistant varieties is perhaps not the best strategy for science impact. Yet East African farmers have developed a considerable number of cultivars. Tissue culture for rapid production of plantlets allows banana farmers to plant virus-free stock and to recuperate rapidly after freak frosts induced by climate change (as in southern China last winter). In all, bananas are interesting. Their specific nature leads banana scientists to be open to innovation in the way they think about innovation. The paper presents such new thinking. It draws on three sources. (i) The international assessment of agricultural science and technology for development (IAASTD), which was approved by 58 governments last April and which reviewed the evidence for how agricultural knowledge, science and technology (AKST) (can) contribute to reaching the combined development and sustainability goals (dealing with hunger, poverty, climate change, global food security and human health). The IAASTD gives smallholder development a central role in securing global food security and points to the importance of trade and markets and of institutional development, in addition to technology. (ii) The convergence of sciences (CoS) inter- and trans-disciplinary research programme, which experimented with pathways for science that can be effective in improving the livelihoods of smallholders in Benin and Ghana. CoS showed how very small the windows of opportunity of smallholders are, and that carefully designed appropriate technology development can do little else than help realise *existing* opportunity. CoS started to explore how institutional change can stretch the windows of opportunity. This will be further explored in CoS-SIS, a 5-year sequel that has just been approved (4.5 million Euros for five years in Benin, Ghana and Mali), and that will focus on strengthening innovation systems as an approach to smallholder opportunity development. (iii) The innovation systems (IS) approach and theory that has emerged in the past decade as an alternative framework to conventional technology supply push. Innovation systems are the third theme of the conference. These three sources will be used to address the topic of the conference: harnessing international partnerships to increase research impact. Special emphasis will be given to approaches that can help minimise pre-analytic choices by researchers: opportunity scoping, diagnostic studies, and multi-stakeholder processes. These approaches help avoid a premature focus of research on yield/ha.

Innovation systems, food security and economic development

J.A. Francis

Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, Netherlands

In 2004, the Technical Centre for Agricultural and Rural Cooperation ACP-EU (CTA) began a process of competence building in the African, Caribbean and Pacific (ACP) region to enhance the participation of experts in science, technology and innovation (ST&I) policy processes. The assumptions were that; little innovation was occurring in the agricultural sector; disconnect existed between the S&T community and policy/decision makers, and limited information was available for supporting informed decisions on increasing investments to support agricultural and rural development. There were two aspects to the programme i.e. formal training to increase understanding of innovation and the innovation systems concept followed by support to ACP organizations to reinforce knowledge and skills through the conduct of national case studies applying a standardized methodological framework for analyzing the agricultural, science, technology and innovation (ASTI) system. This paper reviews the programme evolution and presents the key findings from case studies conducted in 13 ACP countries in subsectors that were considered important either for food security or agricultural diversification or under threat from losing preferential international markets. The subsectors included banana, cassava, cocoa, floriculture, ginger, mango, noni, nutmeg, plantain and rice. It was shown that the policy framework; the knowledge infrastructure and the intensity of the linkages among system actors, for example, those that exist between national research organizations, universities and farmers determine the strengths and weaknesses in the innovation system and the innovative capacity of the actors. It can be concluded that there is need to enhance understanding of innovation processes, the innovation system approach and its relevance to agriculture to create the enabling environment for learning, networking, information and knowledge sharing, influencing ST&I policy and investments for improving the generation, dissemination and uptake of knowledge to drive innovation for achieving food security and economic performance in the ACP region. Capacity building is critical.

Tracking the spill-over of introduced technologies: the case of improved banana germplasm in northeastern Tanzania

J.G. Mowo¹, K.F. Masuki¹, L.A. German², M.N. Kingamkono³ and C.J. Opondo⁴

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A methodology for tracking the pattern and extent of spillover of technologies was tested in the Baga watershed, in Lushoto, northeastern Tanzania using improved banana germplasm as the case study. The aim was to understand the factors responsible for spillover of introduced technologies and the accompanying farmer innovations. Formal surveys, farmer records and focus group discussions were used to establish the path taken and distance covered by the technology, barriers encountered and modifications made by farmers. Results show that farmers make different modifications to the technologies to fit the existing farming systems, and that the pattern of spillover was very much related to existing social networks in the community. Kin (nuclear and extended family)

accounted for 53% of the spillover of improved banana germplasm compared to 47% of non-kin (friends and neighbour) social networks. Improved banana suckers introduced in the watershed were found as far as Dar-es-Salaam; more than 300 km away. The paper reviews the methodology for tracking the spillover of improved banana germplasm, highlighting the key challenges and lessons as well as illustrating the applications of the findings in improving delivery of research and extension services.

Turning African farmers into businessmen or marketizing small-holder Agriculture? Reconciling the market versus social varieties of capitalism in the African agribusiness development debate

C.M.O. Ochieng

Ecoagriculture Partners, Nairobi, Kenya

This paper argues that the fundamental question of development facing African farmers, one that precedes questions about how to turn them into businessmen or connect them to the markets, is that of marketizing the small-holder economy or creating a variety of capitalism conducive to the needs and capabilities of a majority of the African population i.e. farmers. Despite Nobel Laureate Theodore Schultz's demonstration that peasants may be poor but they are rational and efficient, the push to turn African farmers into businessmen, which is based on a variety of market capitalism, implies that they are economically irrational and inefficient. In contradistinction, it shall be shown that African farmers are not only already businessmen, but they are also economically rational and efficient. They just happen to operate under a different variety of capitalism i.e. a social economy, characterized by social capital, social labor, social insurance, traditional knowledge systems and other social institutions. Under market capitalism, profit maximization is premised on marginal revenue equaling marginal cost. However, in a social economy, profit maximization is premised on marginal social costs equaling marginal social revenues. The question of turning African farmers into businessmen or connecting them to markets can thus not be resolved without determining the economic system under which farmers find themselves. In a social economy, this might require the establishment of social economy enterprises; in a market economy, this would require a much broader effort - replacing the institutions of social economy with those of a market economy. Unless the nature of the underlying economic system is taken into consideration, the desire to 'turn African farmers into businessmen or to connect them to markets' may not yield the desired outcomes.

Meeting demand: what growers need and how to respond

E. Boa, R. Reeder, P. Kelly, J. Bentley and S. Danielsen

Global Plant Clinic, CABI, Egham, UK

The Global Plant Clinic grew out of a long standing if poorly known service for diagnosing plant diseases found in developing countries. In 2003 we started to promote plant health clinics in an attempt to improve our understanding and response to farmer demands. Now there are over 60 independent clinics in Asia, Africa and Latin America. Plant health clinics are run by NGOs, farmer cooperatives and others who work closely with farmers. They are run weekly in public places by mainly agronomists and extension workers. Thousands of farmers have asked for advice and for most it is the

first time they have been able to seek answers directly about plant health problems. The 'plant doctors' are generalists and already know local farmers well, an important advantage when starting a clinic. As use of clinics has increased they have requested training and better support so they can advise farmers more effectively. The first GPC training courses looked at recognition and interpretation of symptoms (field diagnosis). We received regular requests for training on control methods but were nervous about attempting to cover many crops and types of problems and because farmer field schools were ostensibly already providing this training. But as we have got to know the people who run clinics and understood the nature of farmers' demands better, we have tested new ways to help meet these demands. I will discuss the usefulness of field diagnosis, outlining of extension messages using the snowman model and farmer peer review to validate extension messages. I will explain how self evaluations help agronomists and extension workers value what they do. Clinics are a new platform for gathering demand and responding to it. They help identify research needs but they are not a universal panacea for complex problems that limit adoption of technologies. They are, however, a listening post that encourages practical responses that solve farmers' problems. They are a new route for strengthening extension-research links and fostering innovation in service delivery as well as use of technologies.

Parallel Session 1: Tracking Adoption and Impact

Venue: Meister Room

Time: 1100–1300

Community-based organizations and their effect on the adoption of agricultural technologies in Uganda: a study of banana production technology

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Local organizations are increasingly used as an alternative to the traditional model of agriculture extension in many sub-Saharan African countries. However, information on key features of these organizations that are important for accelerating technology adoption is still scarce. This paper presents analysis of the different aspects of organizations and how each aspect affects technology adoption among farmers. First, a factor analysis is used to cluster the observed indicators of social capital embedded within organizations into few factors that represent different dimensions of organizations. A Probit model is used to estimate the effect of the organizations on the decisions to use the technology. The effect of organizations on the extent of use of the technology is estimated by an OLS regression and Heckman procedure to account for selection bias. Results indicate that different aspects of organizations affect the adoption decisions differently. Organizations are important in the diffusion and adoption of agricultural technologies but the spill over effects are more important among participants than non-participants. The study findings also reveal that organizations are formed within the village geographical boundaries, implying that they may be limited in

the scope to which they can diffuse technologies beyond the village. Findings have important policy implications for interventions that use organizations as a technology dissemination mechanism.

Conditions of adoption of new technique of vegetative multiplication (PIF) in Cameroon: impact on the diffusion of new banana and plantain cultivars

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The availability and quality of plantain planting material is one of the main constraints to the intensification of this crop. Farmers often use suckers infested with pest and diseases as their only source of planting material. Disease-tolerant cultivars established with clean seed could contribute to food security and help fight against poverty. Three projects PPDR, TARGET, and PRFP in farmer's fields in three provinces (central, south, littoral) of Cameroon promoted new cultivars from FHIA, IITA and CARBAP, and a multiplication technique called PIF (plants issus des fragments de tige) developed by CARBAP. Farmers were also trained in marketing and transformation. The objective of this study was to understand the factors that contributed to the diffusion and the adoption of these technologies among project farmers and to identify their impact at the level of different stakeholders involved in the process. Forty four nursery farmers and 55 other stakeholders such as CPA, AVZ (agricultural extension agents), GIC (common initiative group) were interviewed. Thirty-five (79.5%) farmer's adopted the new technologies while sixteen (34.4%) carried out more activities for transferring the technology. The adoption of these technologies by farmers depended on the financial support for training by organizations, access to planting material, inputs for farmers with economic interest, technical support from the research institution and opportunities. Among other changes are specialized farmer nurseries for plantlet production and more farmer organizations. The improved implementation of such projects should include baseline studies to expand farmer participation, training for farmers and a monitoring of the diffusion and adoption of new technologies.

Determinants of adoption and impact of new hybrid bananas in central Ghana

B.M. Dzomeku¹, C. Staver², H. Garming², D. Sanogo³, G.K.S. Aflakpui¹, A.A. Ankomah¹ and S.K. Darkey¹

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This study was conducted in the two Assin districts of the central region of Ghana to examine factors that influence the adoption of new banana hybrids and other technologies and to assess the impact of these technologies on smallholder farmers' livelihoods. A total of 100 farmers who participated in the dissemination and 30 non-participating farmers from seven communities were selected randomly and interviewed using structured questionnaires. Data collection included the area planted to new cultivars, the use of introduced technologies as well as the importance of traditional plantain cultivars. Special emphasis was laid on the role of

social networks in the diffusion of new planting material and the dissemination of knowledge on improved technologies. The findings revealed that all project participating and over 70% of non-project participating farmers were expanding the planting of introduced hybrids, although all the farmers continued to plant their traditional cultivars. All the non-project participating farmers acquired their planting materials from participating farmers within and outside their communities. The use of the introduced technologies (paring, row planting, pruning and clean seed production) was widespread among project and non-project participants. Dependent on the distance to project sites, knowledge of the new technologies had also spread to non-participant farmers up to a distance of over 30 km. For the distribution of new cultivars, the main players were the extension service, project-farmers and NGOs. In villages where community farmer organizations are active as a result of the project, planting material and knowledge are transferred to non-project participants as well. The formation of community farmer organization as a result of the project had yielded dividend to the community. They had secured oil and processing machines from the government. This is generating employment in the communities. There are also plans to grant these farmers credit. The introduction of new hybrids of plantains has increased farm productivity, leading to improved food security and opportunities to generate cash income through marketing of the produce. However, through seasonality of harvesting periods, achieved output prices were rather low. Major constraints to the further adoption of new plantain technologies are uncertain as a result of land tenure and access to credit. The strengthening of farmer organizations and social networks can be an effective measure to the further dissemination of improved technologies.

Farmers' perceptions and factors affecting the adoption of disease-resistant plantain and banana hybrids in Nigeria

C.C. Aitchedji¹, A. Tenkouano² and O. Coulibaly²

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The study assessed the level of adoption of hybrid cultivars of plantain and banana promoted through farmer-to-farmer diffusion, and determines the factors affecting their adoption and dissemination in four plantain and banana growing areas of Nigeria. Data was analyzed with econometrics (probit model). The results indicate that farmers' capacity to choose and use planting materials and related production techniques was significantly improved by training programs over a period of four years. Farmer's awareness also increased with field days, demonstration plots, farmers' exchange visits and a platform for sharing information on hybrids and associated techniques. Reasons reported by farmers include high yielding, resistance to pests and diseases (black sigatoka), taste/good cooking quality and access to planting materials due to the rapid multiplication technique deployed by the project. Farmers who participated in on-farm trials, demonstration plots and/or field days and other training programs on hybrids and associated technologies during the five last years, adopted the hybrid cultivars because of their direct participation and contact with breeders and other projects partners. The project's collaboration with extension, for organization of annual training programs with pioneer farmers on hybrid cultivars and associated technologies has highly contributed to the large and effective dissemination and adoption of plantain and banana hybrids by small-holder farmers.

Networking banana for research and development in ESA: lessons learnt

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It is estimated that up to 60% of the people in BARNESA countries depend on banana for their livelihoods, giving the crop an immense local importance. Annual human consumption estimated in some countries at 400-600 kg/capita is the highest in the world. Grown on small-scale farms (0.5-3.0 ha), the perennial crop occupies 10-30% of land under crops, impacting on the natural resource conservation in the region. It is estimated that without bananas, many of the countries in the region would have been net importers of food. Against this background, BARNESA was created in 1994 to strengthen NARS to improve the productivity of banana-based cropping systems and to provide a framework for enhancing collaboration by exploiting synergies, avoiding duplication and raising the critical mass for technical research capacity. In planning and executing BARNESA, however, certain assumptions (and presumptions) were made on priority status of the crop for member countries; free exchange of information / technology; the social stability of the region; the accessibility of financial support to address the priorities; and the contribution of banana as a crop to poverty alleviation in the region. Over the last 10 years or more, however it is not known whether these assumptions are still important. Do the network goals and objectives still represent the interests of the participating countries and/or the region? Do the members NARS/ countries want to continue participating in BARNESA. If so what changes, in terms of priorities and collaborating mechanisms would they like to see implemented? These and other issues were put to BARNESA steering Committee meeting to obtain members view to facilitate strategic planning. The results of the questionnaire revealed that BARNESA members would like to continue participating in the network. The research and development priorities have continued to shift in emphasis from pests and diseases (1994) post harvest processing and marketing (2003) to diversity conservation with commercialization of diversity products (2007). In addition the steering committee also wanted to see increased investment in banana commercialization as well as in information/technology sharing between members. These issues have also raised the question about the need for pragmatism and "out of the box" strategies to manage the network to deliver to the expectations of their members.

Socio-economic impacts of tissue culture banana in Kenya through the whole value chain approach

M. Njuguna and F. Wambugu

Africa Harvest, Nairobi, Kenya

Banana is an important staple food and source of income for small scale subsistence farmers in Eastern Africa. However, the production of this crop is hampered by various constraints, including pests and diseases. Africa Harvest through two of its major projects and in collaboration with TechnoServe on marketing, KARI and other collaborator organisations have continued to facilitate the provision of phytosanitary certified tissue culture (TC) planting material to farmers in Kenya, through the a whole value chain approach to improve productivity. This has resulted in significant positive socio-economic impacts at individual farmer and community level. A recent socio-economic impact analysis commissioned by Africa Harvest, done by

Dr. Acharya and Dr. Mary Mackey in Kenya indicate that, TC banana technology helped in increasing banana production from 46,426 hectares in 1996 to about 82,000 hectares in 2006. Although not all additional area came from TC, the TC campaign through project initiatives, provided seedling access, training on good agronomic practice and marketing information to banana growers, increasing overall production. Increase in banana areas of the magnitude of 35,574 hectares (82,000 minus 46,426) within 10 years turn out to be an additional net income of Ksh 5508 million (USD 85,000) accruing by thousands of banana growers attributed mainly to TC-banana technology, good agronomic practices and marketing. The additional income that accrued to TC banana growers (by adopting TC banana in place of non-TC banana) works out to around Ksh 963 million. The potential of scaling up and scaling out the successful TC-banana model project in Kenya to Eastern Africa region and other regions will be discussed during the conference.

Parallel Session 2: Turning Farmers into Business People

Venue: Mandhari Room

Time: 1100–1300

Diffusion of tissue culture banana technologies to smallholder farmers in Kisii district Kenya, using a micro-credit scheme

E.N.K. Okoko¹, F. Makini¹, L.A. Wasilwa², D. Munyi³, G. Mwagi³, M. Karembu⁴ and A. Cheruiyot⁵

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Banana is a major food security and cash crop contributing 80% to rural household incomes in Kisii. The region produces 40% of the bananas consumed in Kenya. Yields have declined over the last two decades to an average of 15 tons/ha against a potential of 50 tons/ha. Farmers attributed this decline to disease infected and pest-infested suckers. Tissue culture (TC) bananas are disease and pest free, mature uniformly and yield 20% more than conventionally propagated suckers. The overall objective of the project was to establish a self sustaining system of production, distribution and utilization of farmer preferred varieties of tissue cultured banana using a micro-credit scheme. Four institutions (Kenya Agricultural Research Institute [KARI], International Service for Acquisition of Agri-biotech Applications [ISAAA], Ministry of Agriculture and K-Rep Development Agency collaborated in project implementation. ISAAA acquired TC plantlets; K-Rep administered and managed the credit facilities whereas KARI and MoA provided technical backstopping and extension services, and linked farmers to markets using farmer field schools (FFS). On-farm activities were undertaken in Kisii highlands between 2003 and 2007 involving 386 farmers in 13 FFS. The partnership contributed to improvement of the banana industry and high economic returns from partners' synergy. A total loan of KES 3,110,950 was disbursed to farmers which enabled them to acquire over 8,910 TC plantlets. Farmers in the 13 (FFS) evaluated five TC cultivars ('Uganda green', 'Nusu Ngombe', 'Grand Naine', and 'Chinese Cavendish') and one local cultivar 'Ngombe' as a control. Results show that the technologies were adopted by 90% of the farmers in project sites and production increased from 15 to 30

tons/ha. Farmers realized incomes 300% higher and several jobs were created in the nursery industry. Provision of credit to farmers contributed to increased adoption of new technologies. Currently an additional 5,000 TC plantlets has been distributed through TC hardening nursery to farmers in the region due to increased demand for clean banana planting materials.

Empowering small-scale farmers to become competitive in banana production and marketing

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Small-holder farming, characteristic of banana production systems in Uganda presents significant challenges with regard to accessing markets by the farmers involved. Small scale farmers are often scattered, disorganized and their production and marketing methods incompatible with the needs of the larger players in the value chain, due to inability to satisfy criteria for assured cultivars, quantity and quality of product. As a result, small-holder farmers have been locked out of certain or all market sectors. Farm gate prices are low yet consumer prices are very high. However, it is hypothesized that opportunities exist to transform small scale agriculture into profitable business if farmers are facilitated to organise themselves into networked groups/associations through which they can collectively market their produce. In this study, working through networked groups, the farmers were able to develop and maintain a market information system, access wholesale markets which offer better prices than middlemen, inputs via bulk purchase, improve crop management including pest, disease management and in-field fruit quality control to obtain market quality bananas. Uniform agronomic practices within groups resulted in better products and facilitated collective marketing which has resulted in farmers margins rising from 20% to 50%.

Privatising the extension service in agricultural sector in Uganda

J. Nanyunja

Uganda Environmental Education Foundation, Kampala, Uganda

Agriculture depends on generation and dissemination of new technology through support of effective research and extension of services. Farmers need all the help they can get in form of sound advice and technical information especially when introducing new and complicated enterprises on their farms. In Uganda under the decentralised service delivery system (NAADS), the local governments are responsible for the delivery of agricultural extension services to the farms. Extension agents teach farmers about proper management practices. Research in Uganda has shown that the degree to which farmers receive the necessary information directly affects the rate of adoption of new innovations. Lack of adequate knowledge prevents farmers from recognising their problems, limited experience, and up-bringing and other cultural factors cause farmers to have incorrect information. The differences in characteristics of farmers in industrialised and less industrialised countries can be attributed to the differences in social structures and customs in the two societies. Due to the prevailing illiteracy conditions that exist in Uganda, interpersonal channels were found to be more efficient in informing and changing attitudes of farmers towards new varieties and practices. Privatisation of the extension services has been

proved to be an efficient method that has to some extent improved the quality of extension services. However, though a lot of money has been injected into extension, the fruit of this is not yet proportional to the input. This is because of the many challenges facing the sector for example embezzling of funds, low capacity of the extension staff and high extension agent to farmer ratio (1: 2000), among others. Privatisation of extension services should therefore be done in an oligopolistic way to ensure a competitive strong stable advocacy to ensure the conditions necessary for technology adoption and diffusion, and training in its technical aspects. This would help to improve quality of extension services.

Sustainable banana production by small-scale growers in Kenya

J.J. Anyango and F.M. Wambugu

Kenya Agricultural Research Institute (KARI), Thika, Kenya

Eastern Province Horticulture and Traditional Food Crops Project (EPHTFCP) came into effect through a loan agreement between the government of Kenya and the International Fund for Agricultural Development (IFAD). The Project was implemented by the ministry of Agriculture and Kenya Agricultural Research Institute (KARI) among others. The objectives of the project were to improve smallholders' income and food security through dissemination of suitable crop technologies in eight districts in Eastern provinces of Embu, Machakos, Makueni, Mbeere, Meru Central, Meru South, Meru North and Tharaka. KARI-Thika was involved in introducing new promising tissue culture (TC) banana cultivars and training farmers through farmer field schools (FFSS) on production husbandry. The use of TC has become popular because of advantages such as freedom from pests and diseases, ease of multiplication, uniform growth, early flowering, increased yields and a commercial agenda. Several trials were conducted on-farm to evaluate TC banana cultivars in a participatory manner whereby farmers used their own selection criteria to come up with cultivars which they considered suitable for their areas. Joint field days helped improve on the research-extension-farmers linkage. Towards the end of the project a study was made to assess the uptake of the TC banana cultivars introduced. This gave an indication of the cultivars that were successful and those not taken up by the farmers. The demonstration plots were established in Meru North (Kyorimba/ Machege), Mbeere (Ishiara/ Kathigi and Kiambindu), Meru South (Mwicuiri self help group and Ntuntuni) and Makueni (KwaKyi and Kikoo). Tissue culture banana cultivars planted in the demonstration plots were 'Dwarf Cavendish', 'hinese Cavedish', 'Valery', 'Paz', 'Williamson', 'Uganda Green Lacatan', 'Gold Finger', 'Grand Naine', and 'FHIA'. The other activity in some selected irrigation schemes was to establish hardening nursery to facilitate accessibility to TC banana plantlets. Among the project outputs was increased demand by farmers for the enterprise by all irrigation schemes, increased acreage in the last few years, farmers ability to choose with confidence the right cultivars to plant, farmers ability to choose the right enterprise i.e. TC banana as opposed to tobacco growing and primary as well as secondary schools adoption of TC banana growing in school gardens. The project had the following impacts: preferred TC cultivars were chosen by the farmers themselves, farmers well fare is taken care of in terms of higher income, improved living standard, do not require food aids, are able to pay their loans in time, no longer exposed to several pesticides as they get high production through orchard sanitation and the enterprise not requiring high labor force. Farmers expressed that this project is sustainable, easy to upscale and replicable especially in schemes where the hardening nurseries were established, has ready market, many farmers in the

neighborhood paying frequent visit to the pioneer groups to gather information, there is an increased catchments growing the TC and so whole sale buyers are likely to visit schemes hence likely to increase their bargaining power and the farmer groups now easily source for other trainings on the enterprise initiated by the CBOs especially on post harvest and marketing.

Sustainable business empowerment for small-holders through local service providers: SNV's experiences in developing the banana value chain in Zimbabwe

E. Mudyazvivi

Netherlands Development Organisation, Harare, Zimbabwe

The problem of value chains collapsing immediately after the project timeframe, when the development organisation withdraws, has characterized numerous cases of market linkages in Zimbabwe. The main contributory factor has been that small-holder farmers continued to be the weakest link in the chain, with insufficient business and agronomic skills to guarantee the critical success requirements of the new chains as well as sustaining the new business relationships. The big question has always been to find a sustainable model of developing farmers' capacities to enhance the success of market linkage programmes. This study recognizes that solving this problem would entail developing a market (demand and supply) for both extension services and business development services (BDS). SNV undertook action research which is largely qualitative that involved reviewing lessons from past market linkage cases and exploring innovations in the process of developing the banana value chain in Zimbabwe. Apart from the traditional way, a new and promising approach emerged which involves local service providers. In this study, SNV discovered that although other chain actors may be useful to stimulate demand for both BDS and agronomic skills, they can not be relied on for sustainability. Eventually, these actors would pursue their core business for efficiency. Developing the capacity of local service providers emerges as a more market driven and sustainable model of ensuring that support services to farmers were customized to their needs and environment, accessible and more affordable. The positive results and lessons from utilizing local capacity builders in value chain development presents a model that market-linkages projects can use to develop sustainable markets for BDS and agricultural extension services. This thereby gives hope of reversing the trend of failure of market linkages projects witnessed in the past, as farmers were left before they are ripe to face the challenges of a new business environment.

Turning farmers into business people: the role of tissue culture bananas in Kenya

J. Mbaka¹ and M.Mwangi² and M. Mwangi³

¹Kenya Agricultural Research Institute, Thika, Kenya; ²International Institute of Tropical Agriculture, Kampala, Uganda; ³Kenyatta University, Nairobi, Kenya

The major biotic production constraints to banana in Kenya are diseases such as Fusarium wilt, black leaf streak, sigatoka, banana streak virus and banana *Xanthomonas* wilt; pests such as nematodes and the banana weevil. In a recent survey on banana in East and Central Africa region, farmers reported that when establishing new banana orchards, 60% of them obtained suckers from their own fields while 30% got them from their neighbours. Knowledge and access to clean planting material was a major regional constraint. However in 1997, the Kenya Agricultural Research Institute introduced tissue

culture techniques to propagate banana to ensure availability of clean planting material. Training on banana production from planting to harvesting, post-harvest handling and value addition was done through farmer field schools, field demonstrations and field days. By 2001, a total of 107,600 plants had been distributed and planted by about 5000 trained farmers. Yields increased from below 10 tons/ha to about 30 tons/ha. After the outbreak of banana *Xanthomonas* wilt in western Kenya in 2006, the first two authors did a spot check on banana production in East and Central provinces of Kenya. The objective was to get an update of banana production and assess what would be at stake if the disease spread to the area. It was found that banana growing in the region was a commercial enterprise with a good bunch going for a farm gate price of 500 Kenya shillings (USD 7.5). It was obvious that the enterprise could alleviate rural poverty. Of interest was the fact that the farmers were planting their own suckers despite having been introduced to tissue culture bananas earlier on. This paper describes the farmers' perception of tissue culture bananas and possible interventions for sustainability of banana growing as a business.

Parallel Session 3: Innovating Delivery Systems

Venue: Likunda Room

Time: 1100–1300

A regional network of dialogue and exchange platforms to improve the identification of farmer's needs and the dissemination of new banana and plantain cultivars

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To improve the identification of farmer's needs and the dissemination of new banana and plantain cultivars in West and Central Africa, CARBAP and its partners have used a mother/baby approach for participatory cultivar evaluation through a regional network of platforms for dialogue and exchange between all the stakeholders of the sector. Eight platforms have been established in Cameroon, Benin, Gabon and Guinea. Each platform includes (i) a common reference plot with 10 cultivars, (ii) a network of 20 farmers, each testing on their individual plots, 4 cultivars chosen among the previous 10 cultivars, (iii) a steering committee in charge of the management of the platform and (iv) a club of local experts and users. Plantain cultivars and hybrids, cooking and desert bananas are chosen according to the production constraints and consumer demands. The platforms are designed and managed in a spirit of partnership using participatory approach. At key steps of the cycle duration and harvest (planting, flowering, harvesting, fruit cooking and transformation), the stakeholders are brought together by the steering committee for joint evaluation. Data on cultivar innovation and participatory approach collected from diverse stakeholders (extension services, NGO, producer organisation, nursery organisation, processors, traders, research institutes) are discussed.

Lessons from the reorganization of the health services in Tanzania for agricultural development, particularly the banana industry

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The reorganisation of services of the health sector in Tanzania has made a major impact in the way grass root communities respond to health challenges. The national health policy document of 2003 has been re-aligned to both the National Strategy for Growth and Reduction of Poverty (NSGRP -also known as MKUKUTA) and the eight internationally agreed millennium goals. Major strides have been made through global partnerships for development, which have led to breakthrough research in Malaria and TB. The implementation of the resulting research findings through well-structured levels of health delivery has significantly reduced mother and child mortality as well as improved to a great extent the HIV/ AIDS awareness campaigns. This translates into good health gains among the banana producers and consumers in Tanzania, and by extension added value to the lives of the entire banana value chain players. On the other hand, demand-driven delivery of health training services has made it possible to deliver world-class health training in Tropical Medicine. Similar approaches could be used in agricultural development to create sustainable banana value chains that will deliver improved livelihoods of the banana industry players. Just like the vision of the health sector is to have a well performing and sustainable health system that can deliver high quality services that are effective and accessible to all, that of the agricultural sector is to have a modernised, commercialised, competitive and effective agricultural system by 2025. The agricultural development just like the health development will make it possible to achieve millennium goals relating to poverty and hunger. This will result from enhanced commitment of the national policy makers and their international development partners to agricultural research for development, and timely training in the emerging crop innovations, as well as information on markets and consumer preferences that can be optimised to improve livelihoods.

Use of partnership extension model to facilitate adoption of IITA plantain and banana-based technologies in Nigeria

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Historically, extension within Nigerian agriculture has been largely a government owned institution, which involve technology transfer or advisory approach as top-down (science push and diffusion of innovation model) or bottom top (farmers needs pull). These push and pull models are yet to realize the potentials of agricultural innovations especially that of cultivars. Empirical data on the adoption level of cultivars in selected states of southern Nigeria show that farmers have utilized less than 50% of the potential of IITA based technologies. This paper present Selesnew's Partnership model of extension as an appropriate measure for improving links with stakeholders. Specifically, the paper reviewed the process of agricultural information dissemination, identified the various actors in partnership extension and their roles in facilitating adoption of IITA plantain and banana, and draw implication for programme

development for sustainable partnership. The paper concluded that both public and extension personnel be involved in the initial survey to identify different categories of plantain and banana farmers in Nigeria, formation of groups based on the intensity of production resources and promotion of economics and technological information to farmers.

Using strategic entry points and linked technologies for enhanced uptake of improved banana germplasm in the humid highlands of East Africa

J. Mowo¹, T. Mbaga², J. Tanui¹, K. Masuki¹, L. German³, J. Wickama⁴ and C. Lyamchai²

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Diagnostic surveys conducted in the mountain districts of Kapchorwa, eastern Uganda and Lushoto, northeastern Tanzania revealed a declining trend in banana production, largely attributed to deteriorating soil health, soil erosion, low adoption of proven banana technologies and lack of innovative scaling-out approaches. Further, most farmers were not practicing soil and water conservation (SWC) because it is labour intensive. Focus group discussions and key informant interviews established that improved tomato, cabbage and banana germplasm were the three most preferred technologies, and hence were considered important “entry points”. The uptake of these technologies was however different, banana being the slowest because of high cost of planting material. Limited planting materials were supplied by the African Highland Initiative (AHI) for multiplication using primary schools and farmer research groups in Lushoto and farmer reflect cycles in Kapchorwa. Improved banana technology was “linked” to SWC stabilized by fodder species to address the multiple constraints of erosion and declining soil fertility through increased manure from well-fed livestock. In this paper, “entry points” refers to interventions addressing priority farmers’ needs while “linked-technologies” refers to integrated complementary technologies holistically addressing multiple constraints, leading to multiple benefits. Results show that large numbers of farmers in Lushoto and Kapchorwa adopted improved banana cultivars and soil and water conservation practices. In Lushoto for example, an increase of about 1125% in farmers adopting improved banana germplasm from the original adopters who were in direct contact with researchers was observed within two years. Meanwhile, in Kapchorwa farmers benefited from cheap banana planting materials produced by members of the reflect cycle. The study shows that the use of innovative scaling out approaches increases the adoption of technologies that appear expensive and those that are less attractive to farmers.

Training requirements of extension workers in banana and plantain technology transfer in southwestern Nigeria

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Agricultural development can be positively influenced by a number of factors, which include constantly changing technology through education and research. This goes to show the significance of the need to identify training needs of extension workers involved in banana and plantain technology transfer with a view to ensuring technology driven development. The study assessed the training requirements of extension workers involved in banana and plantain technology transfer in southwestern Nigeria. In predominantly banana/plantain-producing zones of Ogun, Ondo and Osun states, agricultural development programmes (ADPs) were selected. One hundred and six (50%) of the 209 extension workers in these zones were randomly sampled. Data was collected using pre-tested, structured interview schedule. Data was analyzed using frequency counts, percentages, mean and Pearson product moment correlation. Banana and plantain orchard site selection and preparation, harvesting techniques, orchard establishment and orchard management were the technology dissemination activities involving the extension workers. These accounted for 75.5%, 65.1%, 62.3% and 62.3% of their involvement, respectively. There is still need to improve their knowledge and skills in banana and plantain root management strategies. Extension workers' technology dissemination on the crops was least in pre-nursery management accounting for only 23.6% of their involvement. The mean knowledge score of extension workers on banana and plantain technologies was 61.6%. Correlation analysis between knowledge and involvement of extension workers in banana and plantain technology transfer shows no significant relationship. This implies that the current technology dissemination effort of the extension workers in banana and plantain is not based on their knowledge of improved technologies. This calls for technology driven development of banana and plantain industry with adequate focus on training of extension workers with the aim of improving their knowledge and skill especially in root system management.

Building the banana chain in Somalia: support to Agricultural Marketing Services and Access to Markets (SAMSAM) experiences

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Somalia's main agricultural areas are located along its countries Shabelle and Juba Rivers providing year round quality irrigation water from the Ethiopian highlands to the fertile riverine soils. Through an ingenious system of barrages and dams over 135,000 ha have access to gravity irrigation. In this area the Somali banana industry was flourishing as the largest exporter in East Africa with 12,000 ha under cultivation employing 120,000 people. During the 1991 civil strife, banana production ceased. However, from 1993 to 1997, the sector was partly revived with exports to Europe and the

Middle East, amounting to six refrigerated ships per month loading at the Mogadishu port near the production areas. Due to devastating El-Nino floods and loss of the preferential access to the European markets, exports ceased late 1997, although interest in Somali bananas from Middle East markets remained. Currently bananas are cultivated on 3,000 ha producing which suffices for year-round supply of the local market but does not meet the production and profit potential compared to exports, hence the latter's revival remains high on the agenda. Over the last 5 years, the EC supported rehabilitation of the productive infrastructure in the said agricultural areas but this did not lead to banana export revival. To shine more light on the opportunities and constraints of the Somali banana sector, CEFA implemented the EC funded SAMSAM project which is designed to map and quantify the past and present banana sector, whilst conducting International Business to Business and consumer research in the Middle East. The project applied the value chain approach analyzing chain actors and stakeholders including potential chain leaders. Based on feasibility studies, the project objective is to formulate a chain strategy and organization towards chain design. The paper describes the Somali current and potential banana chain, a SWOT analysis and cooperation scenarios between the Somali banana sector and prospective trade partners abroad.

Parallel Session 4: Profiling Country Perspectives

Venue: Peponi Room

Time: 1100–1300

An innovation capacity analysis to identify strategies for improving plantain and banana productivity and value addition in the Democratic Republic of Congo

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The agricultural sector of the Democratic Republic of Congo continues to suffer from declining productivity after a decade of civil unrest and underinvestment. Plantain and banana are considered the second most important staple crop after cassava. The Congo basin is a secondary centre of plantain diversity. The area planted to plantain/banana has declined from over 400,000 ha in the early 90's to less than 150,000 ha presently. Yields are low and declining and plantain has become too expensive for poor urban households. There are numerous political, economic, social and technological constraints to increase the contribution of banana and plantain to household, community and the national economy. Innovative approaches to identify best-guess bottlenecks and opportunities and to develop initial priorities are needed where the public sector is only recently recovering from decades of civil strife. This preliminary review using the ASTI framework identified the following priorities for action; 1) simple and low cost strategies to estimate production and planted areas and the extent of serious pest and disease threats to guide investment in areas with greatest impact, 2) mapping of production potential based on soils, climate and water sources and ease of

market access to prioritize investment in intensification, 3) piloting of clean seed systems to contain the spread and impact of banana bunchy top virus, and *Xanthomonas wilt*, to multiply highly productive clones of preferred cultivars and to conserve plantain diversity, 4) technology for land productivity stabilization and improvement, including agroforestry techniques for more remote areas, the linkage of animal raising with banana production in areas with higher population densities and efficient use of fertilizers in commercial production with good road infrastructure, 5) improving field access to information on new technologies to farmers and their associations, public extension and NGOs and rural school teachers and 6) farmer and village marketing organizations to capture greater value from plantain and banana markets where clean seed and improved land productivity are piloted.

Meeting the challenge of economic restructuring of the plantain sector in Cameroon

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Plantain is one of the most preferred foodstuffs in Cameroon, especially in towns and forest zones. About 80% of the production is consumed at local level. Plantain highly contributes to the gross national product (GNP). Efforts made so far by the various stakeholders to develop the plantain sector have yielded significant results, but failed to have a decisive impact on its production, since only some few projects have been implemented and few areas covered. The issue of plantain availability for consumption and marketing has been widely discussed in several papers. The available statistics, which date from 1997 to 2001, show that plantain production was 1.2 metric tons in 2001, relatively stagnant since 1975 and the present production does not meet the demand of a rapidly growing population (3.2%/year). The consumption per capita (83 kg/year) started dropping since the 1970s. An analysis of the various constraints highlighted in available literature shows that government commitment is a major requirement for sustaining the sector, and the lack of synergy among the stakeholders is a serious bottleneck. Due to the absence of a coordinating body, partners have the tendency of working independently, which results in a lot of discrepancies in technology transfers. Being aware that plantain has potential for creating jobs, sustaining food security and contributing to rural and economic development, the government has committed itself into developing the sector, by initiating in 2006 a special programme for the economic restructuring of the sector. Taking into consideration the lack of synergy that characterizes the various partners, there is need for establishing a stakeholders' platform to coordinate efforts, enable interaction among them and harmonize technology transfer methods, thus ensuring adequate valorisation of research results for plantain production in Cameroon.

Research-extension-farmer linkage system on banana and plantain in Nigeria: the diffusion of innovations

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The process of introduction and diffusion of innovations in Nigeria is depicted in the research-extension-farmer linkage system. Major innovations in the last six years have brought dynamic changes in the research-extension-farmer linkage system. This paper presents the methodology of the diffusion of innovation on banana and plantain in Nigeria. This is due to the fact that many farmers have not been properly reached by agricultural extension services and the problem of poor production has been attributed to the weak linkages existing between research, extension and farmers. Consequently, the present research-extension linkage scenario in the country has not been able to achieve the prescribed goal of increasing production and improving the quality of life of farmers. Technologies developed by research sub-system on banana and plantain include split corm, split bud and on-field forcing for rapid multiplication of propagates. Others are appropriate spacing for cocoyam/plantain intercrops, plantain cultivars tolerant to black sigatoka, control of lodging through cultural practices and control of plantain diseases. These were subjected to on-farm adaptive research (OFAR), small plot adoption technique (SPAT) and then demonstrations to encourage farmers to adopt. The roles of the research sub-system (National Institute of Horticultural Research), extension sub-system (Agricultural Development Programme), the end users (farmers) and input dealers were analyzed. Activities such as establishment of small plot adoption technique, group meetings, diagnostic surveys, on-farm adaptive research, evaluation of technology, problem identification, visits to on farm adaptive research, visits to research institutes, joint field days, joint report, and priority setting that enhance the effective collaboration of these actors were also examined with the success, failures, options and challenges for the future identified. Conditions for effective linkage among research, extension and farmers to bring about improvement in the living conditions of farmers were also explored in this paper.

Agricultural science, technology and innovation: plantain case study in Ghana

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This study employs the agricultural science, technology and innovation (ASTI) systems analysis framework of the technical centre for agriculture and rural cooperation to assess the policy environment of Ghana and how it enhances key plantain actors' competencies and performance in relation to innovativeness as well as the effectiveness of linkages. Both secondary time series and primary data analysed show that the policy environment in Ghana is fairly supportive of the plantain sub-sector. There is no specific plantain policy; the food and agricultural sector development and other subsector policies specify strategies that directly or indirectly serve as an incentive framework for plantain development. Hence, there were several plantain projects related to technology improvement, dissemination and adoption after the structural adjustment programme of the economy in the 1980's; these have yielded positive results in the 1990s and 2000s. There is significant growth in plantain acreage, output and

yield and producer price. The positive changes in habits, practices and competencies of key actors are clear. Some small-holder farmers have adopted research findings in micro-propagation of new cultivars and integrated pest management (using inorganic fertilisers and pesticides as a last resort). The private sector has invested in plantain flour and small-scale processors have commercialised plantain chips (a snack). The vertical and horizontal linkages among actors are fairly strong though more innovativeness would be required. Actor functions are clear and well understood but the effectiveness of the functions has been questioned. Low budgetary support, poor access to financial markets and high cost of inputs are listed as key constraints to high performance. Many of the actors believe that for high performance, government should increase budgetary support to statutory agencies and the non-governmental organisations should intervene more strongly in credit provision, transportation services and of farmer-based organisations.

Analysis of the agricultural science, technology and innovation systems: a case study of banana in Tanzania

A.P. Maerere, C.L. Rweyemamu, K.P. Sibuga, E.R. Mgembe, E. Rwambali and S. Nchimbi-Msolla

Sokoine University of Agriculture, Morogoro, Tanzania

This study was conducted to collect information on the agricultural science technology and innovation systems (ASTIS) in the banana sub-sector in Tanzania. Major policies were reviewed in respect to their impact on agriculture and the banana sub-sector. Key actors were identified and analyzed with respect to their linkages. The information was collected using two structured questionnaires: one for farmers and another for organizations. Surveys were conducted in four agro-ecological zones of Tanzania that are major banana producers and included the Northern, Eastern, Lake and Southern Highland zones. Generally, Tanzania was found to have well established agricultural and science technology policies. However, implementation was hampered by low investment that did not match with government commitments. Key actors identified in the sub-sector were mainly small-holder farmers, private enterprises and various organizations that were either government, private or NGOs that played major role in creation, diffusion and sometimes utilization of knowledge within the banana sub-sector. Research and training was found to be mainly under the control of the Ministry of Agriculture, Food and Cooperatives and the Sokoine University of Agriculture that falls under the Ministry of Higher Education Science and Technology. Results indicate that 60% of the small-scale banana farmers had received primary education. Land is under family ownership, with on average 1.5 ha of which 25-50% was devoted to banana production. Most banana producers were found to operate on individual basis with collaboration amongst themselves rather than with other actors. The growers lacked specialized training and operated at traditional level with very low use of innovations. It is recommended that all major areas of action require improvement to enhance capacity development by strengthening existing information diffusion system, incentives for innovations, infrastructure, credit schemes, and recognition of banana as an important food and cash crop. Such a change would attract more local, national, regional and overseas involvement.

Innovation in banana value chain development in Metema district, northwestern Ethiopia: IPMS experiences

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International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia

Ethiopia has a diverse agro-ecology and sufficient surface and ground water resources, suitable for growing various temperate and tropical fruits. Although various tropical and temperate fruits are grown in the lowland/midland and highland agro-ecologies, the area coverage is very limited. For example, banana export increased from less than 5,000 tons in 1961 to 60,000 tons in 1972, but in 2003 declined to about 1,300 tons worth less than USD 350,000. The limited development of fruit sector in the country could be attributed to constraints such as limited inputs, skilled manpower and extension approaches and, focus of agricultural development efforts on grain production amongst others. The current government's policy and development strategy prioritizes intensive production and commercialization of agriculture, including fruit production. In an effort to support this change, the International Livestock Research Institute (ILRI) and the Ministry of Agriculture and Rural Development (MoARD) initiated a five-year project with financial assistance from Canada, called improving productivity and market success (IPMS) of Ethiopian farmers. IPMS follows participatory value chain and innovation systems perspectives and focuses on knowledge-based development of identified agricultural commodities with market potential in 10 pilot learning weredas (districts) in four regional states. One of the weredas is Metema where the project introduced banana production. The objective of this paper is to share IPMS experiences in promoting innovation in banana value chain development in Metema wereda. The paper provides a brief history of banana introduction in Ethiopia, describes the value chain in banana production, input supply and marketing and the various innovations that have been introduced to develop the chain, with a focus on actors and action learning processes. The future outlooks of banana value chain and the reasons for the successful adoption of the innovation and the options to sustain it so that the value chain can respond to changing conditions are highlighted.

Posters

Time: 1330–1400

Venue: Meister Tent

Innovating Delivery Systems

I-ID-1

Banana and plantain in Africa: harnessing international partnerships to increase research impact

Farmers Organization Network in Ghana (FONG)

FONG was formed as a result of the follow-up workshop to the “World Food Summit *fyl*”, where farmers in food security came together to form the network.

Farmers Organization Network in Ghana (FONG) is an organization established in 2003 as farmers organization in Ghana.

The Objectives of the network include:

- i. To share information and experiences among member Farmer Organizations through meetings, seminars and coordinating or joint implementation of projects.
- ii. To enhance the capacity of member organizations to enable them achieve their aims through exchange of visits and educational tours.
- iii. Communicate, analyze relevant government policies to farmers and provide a feed back to government on issues that affect farmers through dialogue e.g. production and marketing.
- iv. To act as an intermediary between development partners and members regarding support for programmes.

To the Ghanaian consumer, “banana” seems a simple name for the yellow fruits so abundantly marketed for consumption raw, and “plantain” for the larger, more angular fruits intended for cooking but also edible raw when fully ripe. The types we call “banana” are known by similar or very different names in banana-growing areas.

The annual growth rate of banana in Ghana is 7.47% whilst that of plantain is 5.04%.

Ghana has a total land area of 23 854 000 ha with a population of 20 471 000 of which 23% forms the rural population.

The banana plant, often erroneously referred to as a “tree”, is a large herb, with succulent, very juicy stem which is a cylinder of leaf sheaths, and arising from a fleshy rhizome or corm. Suckers spring up around the main plant forming a clump or “stool”, the eldest sucker replacing the main plant when it fruits and dies.

The mode of propagation is the use of corms or suckers. The corm has a number of buds, or “eyes”, which develop into new shoots. These develop rapidly and become a plant. But in recent times, we have started with cuttings which are not common in Ghana and the rural farmers will be interested in tissue culture.

Banana bunches are harvested with a curved knife when the fruits are fully developed, that is, 75% mature, and the fruits on the upper hands are changing to light green; and the flower remnants (styles) are easily rubbed off the tips.

In Ghana, plantains are consumed at five different stages of ripeness.

Fully ripe plantains are often deep fried or cooked in various dishes.

“Kaklo” is the mixture of ripe banana and corn dough made thicker and rolled into balls which are deep-fried.

In Ghana, green plantains are boiled and eaten in stew or mashed, together with boiled cassava, into a popular dish called “fufu” which is

eaten with soup. The cubes can also be ground into plantain flour. Processing has the added advantage of keeping the peels at factories where they may be converted into useful by-products instead of their adding to the bulk of household garbage. The cultivation of banana is classified into two types, namely; the local and exotic types. The local variety is grown wild or along the banks of streams and cool areas. Plantain peels is also use in the local soap making industry and for other medicinal purposes. Currently tissue culture is an area which farmers will require capacity building in order to increase the production level. This request is from the youth and women in agriculture.

I-ID-2

Redima: enhancing the sharing of information, knowledge and experiences for sustainable *Musa* research and production in Africa

J. T. Tetang¹ and C. Picq²

¹*Redima Coordinator, Bioversity International, Yaoundé, Cameroon;*

²*Bioversity International, Montpellier, France*

Redima, the documentation and information network for Africa, aims to encourage and facilitate the gathering, generation, management and sharing of knowledge and information among stakeholders; improve access to scientific and technical information produced worldwide; and provide a framework that facilitates technology transfer and capacity building. Created in 2004 by the stakeholders of Africa's two banana research networks, CO in West and Central Africa, and BARNESA in Eastern and Southern Africa; Redima also comprises the NARS banana programmes of 25 sub-Saharan African countries. Since its creation, Redima has put in place many tools and services such as a library, a question and answer service, a regional bibliographic database and a list server. The information network also strengthened capacities in managing and sharing knowledge and information, and in writing project proposals by organizing four regional workshops. Redima also co-publishes *frica*, the regional newsletter on bananas and plantain. Future actions include implementing the Redima strategic plan; facilitating the sharing of technologies; assisting NARS in the implementation of their communication strategies; and contributing to the global platform in Africa. Redima is coordinated by Bioversity International through a regional coordinator based at the *Centre Africain de Recherches sur Bananiers et Plantains* (CARBAP) in Njombe, Cameroon. By October 2007, 19 centers from 19 countries had signed the Redima Memorandum of Understanding and are actively participating to the network.

I-ID-3

Africa needs a new mix of traditional and modern farming techniques: divisive, ideological nature of food security debate is a dis-service to Africa

C Makunike

Dakar, Senegal

The debate on how to increase Africa's low agricultural productivity is becoming increasingly shrill and ideological in nature. The sharpest demarcation is between those who favour a high-inputs, biotechnology-based "green revolution" approach, versus those who

advocate various forms of low-inputs “sustainable farming” options. The debate has assumed that there can be very little co-existence between the two. So great is the hostility between the two camps that the “sustainable” side accuses the “green revolution” side of being motivated more by the search for new markets and higher profits on behalf of international agricultural companies, than by concern for African food security. Green revolution advocates in turn dismiss their critics as romanticising low-yield traditional agriculture, backed in that endeavour by modernity-spurning NGOs. Africa is the ultimate loser in the course this debate has taken. It is dangerous for the discussion to be along such simplistic fault lines as green revolution/ biotechnology/high external inputs agriculture, versus low inputs/ sustainable agriculture. The complicated nature of Africa’s agronomic, climatic, food security and economic challenges mean they are not amenable to such stark either/or approaches. This can particularly be illustrated with the issues pertaining to the cultivation of banana. Being seedless, their mere propagation while maintaining variety, keeping the crop free of disease and also staying on top of customer preferences are even bigger challenges than with most other crops. The paper will give examples of how banana issues especially point to the need for Africa to adopt a range of methodologies that in the current heated ideological environment may be considered to be incompatible, the mix depending on the unique local conditions obtaining. The sooner the issues are discussed from this more contextual, more inclusive perspective, the better the prospects of increased African agricultural productivity.

I-ID-4

Improving banana productivity using farmer field schools in Uganda

J. Kubiriba and W.K. Tushemereirwe

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Banana is among the most important food security crops in Uganda, but its production is threatened by a number of constraints, including declining soil fertility, poor management, narrow genetic base, socio-economic problems, post harvest problems, pests (nematodes and weevils), and diseases (Fusarium wilt, sigatoka and banana streak virus). Banana bacterial wilt (BBW), a relatively new disease, is a very destructive disease and caused an estimated yield loss of USD 75 million in 2006 alone. Since 2001 when it was first reported, BBW control initiative (BBWCI) has been able to develop cultural control measures which have been effective in controlling the disease. Massive awareness campaigns were conducted and consequently over 85% of banana farming communities currently know about BBW identification, spread and control. However, only 30% of the farmers have effected control. To improve on the proportion of farmers controlling banana bacterial wilt, the BBWCI adopted use of participatory approaches in promotion of BBW control practices among which was farmer field school approach. BBW was used as an entry point, but improving the productivity of banana on farmers’ fields was targeted in the project. The paper will summarise progress so far in this project.

I-ID-5**The political perspective of banana *Xanthomonas* wilt control in East and Central Africa****M. Mwangi¹, J. Kubiriba² and W. Tushemereirwe²***¹International Institute of Tropical Agriculture, Kampala, Uganda; ²National Crops Resources Research Institute, Kampala, Uganda*

Banana *Xanthomonas* wilt (BXW) critically threatens banana production in East and Central Africa. The bacterial disease is spread by insect vectors, tools and infected plant materials. Cultural disease management measures include debudding, disinfecting tools and avoiding movement of infected plant parts. In addition to these measures, the actions of politicians (either heads of key government institutions or locally elected leaders), are influencing the outcomes of BXW management efforts. Political leaders are more trusted by their electors, and combined with their superior mobilization skills, are more effective in convincing their constituents to participate in BXW management. In Uganda regions with more active leaders have achieved >90% control, compared to <60% where leaders are lax. In Kagera region (Tanzania), BXW has been contained following enthusiastic engagement of local district leadership. On the contrary disease prevalence has almost quadrupled in eastern D.R. Congo where local leaders have not been effectively involved, especially due to civil instability, which politicians could address to enable both local and external interventions to address the pandemic. For example, a more stable and enabling political environment in Rwanda has enabled focussed intervention with considerable reduction in BXW prevalence. In some countries political leaders have played important roles in prioritizing BXW among other key issues in annual development plans, leading to increases in local budget allocations as well as lobbying increased donor support to BXW management activities. Such support has increased human and physical resources to extension and research institutions addressing BXW, leading to better development of action plans and more responsive, stronger implementation structures. Political leaders have been key in linkages to other stakeholders, e.g. donors, NGOs or research institutions and their support is crucial in formulation and implementation of bylaws for effective disease management. This paper provides a comparative analysis of how politics has influenced response to and control of BXW in East and Central Africa.

I-ID-8**Towards practical solutions in enhancing food security: the gender factor in indigenous crop production****G. Wamue-Ngari and M.N. Mwangi***Kenyatta University, Nairobi, Kenya*

Bananas and other indigenous food crops (sorghum, sweet potatoes, cassava, yams, cow peas, etc.) significantly contribute to domestic food security in Africa. These crops are considered “women’s” crops as they are mainly grown by women for subsistence. This presentation specifically focuses on the gender factor in indigenous food crop production in a high potential region (Central province- Kiambu) and a semi-arid region (Eastern province- Kitui) of Kenya. The criteria for selection is that, Kitui being in the arid and semi-arid lands (ASALs), experiences severe droughts that lead to acute food shortages, while Kiambu a high potential district was purposively selected for comparison. Both qualitative and quantitative methods of data analysis and presentation were used. The research revealed

that although indigenous food crops significantly contribute to domestic food security, their production is faced by a number of socio-economic constraints. Rural women play a central role in food production, processing and marketing. Their contribution to the agricultural economy is essential to both food security and rural development. However, the existing agricultural policies have not adequately considered the gender factor in food production. Of particular concern are the traditional biases facing women farmers. With the breakdown of the traditional values, subsistence food production has been left solely to women, yet they do not make decisions involving intra-household resource management. This presentation suggests that, food security and sustainable agriculture would be achieved, if research priorities were more gender focused, to include the central role of women in agricultural labour. Obstacles that hinder women in the production, processing and utilization of indigenous food crops should also be addressed. This research concludes by suggesting several interventions to ensure food security in Kenya. Of importance is the sensitization of all stakeholders in the agricultural sector on the role of indigenous food crops in supplementing domestic food supply.

Profiling Country Perspectives

I-PR-1

Research focus on banana and plantain: Nigerian perspectives

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The contribution of bananas and plantain (*Musa spp.*) to food requirement of man forms the need to identify priority areas of research in the improvement and sustainability of these crops. Multi-disciplinary research of by scientists and documentation of the results are highly acknowledged, as they create the means of access to identifying production problems and the need to properly address them so as to wriggle out of these problems that pose challenges to quality production. An analysis of publications in Nigeria was undertaken to assess the most widely favoured areas of research. It was observed from the analysis that scientists' choice of research focus on need to be demand-driven and contribute positively to the improvement of the crops. This study in line with the aims and objectives of REDIMA-(documentation and information network for Africa) could further strengthen dissemination and validation of research results.

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