

Acceptance of bio-degradable Stoverpack among agricultural products market actors in Kampala and Wakiso districts

Charlton, Adam

3rd NARO-MAK Conference, Kampala, Uganda (14-16 March 2023)

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MAKERERE UNIVERSITY

NARO-MAK CONFERENCE

ABSTRACT 2023

THEME

INNOVATIONS FOR ENHANCING PRODUCTIVITY AND AGRO-INDUSTRIALIZATION



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Message From the Conference Organising Committee



Imelda N. Kashaija
(PhD)

*Conference
Organising
Committee
Chairperson*

Ladies and gentlemen, the organizing committee of the National Agricultural Research Organization-Makerere University (NARO-MAK) Conference welcomes you to the Third Biennial Joint Scientific Conference. This year, the overall theme of the conference, “Innovations for Enhancing Productivity and Agro-industrialization”, is well aligned with Uganda’s National Development Plan III. It was deemed a pertinent topic, as it speaks to Africa and other developing countries that are still reliant on the agriculture sector as their main source of livelihood.

The conference presentations and discussions are condensed into seven sub-themes relating to issues that are pressing for African countries. Six subthemes relate to agricultural value chain nodes while the seventh is crosscutting. The value chain-biased ones are: 1. Challenges and opportunities in mechanization and agro-industrialization; 2. Modernizing post-harvest management and food safety systems; 3 Intensifying crop productivity and seed systems; 4. Accelerating Development of the Animal Resources-based Industry; 5. Managing interactions among agriculture, fragile ecosystems, and changing environment, and 6. Embracing ICT-based innovations for agricultural transformation. In consideration of the need for mechanisms to manage the effects of foreign-based problems, it was deemed important for participants and conference followers to get an understanding of the impact and implications of external shocks such as COVID-19 and the long-lasting war in Ukraine and Russia on our agriculture and agri-food systems. Hence the 7th sub-theme covers emerging cross-cutting issues. Last but not least, other cross-cutting aspects such as gender and equity, HIV Aids, the contribution of public and private partnerships, applications of renewable energy technologies in agriculture, capacity building for agro-industrialisation, and research product commercialization are given a platform in this conference.

The choice of the sub-themes was premised on the realization that:

A key gap in the development of the agricultural sector is the aspect of incomplete value chains. Africa needs to embrace and nurture agricultural value chains that are competitive locally and at the global level. At the same time, the value chains should support the budding agro-industry. Bearing in mind the current challenges of climate change and associated challenges, African countries must urgently focus on enhancing productivity, and optimal as well as sustainable use of resources such as land, labour, capital, and time. In the face of globalization and agro-industrialization, this process has to be facilitated by efficient infrastructure, including institutions that support safety standards coupled with adequate funding.



The agricultural sector must continuously innovate to compete in the changing ecosystem. Appropriate and evolving seed systems, production practices, post-harvest management and value addition to improve marketability are necessary for continuous innovation. In this fast-modernizing era, value chain systems must be supported by improvements in information and communications technology (ICT). ICT can reduce transaction costs, specifically those associated with missing markets and lack of farmer integration into markets. The efficiency of the support institutions that facilitate the value chain is also enhanced by ICT.

The futurity of value chains and success in transforming the agricultural sector rests with the youth. Therefore, the need for future-proofing the youth for engagement in agricultural value chains cannot be over-emphasized. Its impact as well as strategies for comprehensive support to the youth, however, need to be well assessed and understood for the development of appropriate solutions. The need to manage external shocks, especially COVID-19 which is a main factor in vulnerability and unprecedented challenges to agri-food systems around the globe, also informed the topics for this conference.

Notably, this conference was organized specifically to promote dialogue on the practical issues surrounding the above-highlighted aspects. Intentionally, the conference focuses on innovations for agro-industrialization. This path, we believe, is the future in the development of the agricultural sector, especially in Africa. From the discourse at this conference, the knowledge shared on advances in research and innovation, and the ideas generated to inform the transformation of the agricultural sector will be concretized into practical recommendations for use in the formulation of technical and policy interventions.

Ladies and gentlemen, we thank you for coming, and we look forward to fruitful deliberations at this conference.

On behalf of the 3rd Biennial NARO-MAK Joint Scientific Conference, I deliver this message

For God And My Country.



Acknowledgemnt

The Conference Organising Committee (COC) is extremely grateful to the Government of the Republic of Uganda for creating and maintaining an enabling, safe and supportive environment that allows research work to be done and this kind of conferences to be held. It is noted with appreciation that with funding from the Government, the host institutions; the National Agricultural Research Organisation (NARO) and Makerere University (the College of Agricultural and Environmental Sciences - CAES) supported the preparations and running of this conference.

We would like to greatly appreciate the sponsors of this conference. Both current and prospective partners, collaborators and “friends” of NARO and Makerere University have supported the conference financially (direct or in-kind) and morally. These include, USAID Feed the Future – Uganda Institutional Systems Strengthening Activity and the Agricultural Research Activity, aBi Development Limited, CABI-Africa, The World Bank, The Food and Agricultural Organisation (FAO Uganda), Nile Breweries Limited and Prof Nicholus Kiggundu as an individual. Without this support this conference would not have been a reality.

Greatly appreciated are the presenters of both the oral and poster papers for their hard work and willingness to share their knowledge at this conference. The presence of policy makers, development partners, members of the private sector and all of you in your respective capacities cannot be taken for granted. Thank you for participating in this conference.

We sincerely appreciate and thank the Rt. Hon. Prime Minister of Uganda, the Hon Minister of Water and Environment and the Hon, Minister of the Ministry of Agriculture Animal Industry and Fisheries for creating time to officiate the opening and closing of this important conference.

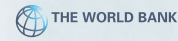
Our efforts as the COC is also hereby acknowledged. Specifically, the COC comprised the following persons: Dr. Imelda N. Kashaija (Chairperson), Dr. Yazidhi Bamutaze (Co-Chairperson) Dr. Moreen Uwimbabazi, Mr. Joseph Mbihayeimaana, Ms. Victoria Mbigidde, Ms. Christine Elong, Dr. Cassius Aruho, Dr. Titus Alicai, Dr. Abel Atukwase, Prof. Bernard Bashaasha, Dr. Alice Turinawe, Dr. Jesca Nakavuma, Mr. Albert Muhumuza, Dr. Jeninah Karungi, Ms. Mary Nantale and Dr. Isaac Dramadri. The services and support given by the rapporteur team led by Mr. Napoleon Kajunju are highly esteemed too.

The abstracts of the papers presented were peer reviewed. The time and experience of reviewers listed below is greatly valued, and we hereby thank you: Prof. Nelson Turyahabwe, Dr. Prossy Isubikalulu, Dr. Experito Muyanja, Dr. Tonny Obua, Dr. Robert Kawuki. Dr. Michael Otim, Dr. SB Mukasa, Dr. Florence Lwiza, Dr. Paul Aseete, Dr. Kanifa Kamatara, Dr. Pius Lutakome, Dr. Swidiq Mugerwa, Dr. Peace Musiimenta, Dr. Donald Kugonza, Dr. Jimmy Lamo, Dr. Joel Buynza, Eng. Alphonse Candia, Eng. Dr. Florence Kiyimba, Dr. John Wasige and Ms. Catherine Agoe. Equally acknowledge here are the COC members who doubled as reviewers.

Last but not least, the COC is appreciative of the ambient conference facilities and excellent customer care availed by Speke Resort Munyonyo Management.

For God And My Country

**The Conference Organising Committee
NARO-MAK Conference,
14-16 March 2023**



Remarks by Deputy Director General-ATP, NARO at the 3rd Biennial NARO-MAK Joint Scientific Conference, 14th -16th March 2023, Resort Hotel Munyonyo, Kampala, Uganda



Dr. Sadik Kassim

*Deputy Director
General-Agricultural
Technology
Promotion(ATP)*

I would like to use the opportunity at the 3rd Biennial NARO-MAK Conference with the theme "Innovations for Enhancing Productivity and Agro-industrialization" to highlight how farmers and other technology end users can access research products and innovations. To increase participation and inclusiveness in Research and Development (R&D) and ensure that relevant technologies and information are generated and disseminated, NARO periodically undertakes demand articulation and priority setting stakeholder engagements. As a result of these engagements, problem-solving and demand-driven technologies are generated, disseminated, and adopted across the country. To ensure the research technologies reach farmers and other end users in a sustainable manner, both public and commercial routes have been used for technology transfer. This is to address concerns of access, quality assurance, technology tracking and traceability, product stewardship and benefit sharing.

Under the public route, NARO uses a number of innovative approaches, especially through the Zonal Agricultural Research and Development Institutes (ZARDIs) and Extension service providers at all levels, to disseminate and upscale technologies for increased access by communities. While under the commercial route, technologies are disseminated through NARO Holdings Ltd, technology licensing, joint venture and start-up/spinoff establishments involving engagements with seed companies and industry players, joint technology incubation and skilling and e-knowledge and information sharing platforms, among others, to accelerate and efficiently transfer technologies to end users. On the other hand, scientific information is shared through scientific platforms such as conferences and scholarly journals both international and local, especially Uganda Journal of Agricultural Sciences (UJAS), run by NARO.

The desire of NARO is to see communities increasingly utilising research products and services for increased productivity and production and consequently improved food and nutrition security, increased household incomes, and social-economic transformation in the country. In this regard, I thank the sponsors and organizers of the NARO-MAK conference as one of the avenues for dissemination of research outputs.

Message from Principal College of Agricultural and Environmental Sciences (CAES)



**Professor
Gorret Nsubuga
Nabanoga**

*Principal, College
of Agricultural and
Environmental
Sciences (CAES) at
Makerere University*

Prof. Gorretti Nsubuga Nabanoga holds a Ph.D in Gender and Natural Resources Management from Wageningen Agricultural University in the Netherlands, a Master of Science in Management of Natural Resources and Sustainable Agriculture from the Center for International Environment and Development Studies from the Agricultural University of Norway and a Bachelor of Science in Forestry from Makerere University. She has previously served as Dean of the School of Forestry and Nature Conservation, Head of Department, Community Forestry and Extension, Faculty of Forestry and Nature Conservation, Makerere University, and Deputy Principal of the College of Agricultural and Environmental Sciences. She is an active researcher with several publications in peer reviewed journals, one book and three book chapters. She has attracted research grants worth billions of shillings that have supported over 30 graduate students. Prof. Nabanoga serves on boards and councils of several organisations such as Makerere University, Buganda Kingdom, Uganda Martyrs University, National Agricultural Advisory Services (NAADS) and is a member of several social clubs. She has a wide network of national, regional and international collaborations and is actively engaged in community outreach. Her current passion is to champion innovations at CEAS for societal transformation.

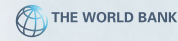


**Dr. Ambrose
Agona**

*Director General
NARO*

I am delighted to make this remark on behalf of the Governing Council, Management and Staff of NARO at the 3rd Biennial NARO-MAK Conference in light of the overall conference theme "Innovations for Enhancing Productivity and Agro-industrialization". The mandate of NARO is to coordinate, oversee and guide agricultural research in Uganda. The mission of NARO is to innovate for sustainable agricultural transformation. NARO Conducts research in all aspects of agriculture including crops, livestock, fish, forestry and cross cutting areas through 16 institutes. The goal of NARO is to increase total factor productivity through generation and promotion of novel research technologies, products and services. NARO's research agenda is aligned to contributing to the achievement of the national aspirations that are on the other hand aligned to the regional, continental and global (SDGs) aspirations. Key in her agenda is contributing to building resilient food system, Agro-industrial development and inclusive economic growth.

NARO is committed to providing solutions in the face of growing complexity of factors threatening food and economic security such as: climate change, rapid population growth, rapid urbanization, and unexpected shocks such as natural disasters and other crises through development of high yielding resilient varieties and breeds; TIMPS;



improvement of post-harvest and storage attributes (e.g. tolerance to aflatoxins, shelf life); improvement of processing and value addition attributes (nutrient density, fortification, safety); development of market differentiated research products tailored to different social and economic classes; and supporting technology transfer and dissemination through provision of early generation seeds, prototypes and information.

Besides contributing to the pool of scientific knowledge some of which will be shared through the conference papers, in the last 10 years, NARO has among others: i) developed over 100 high yielding crop varieties that are commercially produced (maize 32, beans 24, rice 9, sorghum 4, cassava 9, sweet potato 8, mango 5, citrus 3, coffee 10, etc.) and largely driving increased productivity and production in the country leading to reduction in imports, increase in export and increase in cottage industries; ii) developed nutrient dense (bio fortified) staple crop varieties, for example 7 bean varieties rich in iron (>70 ppm) and zinc (>35ppm), and 9 sweet potato varieties rich in vitamin A (5.0 - 11.03mg/100g fresh weight) that are highly demanded by food industries for processing creating jobs in addition to saving the country from health burden of malnutrition especially micronutrient deficiencies estimated at US \$899 (5.6% GDP) million annually; and iii) NARO is currently at advanced stages of anti-tick vaccine development that is envisaged to salvage the country from expenditures on importation of anti-tick vaccines in addition to improving livestock productivity and production.

Based on her achievements NARO is recognized as a centre of excellence for agricultural research on the continent and this has been possible through building networks and partnerships with academia, research institutions, development partners, private sector, farmer organizations and, cultural and religious institutions as has been demonstrated in this conference delivered in partnership with Makerere University and supported by a number of partners.

In this regard I sincerely thank all those who have contributed to the success of NARO and the 3rd NARO-MAK conference as one of the avenues for disseminating research outputs and furthering networks and partnerships for synergy and development.

For God and My Country.



CONFERENCE PROGRAMME

0800-0900	REGISTRATION OF PARTICIPANTS
SESSION 1: OPENING REMARKS	
Venue: Speke Ballroom	
Session Chair: Principal CAES, Makerere University, Prof. Gorettie Nabanoga	
Rapporteurs: Mary Nampeera, Bob About, Carolyn Asapo, Hilda Adage	
0900-0910	Remarks by Vice Chancellor, Makerere University, Prof. Barnabas Nawangwe
0910-0920	Welcome Remarks by Director General, NARO, Dr Ambrose Agona
0920-0930	Welcome Remarks by Chairperson, Makerere University Council, Mrs. Lorna Magara
0930-0940	Remarks by Chairperson, NARO Council, Dr William Olaho-Mukani
SESSION 2: KEYNOTE PAPERS	
Session Chair: DDG-ATP, NARO, Dr Sadik Kassim	
Rapporteurs: Mary Nampeera, Bob About, Carolyn Asapo, Hilda Adage	
0940-1010	Keynote Address: Challenges and Opportunities in Mechanization and Agro-Industrialization in Developing Countries. Mr. Ollen Wanda, Uganda Development Cooperation, Uganda
1010-1020	Discussion – Plenary
1020-1040	Keynote Address: Minimising the impact of COVID-19 on Food Systems. Prof. Robinson Mdegela, Sokoine University, Tanzania
1040-1055	Presentation: Implications of the Russia-Ukraine war on Uganda’s Agriculture. Ms. Florence Nakazi, Economic Policy Research Centre, Uganda
1055-1120	Discussion – Plenary
1120-1145	HEALTH BREAK
SESSION 3: OFFICIAL OPENING CEREMONY	
Session Chair: DDG-RC, NARO, Dr Yona Baguma	
Rapporteurs: Mary Nampeera, Bob About, Carolyn Asapo, Hilda Adage	
1150-1200	Remarks by USAID Uganda Representative
1200-1215	Remarks by Hon. Minister, Ministry of Agriculture, Animal Industries and Fisheries, Hon. Frank Tumwebaze
1215-1235	Official Opening by The Rt. Hon. Prime Minister of Uganda, Hon. Robinah Nabbanja
1235-1240	GROUP PHOTOGRAPH
1240-1300	Guided Tour of Posters and Exhibitions Led by DG NARO and VC Makerere University
1300-1400	LUNCH BREAK
PARALLEL SESSIONS: 1400 – 1700	



0800-0845	REGISTRATION OF PARTICIPANTS
SESSION 5: PLENARY	
Venue: Speke Ballroom	
Session Chair: Prof. John Muyonga, School of Food Technology, Nutrition and Bio-Engineering, Makerere University	
Rapporteur: Mary Nampeera, Bob About, Carolyn Asapo, Hilda Adage	
0855-0910	Presentation: Progress in Soybean Research in Uganda. Prof. Phinehas Tukamuhabwa, Makerere University
0910-0930	Keynote Address: Opportunities for Modernizing Post-Harvest Management for Food and Nutritional Security. Prof. Archileo N. Kaaya, Makerere University
0930-0950	Keynote Address: Accelerating Development of the Livestock-Based Industry. Dr Sylvia B. Angubua, European Commission for the Control of Foot and Mouth Disease
0950-1010	Keynote Address: ICT as a Tool for Accelerated Modernization of Agricultural Value Chains. Mr. Collin Babirukamu, National Information Technology Authority, Uganda
1010-1040	Discussion – Plenary
1040-1100	HEALTH BREAK
PARALLEL SESSIONS: 1100 - 1300 and 1400 – 1700	

0800-0900	REGISTRATION OF PARTICIPANTS
SESSION 8: PLENARY	
Venue: Speke Ballroom	
Session Chair: Prof. Justine Namaalwa, Head of Department Environmental Management and Programme Coordinator MasterCard Scholar	
Rapporteur: Mary Nampeera, Bob About, Carolyn Asapo, Hilda Adage	
0900-0910	Remarks by aBi Development Representative,
0910-0930	Keynote Address: Intensification of Crop Productivity in the Context of Changing Food Systems. Prof. Patrick Okori, RUFORUM
0930-0950	Keynote Speaker: Sustainable Management of Agricultural Production Systems in a Changing Climate. Dr John Wasige, Busitema University
0950-1020	Discussion – Plenary
1020-1050	HEALTH BREAK
1050-1140	Panel discussion: The Oil Palm Industry in Uganda. Moderator: Canary Mugume (NBS). Panellists: Dr Gaberial Ddamulira, Dr Abubaker Muhammad Moki, Mr. John Okiror, Mr David Balironda and Mr Chin Pit Te
PARALLEL SESSIONS: 1140 – 1300 and 1400 - 1500	



SESSION 11: CLOSING CEREMONY	
Venue: Speke Ballroom	
Session Chair: Director DRGT, Makerere University, Prof. Edward Bbaale	
Rapporteur: Mary Nampeera, Bob About, Carolyn Asapo, Hilda Adage	
1500-1520	Conference Summary by Conference Organizing Committee
1520-1525	Closing Remarks by Vice Chancellor, Makerere University, Prof. Barnabas Nawangwe
1525-1530	Closing Remarks by Director General, NARO, Dr Ambrose Agona
1530-1540	Closing remarks by the Minister of Agriculture Animal Industry and Fisheries, Hon. Bright Rwamirama
1540-1600	Closing speech by the Minister of Water and Environment, Hon. Sam Cheptoris

SESSION 4	Sub-Theme 1:	Sub-Theme 2:	Sub-Theme 3:	Sub-Theme 4:
	Challenges and Opportunities in Mechanization and Agro-Industrialization	Modernizing Post-harvest Management and Food Safety Systems	Intensification of Crop Productivity and Seed Systems	Accelerating Development of the Livestock-Based Industry
1400-1530	Venue: Speke Ballroom	Venue: Acacia	Venue: Ebony	Venue: Royal Palm
	Chair: Eng. Dr. Florence Kiyimba	Chair: Dr. Samson Gwali	Chair: Dr. Barbara Zawedde	Chair: Prof. Jessica Nakavuma
	Rapporteur: Dennis Kiiza	Rapporteur: Jimmy Agaba	Rapporteur: John Arinda	Rapporteur: Hannington Bukomeko
Defining fresh pod bean consumption dynamics and market base in Uganda	Effect of nixtamalization on mycotoxin levels and sensory properties of maize products in Uganda	The effect of adoption of improved bean and maize technologies on smallholder income and food security in Uganda	Flock dynamics and approaches for reducing mortality rate among Mubende goats at BuZARDI semi-intensive farm, Hoima, Uganda	
Immaculate Babirye	Archileo Kaaya	Sarah Mutonyi	Williams Guma	
Assessing genotypic variability and genome wide association studies for cooking-time and canning-quality traits in common bean accessions in Uganda	Use of photovoice technique to analyse factors that influence peanut product quality and safety along the value chain in Uganda	Effect of Manure Integrated With Inorganic P and K on Yield of Potato in South West Highlands of Uganda	Assessment of integrated control of East Coast fever (ECF) by induction of acquired immunity in Ankole cattle after natural infection by early diagnosis and early treatment	
Eunice Kesiime	Ruth Martha Mirembe	Joseph Etiang	Ann Nanteza	
Understanding the value chain of agro-forestry trees around Mount Elgon Uganda	Acceptance of bio-degradable Stoverpack among agricultural products market actors in Kampala and Wakiso districts	Response of potato to manipulation of row spacing, fertilizer use, and intercropping with beans in Uganda	Cysticercus tenuicollis in visceral organs of Goats and Sheep in Uganda	
Charles Galabuzi	Stephen Lwasa	Justine Nakiibuule	Joseph Magala	
Unlocking the industrial potential of the banana sector in Uganda	Compliance in farmers' practices to mitigate pesticide residues in Uganda Capsicum exports to the EU	Host and Seasonal effects on the abundance of Bean Leaf Beetles (<i>Ootheca</i> spp.) (Coleoptera: Chrysomelidae) in northern Uganda	Major causes of bovine liver condemnations and its implication for food security in Kampala city abattoirs	
Priver Namanya Bwesigye	Caroline Nankinga	Moses Lutakome	Kanifa Kamatara	
Discussion	Discussion	Discussion	Discussion	

1530-1700	Chair: Dr. Alfred Komakech	Chair: Dr. Ephraim Nuwamanya	Chair: Dr. Jimmy Lamo	Chair: Dr. Fred Kabi MAK
	Rapporteur: Dennis Kiiza	Rapporteur: Jimmy Agaba	Rapporteur: John Arinda	Rapporteur: Hannington Bukomeko
	Pluralistic agricultural advisory service delivery in enhancing sustainable land management among farming households in southwestern highlands of Uganda	A Systems Approach to Exports of Quality Capsicums from Uganda into the European Union	Target Population of Environments, Trait Heritability across the Breeding Stage Gates, and Their Impact on Sweet Potato Breeding in Uganda	Genetic variability in juvenile bodyweights and growth traits of selected indigenous chicken populations
	Alice Turinawe	Caroline Nankinga	Doreen Murenju Chelangat	Muhammad Kiggundu
	Detection and management of soil-borne pathogens in citrus using non-inorganic control practices under green-house conditions	Mitigation Measures for Reducing Tomato Post-Harvest Losses at Farmer Level in the Lake Victoria Crescent Agro-Ecological Zone	Progress in breeding quality protein maize varieties for the highland agro-ecologies of Uganda	The management, physical characteristics, and reproductive performance of Uganda's indigenous goats across agro-ecological zones
	Ronald Kisekka	Damalie Babirye Magala	Frank Kagoda	Ziwena Nantongo
	The potential of Joint crop-animal clinics in strengthening Agricultural Extension Service delivery in Uganda	Consumer Experiences with Processed Bean Products	Sukali Ndizi dessert banana hybrids with resistance to Fusarium wilt disease	Effect of adding graded levels of calcium and sodium bentonites in aflatoxin-contaminated feeds on the performance of layer chickens
	Patience Rwamigisa	Immaculate Babirye	Henry Buregyeya	Nviiri Geofrey
	Discussion	Discussion	Discussion	Discussion

SESSION 6	Sub-Theme 5:	Sub-Theme 2:	Sub-Theme 3:	Sub-Theme 4:
	Managing Interactions among Agriculture, Fragile Ecosystems and Changing Environment	Modernizing Post-harvest Management and Food Safety Systems	Intensification of Crop Productivity and Seed Systems	Accelerating Development of the Livestock-Based Industry
1100-1200	Venue: Speke Ballroom	Venue: Acacia	Venue: Ebony	Venue: Royal Palm
	Chair: Dr. John Adriko	Chair: Prof. Kaaya	Chair: Dr. Geofrey Arinaitwe	Chair: Dr. Joachim Idibu
	Rapporteur:	Rapporteur: Jimmy Agaba	Rapporteur: John Arinda	Rapporteur: Hannington Bukomeko
Nutritional and antioxidant properties of stingless bee, <i>Meliponula bocandei</i> honey from two agro-ecological zones of Uganda	Analysis of the quality of bean and maize seed at key points along the seed value chain – implications for upgrading the seed system	Efficient conditions for in vitro establishment and regeneration of disease-free Ugandan farmer-preferred cassava genotypes	Characterization and domestication of stingless bees in two agro-ecological zones of Uganda	
Patrice Kasangaki	Letaa Emmanuel	Hellen Apio	Patrice Kasangaki	
Effect of an <i>Metarhizium anisopliae</i> on non-target arthropods in farmland	Utilisation of orange fleshed sweet potatoes in production of noodles	Farmer Practices in Management of Oil Palm Weevil in Uganda	Alternative selection indices for simultaneous genetic improvement of multiple traits within indigenous chickens	
Gerald Ongodia	Janet Natocho	Esther Lugwana Nampeera	Geoffrey Akiiki Beyihayo	
Tackling climate change effects in Robusta coffee by enhancing soil health through agroforestry	Response Surface Methodology and Mixture Experiments for optimizing factors affecting the value-addition of agricultural products and for formulating nutritious food products	Hydropriming and Halopriming with Potassium Nitrate Solution to Improve Seed Germination and Vigour of Rice Cultivar Kafa-CI-287	The Zenga cattle of Uganda: insights from morphometric measurements	
Bernard Fungo	Tessema Astatkie	Morish Obura	Brian Martin Babigumira	
Genotype and Environment Effects on Resistance to Sweetpotato Weevil and Stability of Root Neck Length	Postharvest loss measurement along the cassava value chain in Eastern Uganda	A Comparative Analysis of the Different Rice Seed Cleaning Techniques	Effect of calicum and sodium bentonite clays from the Albertine graben region of Uganda as aflatoxin binders on boiler chickens fed contaminated diets	
Florence Osaru	Samuel Edgar Tinnyiro	Ocident Bongo-min	Nviiri Geofrey	
Discussion	Discussion	Discussion	Discussion	

1200-1300	Chair: Dr. Bernard Fungo	Chair: Prof. Muyonga	Chair: Dr. Godfrey Sseremba	Chair: Dr. Prof. Donald Kugonza
	Rapporteur:	Rapporteur:	Rapporteur:	Rapporteur:
	Agronomic performance of two sets international wheat germplasm from ICARDA in Uganda's mid and low altitude environments	Post-harvest handling and loss mitigation in Common Beans in selected districts of Uganda	Pro-Vitamin-A biofortified East African Highland Banana for environmental release in Uganda	Potency of ethanolic extracts of Tithonia diversifolia and Azadirachta indica in control of Helminths in south east agro-ecological zone (SEAEZ) of Uganda
	Bosco Chemayek	Immaculate Babirye	Stephen Buah	Brian Britex Owoyesigire
	Silage quality of different tropical maize inbreds	Routine Programme Monitoring: Evidencing Research Impact of Adoption of Improved Groundnut Technologies in Northern Uganda	Characterisation of Resistant Starch from Selected Banana Cultivars	Analyzing beef price incentives to strength policies for production and exports in Uganda
	Ssempiira John Bosco	Robert Gidoi	Ali Kajubi	Jules Cabrel Nkuinguoua Nana
	Harnessing natural defences for maximizing productivity of trees and forests: lessons from pine species	Kernel morphometric characteristics and oil content among selected shea tree (Vitellaria paradoxa) genotypes in Uganda	Blue morning glory, Ipomoea accuminata, is a potential wild host of Sweet potato feathery mottle virus (SPFMV) that infects sweetpotato in Central and Western Uganda	Potential of Forage and Pasture crops Research in Uganda
	Judith Nantogo	Juventine Boaz Odoi	Jimmy M. Tindamanyire	Allen Molly
Discussion	Discussion	Discussion	Discussion	
SESSION 7	Sub-Theme 5:	World Bank Session	Sub-Theme 6:	Sub-Theme 5:
	Managing Interactions among Agriculture, Fragile Ecosystems and Changing Environment	The Delivery of Agricultural Subsidies in SSA: A case of Evoucher in Uganda	Embracing ICT-based Innovations for Agricultural Transformation	Managing Interactions among Agriculture, Fragile Ecosystems and Changing Environment
1400-1530	Venue: Speke Ballroom	Venue: Acacia	Venue: Ebony	Venue: Royal Palm
	Chair: Dr. Victoria Namulawa	Chair: Dr. Alice Turinawe	Chair: Dr. Lawrence Owere	Chair: Prof. Arthur Tugume
	Rapporteur:	Rapporteur:	Rapporteur:	Rapporteur:

	Isolation and Characterization of Aeromonas hydrophila lytic Bacteriophages Obtained from Selected Aquaculture Farms in Uganda as a safe antibiotic alternative biocontrol agent	The Provision of Agro-inputs in Uganda, who are the influential actors and what are the governance challenges: A case of Uganda	Development of a nears infra-red spectroscopy prediction model for hydroxycinnamic acid esters in Ugandan sweet-potato parent germplasm	Juvenile tree seedlings' establishment in the dry lands of the Lake Albert Crescent Zone (LACZ) in Uganda, using hydro-gels
	Raphael Hans Lwesya	John Ilukor	Arnold Katungisa	Julius Masanyu
	Effect of adding Bacillus species to the water of a coupled aquaponic system on the gastrointestinal microbiota of Mozambique tilapia, Oreochromis mossambicus (Peters, 1852)	A Qualitative Assessment of the impact and scalability of the electronic agricultural voucher subsidy	Somatic embryo production in Ugandan elite cassava genotypes and genetic transformation using the enhanced green fluorescent protein gene	Impact of tree pruning on water use in tree-coffee systems on small-holder farms in Eastern Uganda
	Nasser Kasozi	James Tinker	Stephen Magambo	Joel Buyinza
	Integrated weed management in conservation agricultural systems	Taking Stock of farmers participation in the eVoucher agricultural subsidy program in Uganda	Embracing Radio and ICT as enablers for agriculture and rural development	Pilot demonstration of a satellite-based system for the detection and monitoring coffee wilt disease spread in Uganda
	Otim Godfrey Anyoni	Annet Adong	Gertrude Nalubinga Mwebaza	Sammy Olal
	Occurrence and damage/severity of coffee pests and diseases in central Uganda	Input choices and Productivity effects	Near infrared spectroscopy for high-throughput analysis of starch content in cassava	Establishment of Psyllaephagus bliteus Riek (Hymenoptera: Encyrtidae) as a bio-control agent for Eucalyptus pest Glycaspis brimblecombei Moore (Hemiptera: Aphalaridae) in Uganda
	Nicholas Olango	Deogratious Opolot	Babirye Fatumah Namakula	Violet Namuyanja
	Discussion	Discussion	Discussion	Discussion
1530-1700	Chair: Dr. Winnie Nkalubo	Chair: Prof. Bernard Bashasha	Chair: Dr. Williams Esuma	Chair: Dr. Fred Ssekitoleko
	Rapporteur:	Rapporteur:	Rapporteur:	Rapporteur:

	Community structure and distributional patterns of Pelecy-poda upstream and downstream of Bujagali Hydropower Project along the Upper Victoria Nile	The effect of the e-voucher program on household's farm productivity and food security	Triadic Comparison of Technologies (TRICOT): A Better digital methodology of on-farm crop testing of candidate crop varieties	Occurrence and distribution of the Potato Cyst Nematode <i>Globo-dera</i> spp., on Potato in Uganda
	Stephen Sekiranda	Emmanuel Rukundo	Stephen Angu-dubo	Shahasi Athman
	Agronomic and economic benefit of primary, secondary, micro nutrients in specified fertilizer applications in rice production in Uganda	Effect of Training on Farmers' Awareness and Use of NA-RO-Promoted Packages for Managing Black Coffee Twig Borer and Coffee Wilt Disease on Robusta Coffee	Introgressive hybridization levels of Tilapiine species in Lake Victoria basin, Kenya inferred from microsatellite and mtDNA genotyping based on next-generation sequencing	Host-plant Preference and Oviposition Responses by the Sorghum Midge on Grain Sorghum
	Crammer Kaizzi	Tumuramy Kelle	Kwikiriza Gerald	Joseph Andrew Wandulu
	Instrumentation predicts fruit colour associated with consumer acceptance of cooking bananas (Matooke)	Farmers Practices, Trends, and Incomes from Citrus Production in Teso Region in Eastern Uganda	Statistical Approaches to Improving Crop Production Experiments	Status of wheat stem rust in Uganda two decades after the first report of Ug99 (TTKSK) race
	Elizabeth Khakasa	Isaac Obongo	Paul Gibson	Bosco Chemayek
	Discussion	Discussion	Discussion	Discussion
SESSION 9	Sub-Theme 5:	Sub-Theme 3:	Sub-Theme 7 :	Sub-Theme 4:
	Managing Interactions among Agriculture, Fragile Ecosystems and Changing Environment	Intensification of Crop Productivity and Seed Systems	Cross Cutting Topics: COVID-19, Youth-Proofing and Gender	Accelerating Development of the Livestock-Based Industry
1145-1300	Venue: Speke Ballroom	Venue: Acacia	Venue: Ebony	Venue: Royal Palm
	Chair: Dr. Michael Otim	Chair: Dr. Godfrey Asea	Chair: Dr. Robert Kawuki	Chair: Dr. Collins Okello
	Rapporteur:	Rapporteur:	Rapporteur:	Rapporteur:
	Five Years of <i>Sclerotium rolfsii</i> Research: Prevalence, Pathogen Diversity, and Management of Southern blight on Common bean	Factors Affecting Production, Productivity and Marketing of Apples Grown in Uganda	Incentives and disincentives for Youth Participation in Groundnut Value Chains in Tororo and Nwoya districts of Uganda	Impacts of the Victoria Nile Bujagali hydro-power dam on fisheries and livelihoods
	Pamela Paparu	Rolland Agaba	Daisy Kemigisha	Herbert Nakiyende

Diversity and use of trees for food security in smallholder farming systems of Uganda's Mt. Elgon region	Small size non-marketable tubers and Economic losses in Potato Production: Evidence from Smallholder Farmers in Southwestern Uganda	Impact of Co-vid-19 on Production and Marketing of Milk by Dairy Farmers in Kiboga District, Uganda	Towards designing locally produced poultry vaccines against Infectious bursal disease (Gumboro) in Uganda
Fred Kalanzi	Marion Nyirarukundo	Caroline Nakato	Kabaka Richard M.
Potential to harness soil indigenous entomopathogens resources to manage Sweetpotato weevil in Uganda	Harnessing native rhizobia strains' nitrogen fixation capacity for enhanced pigeonpea productivity in Uganda	Impact of Co-vid-19 on Butchers and their coping strategies in Kampala district	Exploring the coffee species, Coffea liberica in Uganda
Joseph Odongo	Beatrice Sadina	Joan Namakula	Chemutai Job Alunga
Occurrence and severity trends of fusarium wilt disease in oil palm plantations in Kalangala	Analysis of current rice bacterial blight disease situation in Africa and transformative genome editing deployment management	Gendered analysis of vulnerability to climate change among Avocado Smallholder farmers: The case of Southern Tanzania Highlands	Effects of Purified Pituitary Extracts on Ovulation and Spawning in Clarius Gariepinus in Uganda
Otuba Amugoli	Moses Okello	Triphonia Ngailo	Nakasolya Juliet
	Blue morning glory, Ipomoea accuminata, is a potential wild host of Sweet potato feathery mottle virus (SPFMV) that infects sweetpotato in Central and Western Uganda	Labour-Saving Technologies to Mitigate the Effect of Women's Agriculture Time-Use Constraints on Stunting in Rural Uganda	The effect of vitamin E and C supplementation on viability of cryopreserved African catfish [clarius gariepinus] sperm
	Jimmy M. Tindanyire	Racheal Namulondo	Namatovu Aziidah
	New Variants of Xanthomonas vasicola pv. musacearum (Xvm) causing bacterial Xanthomonas wilt found in Uganda	Trends in Readership Index for Uganda Journal of Agricultural Sciences Over the Past Decade	Predicting future heat stress in the pastoral rangelands of Uganda: Implications for milk production
	Vicky Nabakooza	Victoria Mbigidde	Brian Britex Owoyesigire
Discussion	Discussion	Discussion	Discussion



Abstracts: Oral

Sub-theme 1: Accelerating Development of the Livestock-Based Industry

1.1 The Zenga Cattle of Uganda: Insights from Morphometric Measurements

Joseph Kibuye Masaba¹, Brian Martin Babigumira¹, Donald Rugira Kugonza², Denis Mpairwe²

¹National Livestock Resources Research Institute (NaLIRRI), P.O. Box 5704, Wakiso, Uganda

²Makerere University, College of Agricultural and Environmental Sciences (CAES), P.O. Box 7062, Kampala, Uganda

Corresponding author: bbabigumira@gmail.com

The three indigenous breeds of Uganda are Ankole longhorn, Shorthorn East African Zebu or Nganda. Lateral horned Zebu and indigenous African long horned taurine contribute to Ankole Longhorn's ancestry while Zebu and Ankole longhorn (Sanga) contribute to that of Nganda (Zenga). However, these indigenous breeds are poorly characterized. Therefore, the current study aimed at phenotypic characterization of the Nganda and Teso Zebu in Uganda. Data was collected on 41 morphometric variables including breed, coat color; linear and qualitative conformation measurements. The random animal sample included 129 Nganda from central and 63 Teso Zebu from eastern Uganda. We used descriptive and inferential methods to analyze the data. Generally, the Nganda is a chest-humped breed akin to its parent breeds. The breed has a solid brown coat and extremities (e.g., hooves) compared to the wide color variation tending to solid black in the Teso Zebu. The horns of both breeds were oriented upwards, forwards or laterally. Most animals of the breeds had either a medium or large sized dewlap. The Nganda had significantly ($p < 0.05$) higher mean values for all linear body measurements except height at withers. However, all linear measurements except ear length were significantly ($p < 0.05$) affected by the interaction between breed and sex. There was a distinct breed difference in the structure of the rump. Our results demonstrate a superiority of the Nganda over the Teso zebu in terms of linear traits. These results are pertinent in planning the sustainable utilization of these breeds.

Key words: Small East African Zebu, Nganda, Indigenous breeds, Cattle, Uganda

1.2 Alternative Selection Indices for Simultaneous Genetic Improvement of Multiple Traits within Indigenous Chickens

Geoffrey Akiiki Beyihayo¹, Donald Rugira Kugonza², Elly K. Ndyomugenyi¹, Richard Echodu³, Marion W. Okot¹, Filomena Dos Anjos⁴

¹Department of Animal Production and Range Management, Faculty of Agriculture and Environment, Gulu University, Gulu, Uganda

²Department of Agricultural Production, School of Agricultural Sciences, College of Agricultural and Environmental Sciences, Makerere University, Kampala, Uganda

³Department of Biology, Faculty of Science, Gulu University, Gulu, Uganda

⁴Faculty of Veterinary, Eduardo Mondlane University, Maputo, Mozambique

Corresponding author: g.beyihayo@gu.ac.ug

The present study aimed at constructing selection indices for indigenous chickens (IC) based on growth and egg production traits. Two consecutive generations of IC were considered. Hatching weight (HW), weight at two (W2), four (W4), six (W6), eight (W8), and twelve (W12) weeks of growth. Shank length (SL) was measured at two (SL2), four (SL4), six (SL6), eight (SL8), and



twelve (SL12) weeks of growth. The body weight at the onset of lay (WOL), egg weight (EW), clutch number (CLN-60), clutch size (CLS-60), and the number of eggs laid within 60 days (EN-60) were recorded. Genetic parameters were estimated using the restricted maximum likelihood procedure embedded within the variability package of R, version 4.1.1. The selection index package of R, version 4.1.1 was used to estimate the coefficients (b), genetic advance yield (GA), and percent relative efficiency (PRE). Equal weight (w1) and broad sense heritability (wh2) were used as economic weights to construct two sets of alternative selection indices. The weight of hens at four weeks of age (W4) was part of all the indices consisting of two traits and more in both economic weight categories. All selection indices contained WOL. Only SL4 was associated with negative coefficients under both economic weights. In addition, as the number of traits incorporated in the index increases, so does GA, and this subsequently requires more generations and years to achieve the breeding objectives. Alternative selection indices, I17 ($I17 = 5.91W4 - 225.97SL4 + 0.41W12 + 131.49SL12 + 0.42WOL + 11.9EW + 12.6EN$) and I27 ($I27 = 3.58W4 - 134.44SL4 + 0.25W12 + 78.79SL12 + 0.25WOL + 7.44EW + 7.56EN$) with the highest GA and PRE under both weight categories are potential breeding tools for IC. In conclusion, the combination of traits under each selection index remains the same regardless of the economic weight.

Key words: Economic weight, genetic gain, multipurpose chicken, generation, selection response

1.3 Flock Dynamics and Approaches for Reducing Mortality Rate among Mubende Goats at Buzardi Semi-Intensive Farm, Hoima, Uganda

Williams Guma¹, Sylvester Dickson Baguma¹, Lydia Asekenye¹, Lwaki Mulabuke¹, and Joseph Magala¹

¹Bulindi Zonal Agricultural Research and Development Institute (BuZARDI)

Corresponding author: williams.guma@naro.go.ug

Goats are globally important domestic ruminants being kept for meat, milk, skin, byproducts and several socio-cultural purposes. Despite goats being one of the priority animal commodities selected for promotion under Agro industrialization programme of NDP111 to reduce poverty which currently stands at 10% in the Albertine Graben, efforts towards its commercialization are hampered by informal production and marketing, poor breeds, diseases and dry-season feed scarcity.

In an effort to address challenges related to limited supply of producer desired breeds and information packages, BuZARDI established an on station semi intensive Mubende breeding and multiplication farm. We collected production and flock related data for 2 years and computed flock dynamics and mortality rates with the purpose of enhancing precision of decisions aimed at increasing the farm's productivity and using the approach to skill informal farms in future.

The flock size increased from 37 goats in July 2020 to 175 goats in June 2022. Average number of goats in the farm per month was 109.2 (Standard Error of Mean (SEM) = 13.7). The Mortality rate among goats in the farm over the period was 27goats per 1000goatmonths. It's lower than mortality rate (51.3 goats per 1000goatmonths) computed from a flock of 11,826 goats belonging to a sample of 271 farms in Albertine Graben. The main contributors to mortality of goats were worm infestation (33%), fracture and injuries arising from stampedes (18%), Ticks and tick borne diseases (18%), respiratory tract infections (11%) and malnutrition (10%).

In order to mitigate above causes of mortalities we prescribe strict adherence to flock health program; improved parasite management, separation & improved care for kids, vaccinations,



safer feeding, and evidence based disease management, dissemination of formal records management and development of appropriate app for more accurate determination of mortality rates being vital indicator for evaluating farms management practices.

Key words: Flock dynamics, Mortality rate, Albertine Graben

1.4 Towards Designing Locally Produced Poultry Vaccines against Infectious Bursal Disease (Gumboro) on Uganda

Kabaka, Richard, M¹; Ezinga, Richard¹; Godfrey Nsereko¹; Tusubira, Deusdeddit²; Dhikusooka, Swidiq Mugerwa, Kabuuka, Tonny¹

¹Infectious Animal Diseases Laboratory (IADL), National Livestock Resources Research Institute (NaLIRRI), National Agricultural Research Organisation (NARO), P.O. Box 5704, Nakyesasa, Wakiso District, Uganda

²Department of Biochemistry, Faculty of Medicine, Mbarara University of Science and Technology (MUST), P.O. Box 1410, Mbarara, Uganda

Corresponding author: tonny.kabuuka@pirbright.ac.uk

Uganda's agricultural sector is subdued by several challenges like endemic diseases, inadequate disease diagnosis and high vaccine importation costs for the control of poultry diseases like Infectious Bursal Disease (IBD) and Newcastle. These ultimately affect performance and impede poverty eradication through commercial poultry farming. Gumboro disease/ IBD is one of the most detrimental diseases in the poultry industry worldwide. Gumboro virus is very resistant in the environment, allowing its persistence in poultry facilities, even during downtime periods when the chickens are absent. Very virulent virus of infectious bursal disease and variants strains (vIBDV) have been detected in both broilers and layers, necessitating the need for a new vaccine.

This study aims to develop a stable and effective Gumboro/ IBD Ugandan-based vaccine, with complete genome sequencing for the control of Gumboro disease. We collected at least 155 samples from poultry farmers in Mityana, Kassanda and Mubende districts during Feb 2023. Blood, cloacal and oronasal swabs were collected from both chicken and turkeys. Samples are being collected from districts representing the Western, Eastern, Northern and Karamoja sub-regions for incorporation into a virus bank. We currently have setup for RNA extraction of all samples followed by serial passaging or sub-cloning for vaccine development.

Key words: Infectious bursal disease, Gumboro disease, improved vaccine, Uganda

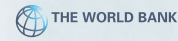
1.5 Major Causes of Bovine Liver Condemnations and Its Implication for Food Security in Kampala City Abattoirs

K. Kamatara, Akram. H. Jjemba, J. Idibu, Z. Nampija and D. Mpairwe

Department of Agricultural Production, College of Agricultural Sciences, Makerere University, Uganda

Corresponding author: kamatarakanifa@gmail.com

Condemnation of liver from beef carcasses attributable to different factors results in substantial loss of protein food resources. This paper measured the quantity of carcass and liver condemned and its implications on food security and monetary losses in three abattoirs in Kampala city. A study was conducted in three Kampala city abattoirs i.e KCCA (n=70), Kalerwe (101) and Wakulukuku (33) abattoirs using postmortem meat inspection from December 2020 to January 2021 to



assess causes of liver condemnations. Results showed that majority of animals slaughtered in Kampala abattoirs came from Western Uganda (38%) with Kiruhura district (20.26%) contributing of the animals. The major causes of liver condemnations were fasciolosis (26, 24.5 and 20%), hydatid cysts (4.9, 4.0 and 3.2%) and calcified cysts (2.9, 2.2 and 1.9%) at KCCA, Kalerwe and Wakulukuku abattoirs respectively. From all the three abattoirs, a total of 1218.8kg of liver valued at UGX 20,719,600 (USD 5919.9) were condemned in a period of two months. Results of this study provide information on major causes of liver wastage in cattle slaughtered in Uganda as well as a huge waste of ideal protein food source and direct financial losses.

Key words: Bovine, Food security, Liver Condemnations

1.6 Characterization and Domestication of Stingless Bees in Two Agro-Ecological Zones of Uganda

Patrice Kasangaki¹, Moses Chemurot², Agnes Otim¹, Christopher Angiro¹, Ronald Mugume³ and Robert Kajobe⁴

¹National Livestock Resources Research Institute (NaLIRRI)

²Department of Zoology, Entomology and Fisheries Sciences (ZEFS), Makerere University

³Rwebitaba Zonal Agricultural Research and Development Institute (Rwebitaba ZARDI)

⁴Faculty of Agriculture, Muni University

Corresponding author: patrice.kasangaki@naro.go.ug

Stingless bees are closely related to the honeybees, bumblebees and orchid bees. Stingless beekeeping offers big opportunity to people who hitherto failed to keep honeybees (*Apis mellifera*) due to their defensiveness (aggressiveness). Stingless beekeeping is not yet developed in Uganda due to lack of knowledge and techniques to keep them compared to the honey bees. Here, we aimed to identify stingless bee species, evaluate their productivity and develop technologies for their domestication in two agro-ecological zones of Uganda (Lake Victoria crescent and Western Highlands). In order to achieve this, stingless bee samples were collected from the two agro ecological zones and identified by classical morphological techniques at the National Museums of Kenya. Experiments to evaluate potential to domesticate and productivity of the bees were carried out. Beehive technologies, management packages and products harvesting methods were developed. Four stingless bee species namely *Meliponulabocandei*, *M. nebulata*, *M. ferruginea* and *Plebeinahildebrandtii* were identified. *M. bocandei* and *M. ferruginea* were found to produce 2-4 liters of honey and 2-3 Kgs of propolis and are highly adaptable under domestication. Out of the seven beehive designs developed, three were suitable for domestication of *M. bocandei* and *M. ferruginea* while one was suitable for domestication of *P. hildebrandtii* according to the nesting site. However, *P. hildebrandtii* produced very small amounts of honey and propolis whose nutritional and medicinal values need to be investigated. Therefore, stingless beekeeping is a viable venture providing alternative to honeybee keeping with superior products compared to those of honey bees.

Key words: stingless bees, propolis, nutritional, medicinal, honey



1.7 Genetic Variability in Juvenile Body weights and Growth Traits of Selected Indigenous Chicken Populations

Muhammad Kiggundu¹, Henry Mulindwa¹, Hussein K. Walusimbi¹, Rose Nangonzi¹, Richard Lumu², Robert Isabirye²

¹National Livestock Resources Research Institute, National Agricultural Research Organization, P. O. Box 5704, Kampala, Uganda

²Mukono Zonal Agricultural Research and Development Institute, National Agricultural Research Organization, P. O. Box 164, Mukono, Uganda

Corresponding author: kiggundumuhammad@gmail.com

Uganda's indigenous chicken (IC) genetic resources phenotypically exhibit great diversity in mature bodyweight and growth performance. However, no study has explored the genetic diversity in juvenile bodyweight and growth performance of selected indigenous chicken populations to aid early selection for these traits. The study determined the genetic variation in juvenile BW and growth of selected indigenous chicken populations (ICP). A base population of IC was assembled from Apac and Lira districts, alongside the IC flock previously assembled and selected for two generations for improved egg production and growth rate, and maintained at the National Semi-arid Resources Research Institute (NaSARRI). Birds collected from each district were separately housed as distinct ICP. Birds were fed the same diet and reared under similar management conditions. Fertile eggs from each population were collected, incubated and hatched separately. Data on hatch weight (BW₀) as well as subsequent bodyweight of the birds were collected on a weekly basis for up to week 4 (W₄). Besides BW, average daily gain (ADG) and relative growth rate (RG) were calculated as proxies of growth traits. Irrespective of population, average BW₀ was 25.3 g (range 17.7 to 38.7 g). BW₀ was significantly higher ($P < 0.01$) for chicks from Apac (26.1 g) and Lira (25.4 g) than from NaSARRI (24.9 g). ADG varied ($P < 0.01$) between populations, ranging between -1.07 to 6.66 g/day, with a mean of 3.37 g/day. ADG was highest (3.69 g/day) and lowest (3.03 g/day) for chicks from Lira and NaSARRI populations, respectively. Also, RG varied ranging between 73.3% to 671.4%, with mean 385.6% across populations. Average RG for chicks from Lira (408.7%) and Apac (410.4%) were comparable but significantly ($P < 0.05$) higher than for NaSARRI birds (344.8%). Broad-sense heritability estimates for BW at different ages were moderate i.e., for bodyweights at hatch (BW₀), week 1 (BW₁), week 2 (BW₂), week 3 (BW₃) and week 4 (BW₄) were 0.35, 0.50, 0.54, 0.47, 0.56, respectively. Genotypic variances for all bodyweight measurements were also significantly different ($P < 0.05$) between populations. Heritability estimates for ADG and RG were 0.41 and 0.49, respectively. Genotype variances differed ($P < 0.01$) across populations for ADG and RG. The findings of the study demonstrate wide phenotypic and genotypic variability in juvenile BW and growth performance. Furthermore, the moderate heritability estimates suggest that there is potential for early artificial selection and improvement based on bodyweight.

Key words: Growth performance, Hatch weights, Heritability, Phenotypic diversity

1.8 Cysticercus Tenuicollis in Visceral Organs of Goats and Sheep in Uganda

J. Magala¹, B. Mudde², P. Mawadri³, Guma Williams⁴, J. Akullo⁵, P.O. Olango⁶ and S.D. Baguma⁷

^{1, 4, 7} National Agricultural Research Organisation-Bulindi Zonal Agricultural Research and Development Institute, P. O. Box 101, Hoima, Uganda

² National Agricultural Research Organisation-Ngetta Zonal Agricultural Research and Development Institute, P. O. Box 52, Lira, Uganda



³ Makerere University-College of Veterinary Medicine, Animal Resources and Biosecurity, P.O. Box 7062, Kampala, Uganda

⁵ Busitema University Arapai Campus- Faculty of Agriculture and Animal Sciences. P.O.Box 236, Tororo, Uganda

⁶ Norwegian Refugee Council – West Nile. P.O. Box 24978, Kampala, Uganda

Corresponding author: joseph.magala@naro.go.ug

Cysticercus tenuicollis is a metacestode stage of *Taenia hydatigena* residing in visceral organs of small ruminants and its effects cause economic losses due to condemnation of visceral organs in the slaughter places. This study reports on the prevalence of *Cysticercus tenuicollis* in small ruminants slaughtered in Lira Municipal Abattoir. A total of 70 sheep and 70 goats were sampled and examined after slaughter for presence of *Cysticercus tenuicollis* in the visceral organs using standard meat inspection procedures. Data was recorded using an abattoir data collection sheet and analysed in SPSS version 20. The study revealed 51.4% of goats and 68.6% of sheep to be infested with *Cysticercus tenuicollis*. Following district of origin for the small ruminants, Otuke district had the highest prevalence of the parasite (82.6%), followed by Kole (72.4%), Alebtong (66.7%), Apac 59.4% and Lira (31.4%). *Cysticercus tenuicollis* was more frequently seen on the intestines (57.8%) of sheep and goats than on any other visceral organs. The liver had a prevalence of 20.7%, the lungs 17.8%, the kidneys 3.5% and the fetal sac; (15.7%) in goats and (12.9%) in sheep. Following the sex of animals, *Cysticercus tenuicollis* was found in 68.8% of female small ruminants as compared to 58.8% in male ruminants. It is recommended to routinely deworm goats and sheep by farmers most especially in districts with the highest prevalence of *Cysticercus tenuicollis* infestation. The sale of the condemned parts of sheep and goats and the feeding of dogs on these contaminated materials should be stopped forthwith. It is also being suggested that a national study be carried out to determine the prevalence and economic impact of *Cysticercus tenuicollis* in small ruminants.

Key words: *Cysticercus tenuicollis*; Goats and Sheep; Abattoir

1.9 Effects of Purified Pituitary Extracts on Ovulation and Spawning in *Clarius Gariepinus* in Uganda

Nakasolya J.¹, C. Aruho², D. Kahwa¹, R. Dungu²

¹Department of Wildlife and Aquatic Resources, CoVAB Makerere University

²Aquaculture Research and Development Centre Kajjansi, NaFIRRI

Corresponding author: juliejuna33@gmail.com

The study determined the amount, quality and effect of LH and FSH hormones in *Lates niloticus* and *Clarius gariepinus* pituitary gland extracts on ovulation and spawning following storage.

A randomized control design was used to study 133 specimens from developing and mature stages of *L. niloticus* from factory grade A and B and 62 mature and ripe *C. gariepinus* pituitary glands. Hormone extraction was done using solvent method while sELIZA was used for quantification. Effect of the hormone was determined by ovulation, fertilization hatching and survival rates. Statistical package for the social Science (SPSS) software version 22.0 was used to analyze data, and P-value of 0.05 was used to measure the association.

The concentrations of LH and FSH in the pituitary gland extracts of *L. niloticus* and *C. gariepinus* varied between 10-11ng/ml for LH and 31-38ng/ml for FSH with average of 10ng/ml for LH and 34ng/ml for FSH per each pituitary gland per 1kg fish.



There was no statistically significant difference in LH and FSH concentrations in both species ($P > 0.05$) in two grades and maturity stages with the exception of developing stages in Grade A and B ($P \leq 0.002$). Despite similar LH and FSH concentration in both species, *L. niloticus* did not induce ovulation in *C. gariepinus*. A concentration of 17ng/ml *C. gariepinus* did not induce ovulation, but that at 34ng/ml and 68ng/ml produced 89,096 eggs and 90,300 eggs, and with 99.5% and 98.3% fertilization rate respectively.

No significant effect was observed between crude and purified pituitary hormones ($P \geq 0.5$). Meaning storage time has no effect on quality of inducing hormones from the *C. gariepinus*.

The presence of hormones in the *L. niloticus* is a good basis for further study to unlock their potential and have them produced massively for commercial purpose since there are huge wastes in the *L. niloticus* processing factories.

Key Words: *Lates niloticus*, *Clarius gariepinus*, luteinizing hormone, Follicle stimulating hormone

1.10 The Effect of Vitamin E and C Supplementation on Viability of Cryopreserved African Catfish [*Clarius Gariepinus*] Sperm

Namatovu A.¹, C. Aruho², D. Kahwa¹, R. Ddungu²

¹Department of Wildlife and Aquatic Resources, College of Veterinary Medicine Animal Resources and Biosecurity

²Aquaculture Research and Development Centre Kajjansi, NaFIRRI

Corresponding author: namatovumuk@gmail.com

This study investigated the effects of vitamin E and C supplementation on the viability of cryopreserved *Clarius gariepinus* sperm cells, fertility and hatchability of the fish eggs. Sperm samples were collected from 30 *C. gariepinus* male broodstocks and diluted in Ringers solution, mixed with cryoprotectants (DMSO 5%) and in varying concentrations of vitamin E/C. The diluent was frozen in programmable deep freezer (-5 to -145°C) and placed in a liquid nitrogen flask for cryopreservation. Results showed that broodfish of 800g body weight had initial sperm motility above 83%. Supplementing *C. gariepinus* milt with Vitamin E concentration of 10iu had a significant higher motility than vitamin E 5iu after three months of storage. Fertilisation and hatchability significantly increased with increasing vitamin E concentration ($p < 0.001$). Sperms in Vitamin C 0iu concentration survived while none survived in C5iu and C10iu concentrations. Survival rate of the hatched fry per Vitamin E concentration and the proportion of fry to survive past the 11 days was 80%. Overall vitamin E 10iu concentration improved viability of cryopreserved *C. gariepinus* sperms, reduce fertility loss and increase hatchability and survival rate of the fry. This suggests that supplementing *C. gariepinus* sperm cells with Vitamin E 10iu during cryopreservation can be effective in long-term preservation of the milt. Consequently it can be used continuously in artificial fertilisation process of *C. gariepinus* eggs by seed multiplies. It is recommended that broodstock weighing over 800g should be used as sperm donors and Vitamin E should be added to the milt to improve the efficiency of cryopreservation of *C. gariepinus* spermatozoa.

Key words: *Clarius gariepinus*, Cryopreservation, Sperms, Vitamins, survival



1.11 Assessment of Integrated Control of East Coast Fever (ECF) By Induction of Acquired Immunity in Ankole Cattle after Natural Infection by Early Diagnosis and Early Treatment

Nanteza Ann^{1*}, Nsadha Zachary¹, Nsubuga Julius¹, Oligo Stephen¹, Kazibwe Anne¹, Terundajja Clare¹, Matovu Enock¹ and Lubega George Willy¹

¹College of Veterinary Medicine, Animal Resources and Biosecurity, Makerere University, P.O. Box 7062, Kampala, Uganda,

Corresponding author: ann.nanteza@mak.ac.ug

The performance of instituting early diagnosis and early treatment of ECF approach in indigenous cattle as an integral component in the routine disease control in an endemic area was assessed. A longitudinal study was carried out in Kiruhura district, southwestern Uganda for six months on 244 Ankole breed of cattle from 18 herds kept under natural tick challenge and relaxed tick control measures. Calves aged three to six months old were recruited and monitored daily by farmers for detection of ECF clinical symptoms. The reported sick animals were treated by veterinarians using Buparvaquone and treatment outcome determined. Monthly follow-ups and blood collections were done to monitor the ECF status. Blood was analyzed for *Theileriaparva* parasites by microscopy, DNA by polymerase chain reaction (PCR) and antibodies by enzyme-linked immunosorbent assay (ELISA). The overall prevalence of ECF clinical disease within six months period was 30.3% (74).

The major symptoms of early clinical ECF disease were fever and enlarged parotid and/or prescapular lymph nodes. The ECF clinical cases were categorized as mild, 24% (18) or moderate, 76% (56). There was an overall recovery rate of 100% (74) of the ECF cases whereby 94.6% (70) showed prompt recovery and 5.4% (4) showed slow recovery. Based on blood analysis, the prevalence of ECF at baseline was 3.7% (9) by blood smear, 31.1% (76) by PCR and 38.1% (93) by ELISA. A significant increase ($P < 0.05$) was shown by increased number of calves with *T. parva* specific antibodies in the sera from 38.1% at baseline to 68.8% after six months. High antibody levels (positive percentage (P) $\geq 50\%$) were detected in all the ECF treated and recovered calves at the end of the six months. The acquired immunity to ECF was high in treated and recovered cattle indicating that natural exposure to infection and effective treatment enhance development of immuno-protection in indigenous cattle in an endemic area. Accurate early diagnosis and early treatment of ECF leads to prompt recovery and protective immunity. The prominent early clinical symptoms for ECF could be exploited in the development of decision support tools for chemotherapy and other integrated control measures.

Key words: *Theileriaparva*, East Coast fever, endemic, chemotherapy, indigenous cattle

1.12 Monitoring Price Incentives for Beef in Uganda

Nkuingoua N.¹, Pernechele V.²

¹FAO's AgriInvest Project

²FAO's Monitoring and Analysing Food and Agricultural Policies (MAFAP) Programme

Corresponding author: Cabrel.Nana@fao.org

Fifty-eight percent of Ugandan households depend on livestock for their livelihoods, with cattle being the most important livestock sub-sector in the country. Over the last years, the Government of Uganda, within the framework of the National Development Plan, has envisaged a variety of investments for the production and exports of livestock products. Despite these efforts, Ugandan beef production experienced a low growth rate of just 1 percent in the last decade. This study



- produced jointly by the Food and Agriculture Organization of the United Nations (FAO) and the Uganda Agribusiness Alliance - reviews price incentives to smallholder beef producers by assessing the effects of trade and market policies and dynamics on domestic beef prices in Uganda from 2005 to 2020. Data used for this analysis include domestic beef prices obtained from the Ministry of Agriculture, Animal Industry and Fisheries, market access costs through primary surveys of beef transporters and traders in Kampala, and beef exports from Uganda Revenue Authority. To measure the level and trend of price incentives, the study relies on a set of renowned indicators, the nominal rate of protection (NRP), nominal rate of assistance (NRA) and the market development gap (MDG). The results reveal that in the past (from 2011 to 2016) breeders were penalized by low prices, while recently they benefitted from prices above the international-equivalent, mainly due to restrictions on cattle movement due to foot and mouth disease (FMD) outbreak, which increased domestic prices. The persistent gaps between domestic and international prices can also be explained by the very limited price transmission and weak market integration of the beef value chain in Uganda. FMD is a critical issue to tackle to improve beef commercialization and competitiveness, together with the significant value chain inefficiencies, such as high transport costs and the presence of informal fees, that still hinder marketing and profitability of this sector.

Key words: beef, price incentives, market access, FMD

1.13 Effect of Adding Graded Levels of Calcium and Sodium Bentonites in Aflatoxin-Contaminated Feeds on the Performance of Layer Chickens

Nviiri Geoffrey^{1,2,3}, Kabi Fred², Kaaya Achileo², Abasi R. Kigozi¹, Muhammad Kiggundu¹, Swidiq Mugerwa¹

¹Beef and meats Research Program, National Livestock Resources Research Institute, P.O.Box 5704, Kampala, Uganda

²College of Agriculture and Environmental Sciences, Makerere University, P.O.Box 7062, Kampala, Uganda

³Ngetta Zonal Agricultural Research and Development Institute, P.O.Box 52, Lira, Uganda

Corresponding author: hgnviiri@gmail.com

The study was conducted to assess the effect of calcium and sodium bentonites from the Albertine Graben region of Uganda on the hen day egg production, feed conversion efficiency, and egg quality indices of layer chicken fed on aflatoxin-contaminated diets. Balanced diets were formulated to meet the nutritional requirements of layers in their different physiological status as developer, grower, pre-layer, and layers' were each laced with aflatoxins to levels of 250 parts per billion (ppb). Three aflatoxin binders including a commercial toxin binder (TB), and two Albertine bentonites (Calcium bentonite (CaB) and sodium bentonite (NaB) were each separately added at graded levels of 0.0, 0.25, 0.5, 1.0, and 2.0% to the contaminated grower, pre-layer and layer diets. The birds were then subjected to the treatments in a completely randomized experimental design replicated 3 times ($n = 15$ layer birds per replicate group). The results indicated that hen day egg production increased with increasing commercial binder inclusion levels following a quadratic trend ($p < 0.05$) while those of the Albertine bentonites followed linear trends ($p < 0.01$). As a result, optimum responses of 52.6 and 48.9% were obtained at 1.21 and 1.76 % inclusion levels of TB and CaB, respectively. On the other hand, egg weight increased quadratically ($p < 0.05$) with increasing commercial binder inclusion level while the increase due to Albertine bentonites inclusion followed linear trends ($p < 0.05$). As a consequence, optimum responses of 52.93, 52.3, and 52.0 g were obtained at 1.49, 1.47, and 1.79% inclusion levels of CaB, TB,



and NaB, respectively. Feed conversion ratio decreased with an increase in commercial binder inclusion following a quadratic trend ($p < 0.01$) whereas the addition of Albertine bentonites resulted in linear responses ($p < 0.001$). As a result, optimum responses of 3.99, 4.03, and 4.12 were obtained at 1.30, 1.83, and 1.76 inclusion levels of the commercial binder, CaB, and NaB, respectively. Hence, based on the feed conversion ratio, the inclusion of calcium and sodium bentonites from the Albertine region at inclusion levels of 1.83 and 1.76%, respectively to aflatoxin-contaminated feeds results in optimum layer performance.

Key words: Aflatoxins; Albertine bentonites; Calcium bentonite; sodium bentonite; layer

1.14 Effect of Calcium and Sodium Bentonite Clays from the Albertine Graben Region of Uganda as Aflatoxin Binders on Broiler Chickens Fed Contaminated Diets

Nviiri Geoffrey^{23*}, Kabi Fred², Kaaya Achileo², Swidiq Mugerwa¹

¹Beef and meats Research Program, National Livestock Resources Research Institute, P.O.Box 5704, Kampala, Uganda

²College of Agriculture and Environmental Sciences, Makerere University, P.O.Box 7062, Kampala, Uganda

³Ngetta Zonal Agricultural Research and Development Institute, P.O.Box 52, Lira, Uganda

Corresponding author: hgnviiri@gmail.com

This study was conducted to determine the optimum inclusion levels of Albertine bentonite clays, their effects on relative organ weights as well as aflatoxin carry-over in the liver, kidney, gizzard, and muscles of broilers fed aflatoxin-contaminated diets. Balanced diets for broiler growers and finishers were each laced with aflatoxins to levels of 250 parts per billion (ppb) during weeks 3-4 and 5-7, respectively. Three aflatoxin binders including a commercial toxin binder (TB), and two Albertine bentonite clays (Calcium bentonite (CaB) and sodium bentonite (NaB) were each separately added at graded levels of 0.0, 0.25, 0.5, 1.0, and 2.0% w/w to the contaminated diets. The birds were then subjected to the treatments in a completely randomized experimental design replicated 3 times ($n = 20$ birds per replicate group) for 5 weeks, after which the broilers were slaughtered for tissue evaluation at the end of week 7. Largely, voluntary dry matter intake increased quadratically ($p < 0.05$) with increasing binder inclusion levels except for TB and NaB in the broiler grower phase which increased linearly ($p < 0.05$). Daily weight gain (BWG) increased quadratically ($p < 0.05$) with inclusion levels in both phases except for TB and CaB which followed a linear trend ($p < 0.05$) in the growers. Cumulative feed conversion ratio (FCR) decreased with increasing binder inclusion levels. Consequently, optimum FCR was recorded at 1.862, 1.864, and 1.877 g of feed/g of BWG at 1.35, 1.70, and 1.5% inclusion levels of TB, CaB, and NaB, respectively. The infectious bursal disease antibody titer increased to optimum values of 2761, 2559, and 2532 corresponding to 1.33, 1.53, and 1.46% inclusion levels of TB, CaB, and NaB respectively. The antibody titers of Newcastle disease increased to optimum titer values of 7.62, 6.89, and 6.91 corresponding to 1.37, 1.48, and 1.48% inclusion levels of TB, CaB, and NaB, respectively. While the decrease in broiler mortality tended towards linearity ($p = 0.07$) due to increasing CaB inclusion levels, a quadratic decrease ($p < 0.05$) was observed with both TB and NaB. The relative liver and kidney weights decreased quadratically ($p < 0.05$) and linearly ($p < 0.01$), respectively. However, that of the bursa of Fabricius increased linearly ($p < 0.001$) with binder inclusion. Aflatoxin carry-over in the liver tissues generally decreased quadratically ($p < 0.05$) with binder inclusion while that of the kidney tissues decreased linearly ($p < 0.05$). Although the commercial binder outperformed the Albertine bentonites, relative organ health



and tissue aflatoxin carry-over in broilers improves with the addition of the bentonite clays due to aflatoxin decontamination. This implies that these bentonite clays can be included at 1.5 and 1.7% inclusion levels of NaB and CaB, respectively in the broiler diets for optimum performance.

Key words: Aflatoxins, Albertine bentonite, Aflatoxin, broiler poultry

1.15 Potency of Ethanolic Extracts of *TithoniaDiversifolia* and *AzadirachtaIndica* in Control of Helminths in South East Agro-Ecological Zone (SEAEZ) of Uganda

Buyi, L^{1,3}, B. Owoyesigire¹, J. Idibu², T. Odoch³ and L. Owere¹

¹Animal Resources, Research Program, NARO/Buginyanya Zonal Agricultural Research and Development Institute, P. O. Box 1356 Mbale, Uganda.

²Department of Agricultural Production, School of Agricultural Sciences, College of Agricultural and Environmental Sciences (CAES), Makerere University, P.O. Box 7062, Kampala, Uganda

³Department of Bio-security, Ecosystems and Veterinary Public Health, College of Veterinary Medicine, Animal Resources and Biosecurity (CoVAB), Makerere University, P.O. Box 7062, Kampala, Uganda

Corresponding author: bowoyesigire@naro.go.ug

Helminthiasis is a key threat to animal industry throughout the globe leading to loss of production and economic gains. In USEAEZ farmers use *Tithoniadiversifolia* and *Azadirachtaindica* based therapeutics as alternatives in control of helminths due to high costs associated with synthetic anthelmintic drugs. An *in-vitro* study was conducted to ascertain the *phytochemical* composition and potency of ethanolic extracts of *T.diversifolia* and *A. indica* in control of helminths. *Haemonchuscontortus* was used as a model nematode worm. Samples of the two plant species were obtained from farmers in Bulambuli district. Samples were treated with 70 % ethanol as an extraction solvent. Anthelmintic activities of two ethanolic plant extracts were determined using dosages of 2.5 mg/ml, 5mg/ml, 10mg/ml, 20mg/ml and phosphate buffer saline (PBS) as a control. Standard phytochemical procedure was used for qualitative analysis. Phytochemical analysis revealed existence of tannins, alkaloid salts, saponins, flavonoids, steroid glycosides, anthracenosides, coumarins and anthocyanosides in both ethanolic extracts. *T. diversifolia* and *A. indica* produced motility inhibition after 2.55 hours and 2.1 hours respectively while in PSB no mortality was observed. Ethanolic extract of *A.indica* showed marked difference in the anthelmintic activity than *T. diversifolia* at the dose rate of 20mg/ml ($p < 0.05$). It was concluded that two plant extracts have clinical indications in treatment of helminthiasis. This offers an excellent opportunity for advances towards developing low cost veterinary herbal drug alternatives in control of helminths to ensure increased livestock productivity in the region.

Key words: Control, Helminths, Plant extracts

1.16 The Management, Physical Characteristics, and Reproductive Performance of Uganda's Indigenous Goats across Agro-Ecological Zones

Ziwen Nantongo^{1,2,3}, Morris Agaba², Gabriel Shirima², Swidiq Mugerwa³, Stephen Opiyo⁴, Raphael Mrode¹, Josephine Birungi¹ Linus Munishi²

¹CGIAR International Livestock Research Institute, P. O. Box 30709, Nairobi 00100, Kenya

²Nelson Mandela African Institution of Science and Technology, P. O. Box 447, Arusha, Tanzania



3National Agricultural Research Organization, National Livestock Resources Research Institute,
P. O. Box 5704, Kampala, Uganda

4The Ohio State University, Columbus, Ohio 43210

Corresponding author: nantongozuena@gmail.com

The unclarity of information about differences in management practices and performance of indigenous goats across agro-ecological zones of Uganda limits precise decision making for their sustainable utilization and conservation. To bridge the knowledge gap, this study evaluated management practices, physical characteristics, and reproductive performance of indigenous goat populations across the tenagro-ecological zones of Uganda. 347 indigenous goat farming households were individually interviewedto assess goat management characteristics. 1021 indigenous goats comprising of Mubende, Kigezi and Small East African breeds were individually assessed for body size, age, body condition score, and reproductive performance. Multiple correspondence analysis (MCA) of management practices across agro-ecological zones revealed that warm and humid zones in central, south and southwestern Uganda highly associate with Mubende goats, practice goat health management, and goats breed by pure, mixed, or cross breeding. Zones in the hot and dry north, northeastern and northwestern Uganda associate with Small East African goats, practice less health management and goats breed by free mating. Descriptive statistics of body size showed that Mubende (34.75Kg) and Kigezi (33.59Kg) goats were significantly ($p < 0.05$) heavier than Small East African (26.99Kg). Furthermore, the highest body weightfor each breed was attained in a different zone; Mubende goats (38.08Kg) in pastoral rangelands, Kigezi goats (34.25Kg)in highland ranges and Small East African goats (28.66Kg) in Northeastern drylands. Age at first kidding was earliest for does in northeastern drylands (12.73months), which also had highest parturitions (11.63) before culling. The study further revealed that kidding rate increases with increase in age, parity order and body condition score. Regression of body weight to body size, age and body condition score revealed that 97.7% and 98.5% body weight of Mubende and Small east African goats respectively was explained by linear body measurements, age, and body condition score. Mosaic analysis of kidding rate across breeds and zones showed higher kidding rate for Mubende goats in pastoral rangelands and Small East African goats in northeastern drylands and northeastern savannah grasslands. Results of this study are useful in guiding sustainable utilization, improvement and conservation programs of indigenous goats in Uganda.

Key words: Indigenous goats, body size, reproduction, agro-ecological zone

1.17 Potential of Forage and Pasture crops Research in Uganda

Allen Molly^{1,3}, Julius Sserumaga¹, Moses Nyine², William Ntega, Ben Lukuyu³, Swidiq Mugerwa¹

¹ National Livestock Resources Research Institute. P.O. Box 5706, Kampala, Uganda

² Kansas State University, Manhattan, KS, United States.

³International Livestock Resources Research Institute. Box 30709-00100, Nairobi, Kenya.

Corresponding author: Allen Molly; allenifine@gmail.com; +256775625144

Like most tropical countries, feed is the primary constraint limiting livestock production and productivity in Uganda, reflected by the low supply of meat, milk, drought power and other animal products, especially during the dry spells. Despite the country's comparative advantage and varied improved livestock breeds, Uganda has a low per-capita meat and milk consumption compared to other African countries such as Ethiopia. The total annual feed produced from unimproved grazing lands and crop residues is inadequate to supply the maintenance level of



feeding for the existing livestock population. This has resulted in critical seasonal feed deficits, weight loss and, in some cases, animal death consigning with drought in many parts of the country every year. This critical feed shortage amidst high demand for animal and animal products calls for improving feed supply and availability including roughages, agro-industrial by-products, and concentrate compound feeds.

Sustainable livestock systems built on a pasture-based production system involve research interventions along four dimensions: (i) germplasm improvement, (ii) grazing and sward management, (iii) cropping system integration, and (iv) tailoring production schedules to feeding regime. Tailored agronomic packages, varietal and genetic improvements of nutritional and functional properties including high-yielding, drought-tolerant, and highly nutritious while reducing the negative environmental impacts caused by livestock production systems are key. A functional seed system will be key to accelerating farmer access to improved varieties and their availability but also drive the largely informal seed system towards a private-led seed system.

Review results indicate improved forage germplasm had on average 2.6 times higher herbage productivity than local controls, with the strongest effect in grasses. Feeding regimes with improved leguminous forages increased milk yield by on average 39%, dry matter intake by 25%, and manure production by 24%. When forage technologies were integrated with food crops, soil loss was almost halved, soil organic carbon increased on average by 10%, and grain and stover yields by 60% and 33%, respectively.

This study demonstrates the potential forage research in the sustainable intensification of crop-livestock systems in Uganda. It highlights the need for multidisciplinary and systems-level approaches and studies to quantify synergies and tradeoffs between impact dimensions. Further research is needed to explain forage agronomic yield variability, unravelling interactions between genotype, on-farm environmental conditions, and management factors.

Key words: Sown Forages, Research Potential, Uganda



Sub-theme 2: Challenges and Opportunities in Mechanization and Agro-Industrialization

2.1 Defining Fresh Pod Bean Consumption Dynamics and Market Base in Uganda

Immaculate Babirye¹, Clare Mukankusi Mugisha², Jean Claude Rubyogo² and Stanley Tamusange Nkalubo¹

¹National Agricultural Research Organization – National Crops Resources Research Institute (NARO-NaCRRI). ²Alliance Centre for Tropical Agriculture (CIAT) and Bio-iversity International

Corresponding author: imbabirye@gmail.com

Beans are a relatively cheap food that is consumed by all age groups and social classes. However, the commodity faces major challenges in post-harvest handling technologies, value addition, and storage capacity, especially the fresh pod beans which tend to be more perishable. 796 randomly selected bean consumers from Kampala, Mukono, Wakiso, and Jinja were interviewed to understand fresh pod bean consumption dynamics and establish their market base. Descriptive statistics, cross-tabulations, and Mean Attribute Scores were (MAS) employed in analyzing the data. Results revealed that 66% of bean consumers in Uganda prefer fresh pod beans to dry beans and 98% of fresh pod bean consumers reside in urban and semi-urban areas. Moreover, 72% of these depend on purchased fresh pod bean products. Consumers were found to purchase fresh pod beans mainly from areas easy to access and those near their homes. Quality influenced purchases more than other attributes such as price, market class, and availability. Consumers preferred to purchase the shelled fresh grain rather than the pods due to ease of preparation, assured quality, and quantity. The red-mottled market class was most preferred by consumers (50%) who were not variety specific. Unlike dry beans where the price is a major driving factor for consumers, very few (29%) fresh-pod bean consumers consider the price of the beans before purchase and this explains the high prices with a 250mls cup ranging between \$0.4-0.7 depending on season and place. Local fresh pod bean consumption is estimated at 180,000 metric tons per annum and valued at approximately \$154 Million. With the existing demand for fresh beans and identified niche markets, investment opportunities especially in value addition and Agro-industrialization can be hastened.

Key words: Consumption, Market, Fresh Bean, Retail, Investment

2.2 Understanding the Value Chain of Agroforestry Trees around Mount Elgon Uganda

Charles Galabuzi^{1,2}, Hillary Agaba^{1,2}, Suzan Nansereko^{1,2}, Catherine Muthuri³

¹National Forestry Resources Research Institute (NaFORRI) P.O. Box, 1752 Kampala Uganda

²National Agricultural Research Organization (NARO) P.O. Box, 295 Entebbe Uganda

³World Agroforestry Center, United Nations Avenue, P.O. Box 30677, Nairobi Kenya

Corresponding author: charlesgalabuzi@gmail.com

As agroforestry tree value chains remain unclear, following the contribution of forestry and allied tree systems towards GDP of most developing countries increasingly become difficult. A study was conducted between January 2018 and December 2020 around Mount Elgon. The objectives were to; i) characterize agroforestry tree species on farms, ii) map the actors roles and flow of inputs to on farm tree value chain and iii) identify issues hindering development of selected



tree products value chain. Qualitative and quantitative data were collected through literature review, KIs and FGDs with 108 respondents. Results indicate both indigenous and exotic woody tree species, selected based on accessibility of planting materials. Woody trees were valued for firewood (38%), shade (22%), timber (12%) and small stems used to support food crops (18%). *Cordia africana*, *Albizia* spp. *Ficus* spp. and *Measospisemini*, were the most important indigenous trees, valued for shade while *Eucalyptus grandis*, *Grevillea robusta* and *Neolamarkia cadamba* were the frequently planted exotic species to supply firewood and timber. The species were highly valued for firewood based to their high combustion and split abilities. The farmers procured planting materials to establish and manage trees on farm, while the middlemen performed one major role of connecting tree farmers to potential buyers. Tree farmers were challenged by insufficient land (87%) and lack of technical knowledge (74%) on tree growth and management, whereas the middlemen and traders were constrained by illegal timber (89.6%), price fluctuations (59%), and lack of market (56%) for processed wood products. Among the opportunities, there is high government interest civil society interest in forest and tree restoration programs in this region. The strategies include; mapping all tree farms and developing standards for tree farming in the region. Mapping is necessary to identify critical sites for tree restoration while standards will help to monitor quality assurance. A policy formulation and review focusing on wood waste potentially used for industrial electricity production is recommended.

Key words: Firewood, Value chain, Tree farmers, Trees on farm, Highland areas

2.3 Assessing Genotypic Variability and Genome Wide Association Studies for Cooking-Time and Canning-Quality Traits in Common Bean Accessions in Uganda

Kesiime, V. E¹, Nkalubo, S. I., Dramdri, I. O.², Mukankusi, C. I., Ochwo, M. S.², Arfang B., I. Nakimbugwe, D.²

¹National Crops Resources Institute, Namulonge P.O. Box 7084, Kampala, Uganda.

²Makerere University P.O. Box 7062, Kampala Uganda.

³CIAT, P.O. Box 6247, Kampala Uganda

Corresponding author: eunicekesiime@gmail.com

Long cooking time of common bean hinders their consumption in Uganda and worldwide especially in regions where fuel is scarce and expensive. The development of common bean genotypes with short cooking time and canning quality traits is very key in accelerating bean consumption especially for the urban poor and the middle-class population. The aim of this study was to assess the genetic variability for cooking time and canning quality traits which included; clumping, splitting, appearance, colour retention, free starch, viscosity, hydration coefficient, washed drain solids and to identify SNP markers associated with the two traits. The accessions were planted in an alpha lattice design with two replications for two seasons. Three months after harvesting, the seeds were tested for cooking time using an automated Matson cooker apparatus and canning quality traits determined following a modified Michigan State University canning protocol. A 4 and 2-fold variation for the two traits respectively was obtained. Heritabilities for these traits ranged from intermediate to high (0.4 to 0.7). A total of 42 significant marker trait associations were observed; on chromosome Pv01 for cooking time and washed drain coefficient, on Pv02; viscosity, washed drain coefficient and washed drain solids. On Pv4; cooking-time, washed drain solids and washed drain coefficient, on Pv5; cooking-time, splitting, hydration-coefficient and viscosity. Clumping on Pv06, visual appeal, colour and viscosity on Pv07, visual appeal, clumping and washed drain solids on chromosome Pv08, clumping, viscosity and washed drain coefficient on chromosome Pv09, colour and viscosity on chromosome



Pv010. Possible candidate genes including; phvul.007G2803001, Phvul.007G2803001 and Phvul.007G280700.2 both on chromosome 7 and Phvul.005G161200.1 on chromosome 5, all associated with seed coat colour were identified by browsing the *P. vulgaris* genome using the online tool Jbrowse on Phytozome v. 12.1 and sequences containing significant SNPs aligned against the *P. vulgaris* reference version 2.1. The corresponding sequences were then used as queries against Arabidopsis thaliana protein data base.

Key words: Assessing, Cooking-time, canning-quality-traits, GWAS, SNP markers

2.4 Pluralistic Agricultural Advisory Service Delivery in Enhancing Sustainable Land Management among Farming Households in South Western Highlands of Uganda

Turinawe A¹, Ainembabazi J H²

¹Makerere University, College of Agricultural and Environmental Sciences, Department of Agribusiness & Natural Resource Economics, Uganda

²African Development Bank (ADB), Abidjan, Cote D'Ivoire

Corresponding author: aaturinawe@gmail.com

Declining land productivity and increasing land and food scarcity, driven by high population growth has precipitated the need for intensification of crop production. Sustainable land management technologies (SLMT) have been suggested as a way to support the intensification process, but these have low adoption rates. Much effort has been put into provision of agricultural advisory services (AAS) geared towards improved adoption of the SLM technologies. As a result, farmers access AAS from diverse sources. The study attempts to unearth the drivers of farmers' choice of access to the source of agricultural advisory service delivery, the impact of source of AAS on adoption of adoption of SLMT, and the impact of source and mode of AAS on crop productivity. The study uses cross sectional data collected from 437 households in the southwestern highlands of Uganda. The multinomial endogenous switching regression model combined with an endogenous switching regression model were used to analyse the data. Results indicate that single source of AAS significantly increases adoption of SLMT whereas multiple sources of AAS generally reduce the adoption of SLMT. In addition, multiple sources of access to AAS and joint mode of delivery of AAS increase crop productivity for farmers. The results further suggest that the proportion of household members with primary education, old household heads and distance to an extension services office are likely to reduce farmers choice of single sources of AAS whereas age of a household head, membership to a farmer group, distance to a nearest market centre, number of markets, access to credit, total land owned and number of extension service providers in the village known by the farmer are likely to increase farmers choice of single source of AAS. As Uganda settles into the single spine extension system, these results point to the need for policy to consider the advantages of having a streamlined agricultural extension system, with coordinated efforts from all service providers and stakeholders. This conclusion is based on the fact that single sources of AAS may increase adoption more that multiple sources.



Sub-theme 3: Cross Cutting Topics COVID-19, Youth-Proofing and Generation

3.1 Incentives and Disincentives for Youth Participation in Groundnut Value Chains in Tororo and Nwoya Districts of Uganda

D.Kemigisha¹, S. Lwasa¹, J. Mugisha¹, A. Kaaya², R.M. Mirembe², D. Musoke³, C.A. Stephens⁴, D.K. Okello⁵

¹Department of Agribusiness and Natural Resource Economics, Makerere University, Uganda

²Department of Food Technology and Nutrition, Makerere University, Uganda

³Department of Disease Control and Environmental Health, Makerere University, Uganda

⁴Agricultural Leadership, Education and Communications, the University of Tennessee, Knoxville

⁵National Agricultural Research Organization, NaSARRI

Corresponding author: daisykemie@gmail.com

The unemployment rate for Ugandan youth is 13.3% despite several government efforts to attract them to agriculture. Groundnut is staple in Uganda, covering 4% of all arable land and could potentially employ many youth. However, there is little empirical knowledge on what drives youth participation in groundnut value chains. The goal of this study was to establish the incentives and disincentives for youth participation in the groundnut value chain utilizing Photovoice.

Photovoice was used to collect qualitative data using photographs, captions and follow-up discussions. Fifteen youth were purposively selected per district (Nwoya and Tororo) and trained to take photos that capture the different groundnut value chain activities from which themes emerged using thematic content analysis in Atlas ti version 6.

These themes summarized the incentives of youth participation as: the benefits of belonging to Farmer groups; short pay-back period; the desire to afford formal education and the desire to follow in parents' footsteps. The study findings also indicated poor yield; post-harvest losses; long labor hours; inadequate storage and processing equipment and facilities; time poverty; inadequate land and capital; and poor transport infrastructure as disincentives of youth participation. In conclusion, increasing access to land, capital and farmer groups as well as mechanization is likely to drive youth to participate more in groundnut value chains.

Key words: drivers, youth participation, groundnut, incentives and disincentives, Uganda

3.2 Trends in Readership Index for Uganda Journal of Agricultural Sciences Over the Past Decade - Oral

Victoria Mbigidde¹, Robert Kawuki², Julius Pyton Sserumaga³, Nasser Kasozi⁴, Candia Alphonse⁵, Yona Baguma⁶, Gerald Agaba¹

¹National Agricultural Research Organization, Entebbe, Uganda

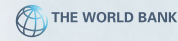
²Root crops Department National Crops Resources Research Institute (NaCRRI), Kampala, Uganda

³National Livestock Resources Research Institute, Kampala, Uganda

⁴Abi Zonal Agricultural Research and Development Institute, Arua, Uganda

⁵Agricultural Engineering and Appropriate Technology Research Center, Kampala, Uganda

Corresponding Author: Victoria.mbigidde@naro.go.ug



Enhancing access to quality scientific information, knowledge and innovations is vital for society socioeconomic transformation. Accordingly, packaging and dissemination of agricultural research outputs is critically important for communities that primary depend on agriculture. It's for this reason that the National Agricultural Research Organization (NARO) undertook a significant step to enhance science communication by launching the Uganda Journal of Agricultural Sciences (UJAS). Having been in existence for the past 17 years, a retro- prospectivereview was conducted to get insights into number of articles published with focus on thematic areas disaggregated by sex, abstract views by year, article downloads by year and country, and distribution of thematic areas. Data from 1993 to 2021 indicates that the highest number of peer-reviewed articles were published in 2004 representing 35% of the total number of publications. The highest number of abstract views were recorded in 2022 (122 downloads) as compared to 101 in 2017. Regarding article downloads, the highest were observed in 2021 and the least being in 2017. Total downloads currently stand at 265,044 for the past 6 years with an audience of over 200 countries. These Trends have informed the new UJAS strategy that is being finalized to further guide its investment and operations as it aspires to serve better.

Key Words: Agriculture, Dissemination, Knowledge sharing, Publications.

3.3 Impact of Covid-19 on Production and Marketing of Milk by Dairy Farmers in Kiboga District, Uganda

Namakula J.¹, Ninsiima G.¹ and Ilukor J.^{2,1}

¹Department of Agribusiness and Natural Resource Economics, Makerere University, P.O. Box 7062, Kampala, Uganda.

²Living Standards Measurement Study (LSMS), Survey Unit, Development Data Group, World Bank, Kampala, Uganda

Corresponding author: jnamakula8477@gmail.com

High and sustained milk production in dairy can only be sustained by regular rainfall, good farming practices such as adequate feeding of cows, disease and pest management and selection of superior animals for breeding. Marketing of milk on the other hand is an important component for achieving profitability and sustainability of a dairy enterprise. World over especially in sub-Saharan Africa, production and marketing of agricultural products were impacted by Covid-19 in various ways. This study therefore was conducted to assess the impact of COVID-19 on the production and marketing of milk in Kiboga district. Data were collected from 150 dairy farmers who were randomly selected from three sub counties in Kiboga district. The collected data was analysed using descriptive statistics, t-tests and regressions. All the interviewed dairy farmers reported that Covid-19 had affected the production and marketing of their milk. There was a significant difference in the price per litre of milk sold before covid-19 and after the lock down was lifted. There was a decline of 1.4% in the productivity per cow per day during the lockdown compared to before the pandemic. There was also a decrease in the average price of a litre of milk sold to dairies 34.9%, cooperatives 37.3% and spot markets 10% during the lockdown. After lifting the lockdown, the productivity of the cows is seen to have gone back to the way it was before the lockdown and the price of a litre of milk is reported to have gone higher than it was before Covid-19. This was because of the increase in the costs of production. There was an increase in the weekly costs of production especially spraying (45%), and treating cattle (77.6%). Most of the farmers did nothing to cope up with the decrease in milk prices, reduced the prices charged per litre in order to cope up with the reduction in the number of customers. The increase in the price



of milk after the lockdown was lifted is likely to scare away customers and at the same time drive farmers to making losses. Government and other stalk holders should reduce on the taxes imposed on inputs like pesticides which have resulted into high production costs.

Key words: Covid-19, Milk prices, Volumes of milk sold and dairy farmers

3.4 Impact of Covid-19 on Butchers and their Coping Strategies in Kampala District

Namakula J,¹ and Ilukor J.^{2,1}

¹Department of Agribusiness and Natural Resource Economics, Makerere University, P.O. Box 7062, Kampala, Uganda.

²Living Standards Measurement Study (LSMS), Survey Unit, Development Data Group, World Bank, Kampala, Uganda

Corresponding author: jnamakula8477@gmail.com

The study examined the impact of Covid-19 on butchers and how they coped up with the effects using data collected from 120 butchers in the five divisions of Kampala City. All the butcher men interviewed reported COVID-19 to have affected meat sales. In addition, there was significant decline in daily supply of beef (77 kg) and goats' meat (36kg) during COVID-19 lock down from 132.66 kgs of beef supply and 51.35 kgs of goat meat supply before COVID-19. Similarly, there was significant decline in the weekly sales for both beef (505kgs) and goats' meat (222kgs) from 831.06 kgs of beef sales and 325.36 kgs of goat's meat sales before Covid-19. However, after the lifting of the lock down supply and sales increased but not to the original levels before COVID-19. The decline in supply and sales as well as recovery were associated with butcher men's experience, liquidity, and number of sources of meat. The butcher men's purchase or buying and selling prices also significantly increased and never reduced even after the lifting of the lock down. The number of customers also significantly declined during the lock down but recovered after the lifting of the lock down but not to its original state before the lock down. The main coping strategies were to increase the sales price, reducing quantity bought from the source, reaching out to customers on phone, using customer delivery methods and diversification to alternative economic activities mainly farming, trading and boda-boda riding. The increase in prices even after the lifting of the lock down, reduction in the quantities and the reduced number of customers means COVID-19 has led to reduced consumption of the meat which is likely to exacerbate malnutrition especially among the poor and lead to loss of income for livestock farmers. The mean change in employment increased from 1.108 before Covid-19 to 1.12 during the lockdown. This is because butchers decided to employ their family members who had lost jobs and their children who were at home. Government should design incentives to encourage butchers not to increase prices and those that boost poor people incomes.

Key words: Butchers, Covid-19, Kampala, beef, and goat's meat

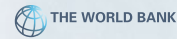
3.5 Labour-Saving Technologies to Mitigate the Effect of Women's Agriculture Time-Use Constraints on Stunting in Rural Uganda

Namulondo R¹, Bashaasha B²

¹Department of Economics, Faculty of Science and Education, Busitema University, Tororo, Uganda

²Makerere University, College of Agricultural and Environmental Science, Kampala, Uganda

Corresponding author: renamulondo@gmail.com



Women's time allocation is a dimension of women's empowerment in agriculture, and is recognised as a pathway through which agriculture can affect child nutritional status in developing countries. Longer hours of farm work can potentially increase women's time constraints, reducing the time allocated to child-caring responsibilities and raising the risk of poor child nutritional status. Using a three-wave household panel dataset from the Feed the Future Innovation Lab on Nutrition surveys in the north and southwest of Uganda, we tested the hypothesis that the negative effect of women's agriculture time-use constraints on child stunting is mitigated for households that use labour or time-saving agricultural technologies (LSATs). The results show a positive and significant association between the number of hours per day that women spend on agricultural work and the risk of stunting in children aged zero to 23 months who live in households that do not use animal traction for ploughing. However, this association is statistically insignificant, and even turns negative for households that adopted the labour-saving technology. Our findings indicate that LSATs have the potential to lessen a household's agricultural workload, giving mothers more child-caring time, and hence improving child nutritional status. Therefore, agriculture could have better nutritional outcomes if policies and programmes were designed to have interventions that reduce the workload in farming activities and thus reduce pressure on women's time.

3.6 Gendered Analysis of Vulnerability to Climate Change among Avocado Smallholder Farmers: The Case of Southern Tanzania Highlands

Ngailo T.¹, Rutalebwa E.¹

¹Dar es Salaam Institute of Technology, P.O Box 2958 Dar es Salaam

Corresponding author: triphongailo@gmail.com

Avocado (*Persia americana*) is one of important world fruit crops. In Tanzania, Avocado farming which is dominated by smallholder production under rain-fed system has become a very important fruit commodity. However, climate change effects the avocado industry in a range of ways through impacts on growth, disease risk, fruit quality and industry location. Climate change is projected to be a major threat for the sector resulting in variability in avocado smallholder farmers' productivity and income. The impact of climate change is expected to vary greatly among regions, sectors and social groups and communities. It is also expected to vary between gender groups. Therefore, this study intends to address gender differentiated vulnerabilities to climate change in the Southern Highlands regions of Tanzania where the temperature and rainfall stresses are relevant. Data was collected from 59 Men and 45 women farmers randomly selected avocado smallholder farmers in the representative regions of Njombe, Mbeya and Songwe using structured survey questionnaires that contained both open- and closed-ended questions. Results of the analysis indicated difference between men and women avocado smallholder farmers' vulnerability to climate change in favor of the latter. It was also found that there are gender differences in terms of socio-economic characteristics and social networks in facing the threat of climate change. Therefore, emphasis is required to reduce vulnerability through gender disaggregated interventions and hence policy makers need to ensure that development policies include gender oriented adaptation options to create resilience to the impacts of climate change.

Key words: Climate Change, gender, Avocado, Smallholder, adaptation strategies



Sub-theme 4: Embracing ICT-Based Innovations for Agricultural Transformation

4.1 Triadic Comparison of Technologies (TRICOT): A digital methodology of on-farm testing of candidate crop varieties

Stephen Angudubo¹, Clare Mukankusi Mugisha¹, Kauê de Sousa¹, Rhys Manners², Joost van Heerwaarden³, Anna Muller¹ Carlos Quiros¹, and Jacob Van Etten¹

¹Alliance of Bioversity International and International Center for Tropical Agriculture (CIAT)

²International Institute of Tropical Agriculture (IITA)

³Wageningen University & Research - WUR

Corresponding author: s.angudubo@cgiar.org

Crop variety development culminates into late-stage evaluation of the candidate crop varieties on farm. Breeding programs conduct on-farm testing using several approaches such as mother-baby trials. The conventional participatory variety selection (PVS) approaches are complex and costly. Conventional formats of data collection involving several varieties are often difficult for farmers. The execution of the trials requires efforts and expertise for timely delivery of complex logistics, and collaborations. Other problems highlighted in Misiko (2013) include voting based on snapshot observations, farmers neglecting the fields, and low adoption or dis-adoption of varieties, due to failure to observe key traits under trial conditions.

The Triadic Comparison of Technologies (Tricot) is a research methodology for on-farm testing of candidate crop varieties, and management practices. It enables a participant to perform small, and easy tasks, and keeps them motivated, hence cost-effective. The trial design, and data collection are supported with digital tools leading to quick analysis, and robust data for variety placement decision. It helps farmers to identify the most suitable technology for the local farm conditions during testing or validation of candidate crop varieties.

Tricot involves many (up to 1000) men and women, who assess the candidate crop varieties in small fields (Jacob et al. 2016). Up to 20 candidate varieties can be evaluated using this approach where each farmer receives three (3) randomly selected candidates. Since the candidate varieties are evaluated by many farmers, the Tricot serves as preliminary dissemination platform. Thus, increasing adoption of improved crop varieties for increased productivity which ultimately contributes to improved food security, nutrition, and income.

Key words: Citizen science, crowdsourcing, Tricot, Digital ecosystems, farmer-centered

4.2 Routine Programme Monitoring: Evidencing Research Impact of Adoption of Improved Groundnut Technologies in Northern Uganda

¹R. Gidoi, B. Owoyesigire¹, L. Owere¹, A. Wasukira¹, B. Chemayek¹, D. Baguma², W. Aupal²

¹ NARO Buginyanya Zonal Agricultural Research and Development Institute P.O BOX 1356, Mbale, Uganda.

² NARO Bulindi Zonal Agricultural Research and Development Institute P.O BOX 101, Hoima, Uganda.

²Uganda Technology and Management University, P.O BOX 7062 Kampala, Uganda

Corresponding author: robertsgidoi@gmail.com



Agricultural technology is developed for smallholder farmers essentially for attaining higher yields and economic turnover. Despite the effort to introduce improved varieties of (Serenut 2T, 3R, 4T, 5R, 6T, 8R, 11T and 14R), it was observed that there is low adoption of the groundnut technologies among rural households in Northern Uganda. Routine feedback of scientifically collected data about adoption of the improved groundnut technologies is also a challenge. The objective of the study was to examine the relationship between routine monitoring and adoption of improved groundnut technologies in Dokolo and Nwoya districts. The study adopted a correlational survey design where both quantitative and qualitative approaches were used. Data was collected using questionnaires administered to 236 respondents. Data analysis was done using a Statistical Package for Social Scientists (SPSS). Quantitative analysis was done using regression analysis and correlation coefficients while qualitative analysis was conducted using content and thematic analysis. Results revealed a weak and low significant positive relationship between routine programme monitoring and adoption of improved groundnut technologies in the two districts, since the P value ($p=0.000 < 0.05$). Results also revealed a significant weak positive correlation between routine programme monitoring and adoption of improved groundnut technologies ($r=0.288$, $p < 0.05$). Routine monitoring improves access to quality and reliable agricultural information as well as strengthening the seed system and enhancing dissemination and adoption of improved groundnut technologies.

Key words: Routine Monitoring, Adoption, Impact and Groundnut technologies

4.3 Embracing Radio and ICT as Enablers for Agriculture and Rural Development

Nalubinga G.

Program Officer East Africa,
Farm Radio International

Corresponding author: gmewbaza@farmradio.org

Food insecurity remains a challenge in the African continent due to low agricultural productivity attributed to a myriad of factors, which in recent years have been exacerbated by climate change and low capacity to harness Information and Communication Technology (ICT). Access to markets, finance and information are keystones for agricultural growth and decision making. A major impediment for smallholder farmers to exploit the benefits of ICT is lack of infrastructure and mobile networks in rural areas coupled with low levels of literacy to utilize existing media. This is especially challenging for women farmers. Radio and ICT have a great potential to expedite access to a variety of agricultural information by millions of people in a timely manner, and if gender equality considerations are effectively integrated in the approach, can contribute to bridge the gap in women's access to key information.

In noting emerging challenges facing the agriculture sector e.g. fragmented coordination of the diverse players of agricultural extension services; poor adoption of technologies and best practices with only 15% of technologies generated by research institutions reaching farming communities and inequality (among men, women and other marginalized groups) in access to extension services/opportunities across the country ; Farm Radio International (FRI) in this abstract demonstrates how radio and ICTs play a major role in enhancing agricultural productivity, drive transformation and boost farmer livelihoods by innovatively creating linkages among farmers and other agriculture sector players. A meta-analysis of the adoption of agricultural technology in sub-Saharan Africa revealed that although many agricultural technologies exist to improve yields, adoption remains low. Findings established that 18 out of 38 determinants commonly believed to influence technology adoption are primarily related to information access among other factors.



Methodology

FRI is working with Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and a variety of private and public stakeholders to establish a network of digital extension platforms hosted at 12 radio stations reaching on average 1.5 million people (*per station*) to create dialogue and knowledge sharing communications hubs that provide rural farmers with latest regenerative agriculture practices as well as marketing and business advice.

4.4 Pilot demonstration of a satellite-based system for the detection and monitoring coffee wilt disease spread in Uganda

Olal S¹., Bitalo D¹., Olango N¹., Akodi D¹., Apunyo P²., Kagezi G¹., Arinaitre G¹

¹National Coffee Research Institute (NaCORI), P.O. Box 185, Mukono, UGANDA

² Environmental Surveys, Information, Planning and Policy Systems (ESIPPS), P.O Box 33011, Kampala, UGANDA

Corresponding author: Sammy Olal (PhD) – sammyolal83@mail.com

Effective management of diseases including coffee wilt caused by *Fusariumxylatriodes* Steyaert, the most devastating disease of Robusta coffee in Uganda, requires fast and efficient detection and close monitoring, unfortunately this is not being conducted in Uganda. Coffee wilt disease diagnosis is currently done mainly using field symptoms and microscopy while monitoring is by physical surveys both of which are hectic, slow, and less effective. These methods require physical field visits which are both time consuming and expensive and applicable during a pandemic like the COVID-19. Unmanned aerial vehicles or drones have been demonstrated to have a high potential utility for improved disease detection and monitoring due to reduced time needed for disease scouting, and cost effectiveness. This study, piloted the use of a drone to detect and monitor the spread of the disease in Uganda. A drone equipped with a multispectral camera capturing images in the four bands of Green (550nm), Red (660nm), Red-Edge (735nm) and NIR (790nm) in a 5 acres coffee field in Buikwe district. The GPS coordinates of the extents of the farm were captured and used to develop flight mission plans on the android device. The farm was then mapped at a height of 30m. The images were processed using Agisoft drone mapping software to derive orthomosaics of the farm. ArcGIS image analyst and raster calculator were used to compute indices and draft algorithm signatures for differentiating healthy and infected plants. A map was generated showing healthy and infected trees. The results estimated the disease incidence to 27.2% as compared to 33% ground truth data, which is 72% as accurate as the ground truth data. The drone application was a stepping stone to gather signatures of the infected and healthy coffee to be configured for the disease detection and monitoring using high-resolution satellite imagery.



Sub-theme 5: Intensification of Crop Productivity and Seed Systems

5.1 Factors Affecting Production, Productivity and Marketing of Apples Grown in Uganda

Agaba R.^{1,2}, Nimusiima M.¹, Ashaba D.³, Alex B.¹

¹ National Agricultural Research Organization, Kachwekano Zonal Agricultural Research

² College of Agricultural and Environmental Sciences, Makerere University, P. O. Box 7062, Kampala, Uganda

³ Development Institute, P.O. Box 421, Kabale, Uganda

Corresponding author: rondessblessed@gmail.com

Apple is an important high value crop offering vital health benefits to consumers. Apple fruits are a rich source of vitamins A, B, and C, large amount of proteins, carbohydrates, minerals, fiber and phenolic compounds useful in wound healing. Apple growing was introduced to Uganda in 1999 and has spread in Kigezi and Buhweju highlands, areas around Mt. Rwenzori and Elgon and Central Uganda. However, low production, productivity and marketing is hindering economic benefits to farmers. The objective of this study was to assess factors affecting production, productivity and marketing of locally produced apples. A cross-sectional survey was conducted using a semi-structured questionnaire administered to farmers with productive orchards 13 in districts across Kigezi, Rwenzori and Buhweju sub regions. The data were analysed using descriptive statistics, multivariate regression and logistic regression methods. Results from descriptive analysis revealed that majority of apple farmers had 35.5% at tertiary and university, primary (30.6%), secondary (28.0%) education but dominated by elderly males (81%) above the age of 50 years (57%). Farmers allocated 38.3% of land to apple growing, with 52% of the 106,000 apple trees as Anna and Golden Dorset varieties. The orchard management practiced by farmers included defoliation (84%) and weeding (82.7%), followed by pruning, bending and staking. Apple fruits amounting to 25.4 million fruits weighing 3300 metric tons are harvested in two seasons annually. Results of multivariate analysis revealed that total costs of production, total land owned and belonging to a farmer group significantly ($p < 0.05$) influence apple production and that sex of the farmer, age of trees, total number of trees per acre, and pest and disease occurrence significantly ($p < 0.05$) influence apple productivity. However, the apple farmers lacked access to formal markets with only 24.9% of farmers accessing farm gate, road side hawking, fresh fruit markets in their production areas. Logistic regression results indicate that sex of the farmer, yield per acre, location of orchard and total costs of production significantly ($p < 0.05$) influence farmer participation in apple marketing. In conclusion, apple production and productivity is greatly influenced by socio-economic factors of farmers such as education level, and age while productivity is affected by knowledge and group membership and marketing is affected by sex, yield and location of apple farmers in Uganda.

Key words: Adoption, Apples, Apple-culture, Apple products, Markets



5.2 Efficient conditions for in vitro establishment and regeneration of disease-free Ugandan farmer-preferred cassava genotypes

Hellen B. Apio¹, Titus Alicai¹ and Emmanuel Ogwok^{1,2*}

¹National Crops Resources Research Institute, NaCRRI, Namulonge, P. O. Box 7084 Kampala, Uganda.

²Department of Biology, Faculty of Science, Muni University, P.O. Box 725 Arua Uganda.

Cassava (*Manihot esculenta* Crantz) is majorly devastated by two viral diseases, cassava brown streak disease (CBSD) and cassava mosaic disease (CMD), resulting in 100% yield loss. Being a clonal plant, nodal cuttings (NC) and shoot apical meristems (SAMs) are the best explants for production of disease free planting materials. In this study, NCs and SAMs were used to determine reliable indicators for successful in vitro establishment of cassava. Eight cassava genotypes (NASE 3, NAROCASS 1, NAROCASS 2, NASE 13, NASE 19, NASE 12, TME 204 and ALADO) were used for the study. Leaf samples were collected from 30 stakes of each of the eight genotypes planted in the screen house. The leaf samples were pooled and screened for presence and/or absence of CBSD and CMD by PCR using virus specific primers. Nodal cuttings were excised from screen house grown plants, surface sterilized to rid-off contaminants and established on Murashige and Skoog (MS) Medium. Using the sprouted stakes, 5-mm sized SAMs were excised, surface sterilized and reduced to 0.5-1 and 2-3 mm sizes. The SAMs were established on MS medium with varying concentrations of plant growth regulators (PGRs) (0.5, 1, 2) ml/L Benzylaminopurine (BAP) and (2, 4) ml/L Naphthalene acetic acid (NAA), Kinetin (KIN) and BAP respectively. Data on number of leaves, roots, nodes and plant length were collected from regenerating NC and SAMs and analysed using ANOVA two way factorial design at $P \leq 0.05$ of GenStat 12th edition. PCR results revealed the pooled leaf samples were free of both CBSD and CMD for all genotypes. Establishment and regeneration of NCs was possible with MS medium for all genotypes. NC of NASE 19 produced the highest number of leaves and nodes while NAROCASS 1 had the least. Plant length for NC was highest in NASE 13 and least in NAROCASS 1. For the SAMs, the concentrations of (2, 4) ml/L BAP followed by 2 ml/L NAA facilitated their establishment and regeneration in comparison to KIN. SAMs of 2-3 mm and 0.5 - 1 mm sizes regenerated better at 2ml/L BAP. SAMs of 2-3 mm, Alado produced the highest number of leaves and nodes while NASE 14 and NAROCASS 1 respectively had the least. The three PGRs used facilitated regeneration NASE 19 SAMs of 0.5-1 mm sizes despite the concentration used. Both NCs and SAMs of the different genotypes produced leaves, nodes, roots and there was an increase in plant length. These parameters give a clear picture of the vigor of different genotypes in vitro, which help to postulate the number of plants generated through micro propagation and subsequent bulking up for each genotype, therefore availing clean seed to farmers, thus boosting their production and productivity.

Key words: Cassava genotypes, cassava diseases, shoot apical meristems, nodal cuttings, plant growth regulators.

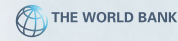
5.3 A Comparative Analysis of the Different Rice Seed Cleaning Techniques

Ocident Bongomin¹, Stella Odur Okello¹, Robert Kyambadde¹ and Jimmy Lamo¹

¹National Crops Resources Research Institute, P.O Box 7084, Kampala, Uganda

Corresponding author: ocidentbongomin@gmail.com,

Tel. +256779245557/+256756243075



Although rice has been regarded as a strategic crop for increasing incomes and food security in Uganda, the sub-sector is still characterized by yield gaps, post-harvest losses and poor seed systems. These have resulted in low productivity and inefficiency. Rice seed cleaning play important role in seed management system and crop production. Additionally, established seed companies with effective seed cleaning facilities do not find rice to be a particularly appealing investment because it is an inbred crop with high rate of trade multiplication. Therefore, appropriate seed cleaning techniques that are affordable to small-scale seed producers need to be developed and adopted. The main aim of this study is to compare the different simple rice seed cleaning techniques and recommend the improvement of the best technique. In this study, four rice cleaning techniques including traditional (manual winnowing), mechanical winnower, two floatation cleaning techniques (without salt and with salt) were compared. The percentage of chaff removed was used to compare each technique. Equal amount (5kg) of unclean KAFACI-67, a promising pre-release rice seed was used for each technique and after the cleaning, the chaff removed was weighed using the precision digital weighing scale. The results of the study showed that the floatation with salt mixture has high chaff removal percentage (10.2%), followed by floatation without salt technique with 8.8%. The mechanical winnower has the chaff removal percentage of 6.2%, the hand winnower performed the least with the chaff removal percentage of 5.8%. With these, flotation with salt cleaning technique outperformed the other techniques. Therefore, we recommend the development and diffusion of this cleaning technique to reach the small-scale farmers so as to improve seed germination by planting clean seeds.

Keywords: rice, cleaning technique, small-scale farmers, chaff removal percentage, seed systems

5.4 Pro-Vitamin-A biofortified East African Highland Banana for environmental release in Uganda

Stephen Buah^{1,3*}, Jimmy M. Tindamanyire¹, Priver Namanya¹, Jerome Kubiriba¹, Jean-Yves Paul², Robert Harding², James L. Dale² and Wilberforce K. Tushemereirwe¹

¹National Agricultural Research Laboratories, Kawanda, Wakiso, Uganda.

²Centre for Agriculture and the Bioeconomy, Queensland University of Technology, Brisbane, QLD, Australia

³Kyambogo University, Department of Biological Sciences, Faculty of Science, Kampala, Uganda

Correspondence: buahs@yahoo.com

Vitamin A deficiency (VAD) remains a serious public health problem in Uganda, particularly among children below five years (38%) and women of childbearing age (36%). Our project aimed to complement existing intervention strategies by developing farmer and consumer-acceptable cooking bananas with sufficient pro-vitamin A (pVA) to meet at least 50% of the estimated average requirement (EAR) using a genetic engineering approach. Specifically, the current study was to identify one lead event and one backup event for each of cultivars Nakitembe and Hybrid M9 that will be suitable for consumption and environmental release in Uganda to alleviate VAD.

Out of the 356 Hybrid M9 and 162 Nakitembe, 61 and 50 events respectively, met the primary selection criteria based on fruit pVA levels and yield. The promising lines were subjected to advanced molecular characterization that resulted in the selection of 5 elite events for each of the cultivars. Multi-location confined field trials were established at four sites. Each line had 20 replicates and was planted in a 4x5 randomized block design, with non-transgenic cell line and farmer tissue culture controls as checks.



Two lead events for Hybrid M9 with pVA levels consistently above the target of 20 µg/g dwβ-CE while two Nakitembe events had over 40 βg/g dwaverage β-CE over two generations. These selected lead events are considered for release pending regulatory approval.

Key words: β-carotene, confined field trial, malnutrition, transgenic, pro-vitamin A

5.5 SukaliNdizi dessert banana hybrids with resistance to Fusarium wilt disease

Henry Buregyeya¹, Ivan Kabiita Arinaitwe¹, Naboth Oyesigye¹, Waniale Allan¹, Kephaz Nowakunda¹, Patrick Rubaihayo², Priver B. Namanya¹, Jerome Kubiriba¹, Wilberforce K. Tushemereirwe¹

¹National Agricultural Research Laboratories (NARL), P.O. Box 7065, Kampala, Uganda.

²College of Agricultural and Environmental Sciences, P. O. Box 7062, Makerere University, Kampala, Uganda

Corresponding address: henrymanrb@gmail.com

The dessert banana industry in the East and Central African (ECA) markets is worth US\$1 billion. Of this, the commercial value of dessert bananas traded in the region is only about US\$30 million being only 3% of the demand in the region. The popular dessert banana cultivars which include Musa AAA- Gros Michel (Bogoya) and apple banana (Musa AAB, SukaliNdizi) comprise less than 10% of the cultivar profile on farm due to Fusarium wilt disease of banana caused by *Fusarium oxysporum* f. sp. *cubense* (Foc Race1). Two dessert banana genotypes "NAMU1" and "NAMU2" resistant to Foc Race1 and high yielding were developed through conventional cross breeding and evaluated for fruit quality, yield and consumer acceptability. The improved dessert banana hybrids yielded >50% higher by than their susceptible SukaliNdizi controls. Instrumental fruit quality parameters being fruit firmness, soluble solids content (SSC), titratable acidity (TA), and sugar/acid ratio were not significantly different between NAMU2 and SukaliNdizi. However, NAMU1 had a higher sugar/acid ratio ($17.61 \pm 1.000a$) and a lower TA ($2.08 \pm 0.030c$). Fruit shape, peel and pulp colour were similar in all genotypes. The sensory consumer analysis on five attributes; color, aroma, flavor, texture, and overall acceptability was the same for all the genotypes. Preliminary market testing shows willingness to buy the dessert hybrids for a price similar to that payable for SukaliNdizi. Once released the FOC resistant dessert hybrids will not only fill the huge supply gap in the ECA regional market, create employment along banana value-chain, increase household incomes according to NDP III and PDM, but will potentially enable Uganda to participate in the lucrative global export market for dessert banana.

Key words: SukaliNdizi dessert hybrids, Fusarium wilt, resistant, consumer acceptable

5.6 Target Population of Environments, Trait Heritability across the Breeding Stage Gates, and Their Impact on Sweet Potato Breeding in Uganda

D.M. Chelangat¹, M. O. Anyanga¹, P. Musana¹, B. Oloka¹, A. Alajo¹, R. Odama¹, F. Osaru¹, R. Aboyo¹, J. Asiimwe¹, A. Katungisa¹, J. Adero¹, S. Letia¹, R.T. Ssali³, B. Olukolu⁵, G. da Silva Pereira⁶, H. Campos⁴, G.C. Yencho² and B. Yada¹

¹National Agricultural Research Organization (NARO), National Crops Resources Research Institute (NaCRRI), Namulonge, P.O. Box 7084, Kampala, Uganda

²Department of Horticultural Science, North Carolina State University, 214 Kilgore Hall, Box 7609, Raleigh, NC 27695-7609, USA



³International Potato Center (CIP), Kampala, Uganda

⁴International Potato Center (CIP), Lima, Peru

⁶Department of Agronomy, Federal University of Viçosa, Brazil

⁵University of Tennessee, Knoxville, TN, 37996, USA

Sweetpotato (*Ipomoea batatas* L. Lam) is a resilient food security crop grown in a wide range of marginal environments that is now exhibiting a decline in on-farm production in Uganda. With changes in climate, the crop exhibits greater differential phenotypic expression for key traits among genotypes. These emerging changes necessitated more extensive and costly phenotyping in different sites of the country by the breeding program. This was done in order to capture genotypic response to the geographic location, microenvironment, and pest and disease pressure. The program has great need to identify target population of environments (TPE) for breeding in Uganda. This study therefore sought to optimize the breeding pipeline by determining heritability of key traits across the stage gates and establishing the mega environments for sweetpotato phenotyping within Uganda. Data from different stage gates, preliminary yield trial (PYT), and intermediate yield trial (IYT), advanced yield trial (AYT) and uniformity yield trial (UYT) was used for this study and analyzed using linear mixed models. The analysis revealed that the heritability for key traits (sweetpotato virus disease-SPVD, Alternaria blight -ALT, sweetpotato weevil severity-SPW and yield) was high at advanced stages like the UYT (0.4 -0.7) and AYT (0.4-0.6) and moderate for early-stage gates. Disease traits had higher heritabilities compared to yield and SPW. The TPE analysis of the AYT data from 13 environments revealed that sweetpotato growing sites were subdivided into 4 mega environments based on the winning genotype. To confirm the subdivision of the testing sites, a correlated response to selection (CR/DR) in the sub-divided regions was calculated. CR/DR was 0.19 a value much smaller than 1 which implied that it was convenient to subdivide the TPE. This showed fewer testing sites would be used for sweetpotato phenotyping at reduced costs.

Key words: Sweetpotato, Heritability, Stage gates, Correlated response to selection

5.7 Status of wheat stem rust in Uganda two decades after the first report of Ug99 (TTKSK) race

Bosco Chemayek¹, Lawrence Owere¹, Arthur Wasukira¹, Lorna Kwaka¹, Stephen Wobibi¹, Yoseph Alemayehu⁴, Mehran Patpour², Ellen Jørgensen², Mogens S. Hovmøller², Les J. Szabo³, David Hodson⁴

¹National Agricultural Research Organisation, Buginyanya Zonal Agricultural Research and Development Institute, P. O Box 1356 Mbale

²Dept. of Agroecology, Aarhus University, Forsøgsvej 1, DK-4200 Slagelse

³USDA-ARS Cereal Disease Laboratory, 1551 Lindig Street, University of Minnesota St. Paul, MN

⁴International Maize and Wheat Improvement Center, El Batán, Texcoco, Estado de Mexico, C.P. 56237, Mexico

Stem rust surveys were conducted in key wheat growing regions of Uganda during two cropping seasons 2018B (Sept-Dec) and 2019A (Apr-Aug) with the objective of establishing the incidence and severity of stem rust as well as identifying the races currently present. Results from the 2018B survey indicated that 95% of the fields surveyed in the east and 64% in south western had stem rust. Across both regions the stem rust severity was 'MSS-S' in 57% of the fields, 'MS' in 30%, 'MR'



in 10% and 'R' reaction in only 3% of the fields surveyed. The incidence of stem rust was low in eastern region in 2019A, with only 35% of the fields surveyed having stem rust contrary to south western region where 100% of the fields had stem rust. Of the fields with stem rust, severity was higher with 68% of the fields having infection type 'S', 16% had 'MSS', 11% had infection type 'MS' and only 5% had 'MR' infection. Twentyfour samples collected in 2018B were genotyped with Pgt core SNP markers: 18 (75%) of the samples tested positive for the Ug99 race group (Clade I); 4 (17%) belonged to Clade IV-B associated with Pgt races TKTF and TTF; and 2 (8%) of the samples could not be genotyped. The 18 samples that tested positive for Ug99 race group were further genotyped with 15 SNP additional markers. The majority of these samples (89%) were genotyped as AF-001.ad associated with races TTKSK, TTKST and TTHST, while 11% were genotyped as genotype AF-001.a associated with races TTKSK and TTKTK. In 2019A season, 27 d-samples were genotyped with Pgt core SNP assay: Ug99 race group (clade I) was the most predominant genotype with 14 samples (54%); 6 samples (23%) belonged to the clade IV-B genotype associated with Pgt races TKTF and TTF; 2 samples (8%) were clade IV-E.2 genotype associated with races TKTF, TKPTF and TKTF; 1 sample (4%) were clade IV-F genotype associated with race TKTF; and 1 (4%) sample did not match any Pgt SNP/genotype in the database and may represent a new genotype. Furthermore, 2 samples collected from rye did not match anything in the database implying it is likely *Puccinia graminis* f. sp. *secalis* (Pgs). Stem rust race Ug99 the first known race of *P. graminis* tritici with virulence on resistance gene Sr31 was first detected in Uganda in 1998 and designated TTKSK based on north America nomenclature system. Current pathogen monitoring identified eight more variants (TTKST, TTKTK, TKTF, TKTF, TKTF, TKPTF, TTF, TTHST) in the Ug99 lineage in addition to the original Ug99 (TTKSK) in various wheat-growing areas in Uganda. Molecular analysis showed that the pathogen has mutated into 8 more variants in the last 20 years although the original Ug99 race group is still predominant.

Key Words: Clade, Genotype, Severity, SNP marker, Ug99

5.8 Exploring the coffee species, *Coffea liberica* in Uganda

Chemutai, J.A.^{1*}, Nanyonga, J.², Lutaakome, S.E.²

¹National Coffee Research Institute, P.O Box 185, Mukono, Uganda.

²Uganda Coffee Development Authority (UCDA), P.O Box 7267, Kampala, Uganda.

Corresponding author: chemujob2@gmail.com

Uganda is Africa's largest coffee exporter as well as a centre of origin of *Coffea robusta* that constitutes about 80% of the country's production followed by *Coffea arabica*. Uganda has instituted a number of reforms in its coffee sector including establishing a target of 20 million 60kg coffee bags by 2025 up from 5.2 million bags in 2017/2018. Achieving this target will require the country to devise practical ways of minimizing emerging production challenges that include increasing pest and disease pressure, low soil productivity in addition to the increasing frequencies of prolonged droughts associated with climate change. Due to these challenges, farmers are increasingly adopting a highly resilient *Coffea liberica* species (*Liberica coffee*). A study involving focus group discussions and structured interviews was therefore conducted using cluster sampling on a sample of randomly selected farmers (107), traders (1), coffee exporting companies (4) and nursery operators (1) by a team from coffee researchers from the National Coffee Research Institute and the coffee regulatory Authority. This was conducted in Uganda's emerging major *Coffea liberica* growing districts of Butambala, Kamuli, Kyotera, and Luweero in central Uganda and Arua, Moyo, and Koboko in the West Nile region. The study was aimed



at exploring the factors underscoring the increasing interest in the species, challenges of its production, its value chains, mapping out its potential in Uganda's coffee sector as well as identifying potential areas for research and intervention. Farmers in the order of importance cited its conducive harvest time in the times of limited alternative income sources, excellent yields (10-200kg) of red cherry per tree) as well as high/absolute resistance to pests and diseases especially coffee wilt disease and coffee leaf rust as the major factors driving its preference. Cupping of the species samples was done by a panel of experts in a reputable regulatory agency laboratory (UCDA), samples had a high average cup score of 80% with various special profile notes and coffee bean attributes. Given its high cup quality score and other special cup profile attributes, the study identified the species to have a great potential in diversifying the fortunes of the coffee sector. From the study findings, the *liberica* coffee could be marketed as a unique single origin specialty coffee or a special coffee blend for introducing special cup profiles for coffee enthusiasts. For researchers, the species exhibited special attributes of breeding interest including cup quality, sturdiness hence a good source of genetic diversity for improved coffee variety selection and development.

Key words: *Coffea liberica*, cup quality, resilient coffee.

5.9 Effect of Manure Integrated With Inorganic P and K on Yield of Potato in South West Highlands of Uganda

¹Etiang J, ²Mateka B, ²Uzatunga I, Mwesige R, ²Barekye A and ¹Owere L,

Corresponding Author: ETIANG JOSEPH

Soil Fertility Scientist

Crops and Natural Resources Programme

National Agricultural Research Organisation, Buginyanya

P.O. Box 1356, Mbale

Mobile: +256772452606

Email: joerets@gmail.com

National Agricultural Research Organisation

Kachwekano Zonal Agricultural Research and Development Institute

P.O. Box 421, Kabale - Uganda

Potato (*Solanum tuberosum* L.) is an important food and cash crop in Uganda especially in the highland areas of eastern and south west Uganda. This study was conducted to evaluate the response of potato yield to manure integrated with inorganic P and K fertilizers. The trial was conducted over two growing seasons of 2019B and 2020A. Four factors were assessed namely, variety, manure, K and P. The three varieties were; Naropot4, Victoria and Kinigi. Two levels of manure were 0, and 1000kg/ha, two levels of P (0, and 50kg/ha) and two levels of potassium (0, and 100 kg/ha). Manure, K and P were combined into five combinations namely; Control, Manure, Manure+P, Manure+K and Manure+P+K, which were assessed for all the three varieties in a split plot arrangement. Data was collected on number of tubers of three grades i.e., large, medium and small sized tubers. Naropot4 gave the highest number of tubers 49 tuber/m², against 18tubers/m² by victoria and Kinigi. By variety, Naropot4 yielded 24.87t/ha followed by victoria with a yield of 18.8t/ha and least by Kinigi with a yield of 14.1t/ha. By treatment manure+P+K gave average yield of 21.93t/ha against the control of 16.57t/ha. Victoria gave high number of large tubers of 5.4kgs/m² followed by Kinigi with 4.3 kgs/m² and least by Naropot4 with 4.1kgs/m² of large sized tubers. Application of manure+P+K gave



highest yield of large sized tubers of 6.2kgs/m² followed by manure where yield was 5.1kgs/m² of large sized tubers against the control of 3.7kgs/m². Naropot4 is good in production of high tuber numbers especially in seed multiplication. For large sized tubers integration of manure+P+K is recommended. Where inorganic fertilizers are lacking then application of manure is equally better than the control.

Key Words: Potato, Integration, manure, Fertilizer

5.10 Near infrared spectroscopy for high-throughput analysis of starch content in cassava

Babirye Fatumah Namakula^{1,2}, Ephraim Nuwamanya^{1,2}, Michael Kanaabi,^{1,2} Enoch Wembambaz^{1,3}, Paul Gibson², Richard Edema², Manze Francis^{1,2}, Robert Sezi Kawuki¹

Affiliations

¹National Crops Resources Research Institute, ²Makerere University, Kampala, Uganda, ³University of Ghana, Accra, Ghana

Correspondence: Babirye Fatumah Namakula

fatumahb7@gmail.com, +256785057021

Cassava starch is important globally for use in food, feed and industrial applications. It has gained prominence in Uganda as a product with great potential for agro-industrialization, import substitution and increased exports. It is for these reasons that cassava breeding for high starch content varieties has become a priority. Research to improve cassava starch content through conventional breeding aimed at developing new cassava varieties for both food and industry is underway in Uganda. However, prior to this study, only few samples could be analyzed for starch content quantification using laborious and slow wet chemistry approaches. This limits progress and rates of genetic gain in breeding. Near infrared spectroscopy (NIRS) offers an elegant, fast and efficient alternative for analysis of constituents in samples with minimal preparation. This study evaluated the potential of NIRS to predict starch content in cassava; 115 clones planted at Namulonge were evaluated. Two roots per clone were sampled. Starch content was analyzed using a modified acid hydrolysis and sugar analysis determination method. Spectra were taken on flour samples in duplicate using a portable Vis/NIRS device (Quality Spec Trek: S-10016). WINISI software was used for model development. The performance of mathematical pre-treatments was also evaluated. Starch content ranged from 21.48 to 73.97% on dry weight basis. Performance of standard normal variate and de-trend (SNVD) with second derivative calculated on two data points and smoothing (SNVD+2222) was the best mathematical treatment for calibrations developed. NIRs predictions were reliable for starch content ($R^2_c = 0.850$, and $1-VR = 0.52$), indicative of screening purposes for cassava breeding population. Results show that starch content can be efficiently analyzed using NIRs, enabling simultaneous determination of the constituents hence increasing gain.

Key words: Starch content, NIRS, calibration, prediction



5.11 Statistical Approaches to Improving Crop Production Experiments

Paul Gibson, Dept. of Agricultural Production, College of Agricultural and Environmental Sciences

Optimum statistical design and analyses provide greater ability to identify the best treatment or genotype. Experiments often give sub-optimal decision-making power due to sub-optimal data accuracy. Key areas deserving attention are:

- 1) Clearly defined calculations to compare treatments
- 2) Using the experimental design best suited to the purpose.
 - a. Single treatment factor
 - i. CRD--usually not ideal if error $df > 10$
 - ii. RCB—standard design unless $trt\# > 15$
 - iii. α -lattice—improved data at no greater cost or risk if $trt\# > 15$
 - iv. Augmented—if genotypes too many to fully replicate
 - v. Row-column designs – combine best features of above
 - b. Two treatment factors
 - i. RCB—if both factors equally important
 - ii. Split-plot – if error $df > 10$, and 1 factor or the interaction needs more precision than the other. Construct skeleton ANOVA to help decide.
 - iii. Split-block—for certain constrained layouts
 - c. Single treatment factor in multiple environments
 - i. As single above—unless unable to fully replicate in each environment
 - ii. Augmented – if too many entries to fully replicate
 - iii. Partial replication (p-reps)—if large number of genotypes in several environments and/or if seed is insufficient
- 3) Analysis of one environment
 - a. According to design, can use positional rows and columns as covariates
 - b. Mixed-model ReML – produces BLUPs often superior to BLUEs
- 4) Analysis across multiple environments
 - a. As above
 - b. Use Treatment x Environment as F-test denominator and as error term for SEM, SED, LSD (The unique effect of each environment on treatment response adds random variation to the treatment mean across environments)
- 5) Using a multi-variable index if appropriate
- 6) Reducing experimental error
 - a. Select uniform experimental site
 - b. Carefully control unintended variation at every step -- growing / handling seed, closely supervise all helpers
 - c. Use all available statistical techniques to reduce experimental error (covariance analysis, transformation)



Further explanations are available at Statistics.AglImprove.Africa, or contact me at pgibson@AglImprove.Africa.

5.12 Progress in breeding quality protein maize varieties for the highland agro-ecologies of Uganda

Frank Kagoda¹, G.N. Nafuna², E. Basena¹ and L. Owere¹,

¹Buginyaya Zonal Agricultural Research and Development Institute (BugiZARDI), P.O. Box 1356, Mbale, Uganda

²Makerere University, College of Agricultural and Environmental Sciences, Kampala, Uganda P.O. Box 7062

Corresponding author: Frank Kagoda. E-mail: fkagoda@gmail.com

The highland areas of Uganda (1500 to 3000 masl), continue to experience a stagnation of maize grain yield, rarely exceeding 2 t ha⁻¹. The extensive use of unimproved varieties has greatly contributed to the low grain yields. Such varieties are further characterized by low levels of essential nutrients especially proteins and vitamins, yet these are necessary for vulnerable children and mothers. This study aimed at developing maize varieties with desirable levels of lysine and tryptophan, and tolerance to the maize lethal necrosis (MLN). A total of 59 maize inbred lines having quality protein maize (QPM) traits were obtained from CIMMYT- Ethiopia in 2018. The accessions were screened to the best 12 parents and then intercrossed in a half diallel mating design to generate 66 single cross hybrids, from which 40 were selected and evaluated in a preliminary yield trial (PYT) at Buginyanya in 2019 A season. The best single crosses from the PYT were test-crossed with selected MLN tolerant male inbred lines from CIMMYT - Kenya to obtain 15 three-way cross (TWC) hybrids. The TWC hybrids were evaluated for adaptability in advanced yield trials (AYTs) during 2020 A season in Rwebitaba, Kalengyere and Bukwo, from which the best ten were selected for National Performance Trials (NPT) in 2021 A and 2021 B seasons in Bukwo, Buginyanya, Zombo, Nebbi, Rwebitaba and Kalengyere. Eight candidate varieties namely Q150114, Q444638, Q160138, Q160114, Q444614, Q150138, Q160121 and Q150121 exhibited good agronomic qualities such as good ear aspect, tolerance to MLN and lodging, and high grain yield (5.0 to 8.2 t ha⁻¹). Of the eight, only 4 varieties (Q150114, Q160138, Q444614 & Q160114) exhibited high levels of tryptophan and lysine following a High Performance Liquid Chromatography (HPLC) test and will subsequently be recommended for release.

Key words: Grain yield, Highland, Maize, Maize Lethal Necrosis, Quality Protein Maize

5.13 Agronomic and economic benefit of primary, secondary, micro nutrients in specified fertilizer applications in rice production in Uganda

*Kaizzi C. Kayuki¹, ¹Nansamba Angella, and ²Rugema Hillary

¹National Agricultural Research Organization (NARO)

National Agricultural Research Laboratories (NARL) – Kawanda

²Grainpulse (U) LTD

Corresponding Author: kckaizzi@gmail.com

Rice has become an important crop for food, nutrition and income security for smallholder farmers and for the economy of Uganda. Rice yield per unit area is low, this is partly attributed to low and declining soil fertility. Increased use of inorganic fertilizers and/or supplemented manure is required



to improve soil fertility and increase rice production. Two sets of trials were conducted during 2020 and 2021 in Amuru District with the following objectives for Set 1 to determine which secondary and micro nutrient limit rice yield; and Set 2 comparing the yield and economic benefit of applying rice specific NPK blend to application of NP as DAP and urea. Each farmer had one rep, with other farmers serving as replications. There were 10 to 15 farmers, or replications per trial per season. There was a significant increase in grain yield of 2.6 t ha⁻¹ above the control (1.7 t ha⁻¹) with application of a combination of NP with K, Ca, Zn, B and Cu. Omitting either K, Ca, Zn, B or Cu on average resulted in a significant decrease in grain yield (0.74 t ha⁻¹ vs. 4.3 t ha⁻¹ - when all the nutrients were applied). The net benefit of adding K, Ca, Zn, B and Cu to NP was Uganda Shillings 1,602,000, 739,000, 834,315, 906,189, and 1,057,603, respectively. There was a significant increase in rice yield of 1.5 t ha⁻¹ with a benefit to cost ratio (B/C) of 2 with application of (125 kg DAP + 125 kg urea) ha⁻¹ compared with 2.3 t ha⁻¹ and a B/C of 2.3 with application of (250 kg rice specific NPK + 125 kg urea) ha⁻¹, confirming that rice specific fertilizers are better than application of NP only.

Key words: DAP, Rice Specific NPK, net benefits, nutrient omission trials, secondary and trace elements

5.14 Characterisation of Resistant Starch from Selected Banana Cultivars.

AliKajubi¹, M. Matovu¹, J. Kubiriba¹, R. Baingana², P. Namanya¹, and W. Tushemereirwe¹

¹National Agricultural Research Laboratories (NARL), P.O. Box 7065, Kampala, Uganda.

²College of Natural Sciences, P. O. Box 7062, Makerere University, Kampala, Uganda

Corresponding address: alikajubi@gmail.com

Starch is nutritionally divided into readily digestible, slowly digestible, and resistant starch (RS) basing on digestibility. Resistant starch is the proportion of starch that eludes digestion in the ileum and passes into the colon where it is fermented into short chain fatty acids (SCFAs) by microflora. Resistant starch is classified into five subtypes: RS1 and RS2 occur naturally in grains and granules of bananas respectively while RS3, RS4 and RS5 are modified types. Combined with glycemic control, butyrate the major SCFA from RS2 fermentation elicits RS health benefits; including lowering metabolic markers for cancer, cardiovascular disease, diabetes and promoting healthy gut thereby preventing the advance of corresponding non communicable diseases (NCDs). Resistant starch type 2 was isolated from green bananas using alkaline and enzyme treatment. This was characterized for granular structure and molecular organization using light and scanning electron microscopy and Fourier transformed infra-red spectroscopy (FTIR) respectively. The physiochemical and functional properties were also investigated. High levels of RS up to 80% (dwb) were obtained from *Musa ABB cv Kayinja* and other banana cultivars without modification by chemical or mechanical treatment. Although the banana RS exhibited varying granule sizes, shapes and micro-architecture, they had similar chemical structure (C-type) with intensity ratios of the crystalline regions ranging from 0.95 to 1.09. Chemometric data analysis generated three [3] distinct groupings presenting a powerful tool for reliable discrimination between RS2 derived from different cultivars. The study demonstrates that RS2 can be isolated from green bananas and chemometrics can aid selection of cultivars for the prospective application of RS2 as a nutraceutical countering non communicable diseases (NCDs).

Key words: Resistant starch, banana, nutraceutical



5.15 Development of A Nears Infra-Red Spectroscopy Prediction Model for Hydroxycinnamic Acid Esters in Ugandan Sweetpotato Parent Germplasm

Arnold Katungisa¹, Benard Yada^{1*}, Doreen M. Chelangat¹, Agnes Alajo¹, Paul Musana¹, Joan Adero¹, Regina Aboyo¹, Jennifer Asiimwe¹, Sunday Letia¹, Profilio Tukundane¹, Stellah Namazzi¹, Florence Osaru¹, Farouk Kisekka¹, Titus Alicai¹, Christopher Omongo¹, James Odongo¹, Reuben Ssali⁴, Stephen Angudubo¹, Jamilu.E. Ssenku², E. Nuwamanya^{1,3} & Milton A. Otema¹

¹National Agricultural Research Organization, National Crops Resources Research Institute-Namulonge, P.O. Box 7084, Kampala, Uganda

²College of Natural Sciences (CoNAS), Department of Plant sciences, Microbiology and Biotechnology, Makerere University, P.O. Box 7062, Kampala, Uganda

³College of Agriculture and Environmental Sciences (CAES), Makerere University, P.O. Box 7062, Kampala, Uganda

⁴International Potato Center (CIP)

Corresponding author: yadabenard21@gmail.com, +256 772889069

The NIRS is a robust analytical tool, chemical free and transforms spectra data into absorbance values by $(\log 1/R)$, which corresponds to overtones of vibrational modes involving C–H, O–H, and N–H chemical bonds. Therefore, the study aimed at developing a NIRS calibration model for robust sweetpotato storage root HCA phenotyping in parent sweetpotato germplasm. The study focused on chlorogenic acid esters, one of the major hydroxycinnamic acid esters in sweetpotato. Profiling of HCA concentration was achieved by use of a shimadzu HPLC system equipped with the Zorbax Eclipse XDB plus C18 (Pearson et al., 2014) for chemometric calibration. One-inch squared sweetpotato storage root flesh cubes from 115 clones were scanned by Quality NIRs spectrophotometer and spectra data collected from wave lengths of 350 – 2500 nm. Regression modeling aided the development of NIRS partial least regression (PLS) HCA prediction model and scattering effect by use of multiplied scatter correction using the Unscrambler X 10.4 software. The principal component regression and partial least squares were evaluated after pre-treatment. Developed PLS model showed a correlation values (r) of 0.965 and 0.999, bias value of -0.173 and 0.000 for cross validation and calibration, respectively. Root Mean square Error Cross Validation indicating prediction power was 1.098 for cross validation and 0.169 for calibration set. Similarly, the study revealed a very strong significant (Tukey's test, $p < 0.05$) chlorogenic acid content (ppm) variation ($F = 23.69$, $df = 67$, $p < 0.001$) ranging from 0.31 ± 0.00 for "Bwanjule" to 15.73 ± 5.07 for "Karrot Dar". Generally, the NIRS statistical model developed will be used for selection of sweetpotato weevil resistance in breeding populations.

Key words: chemometrics, near-infrared spectroscopy (NIRS), Hydroxycinnamic, Sweetpotato, weevil.

5.16 Instrumentation predicts fruit colour associated with consumer acceptance of cooking bananas (Matooke)

Elizabeth Khakasa^{1,2}, Charles Muyanja², Robert Mugabi², Arinaitwe Ivan Kabiita¹, Brigitte Uwimana³, Priver Namanya¹, Kephias Nowakunda¹

¹National Agricultural Research Laboratories (NARL), P.O. Box 7065, Kampala, Uganda.



²School of Food Technology Nutrition and Bioengineering, College of Agricultural and Environmental Sciences, P. O. Box 7062, Makerere University, Kampala, Uganda

³International Institute of Tropical Agriculture

Color is one of the key sensorial attributes responsible for the acceptance of new or improved banana hybrids. Measurement of colour during evaluation of matooke hybrids for consumer acceptance was conducted through sensory panels, which is subjective, cumbersome, time consuming and therefore expensive. The objective of this study was to establish the relationship between sensory panels and instrumentation to accurately and cost effectively quantify colour associated consumers' satisfaction of matooke. An untrained sensory panel (n=256) was used to evaluate the likability of color for the samples while a trained sensory panel (n=12) objectively assessed the color quality. Instrumental measurement of CIE L*a*b* colour values were measured using a Konica Minolta chroma meter CR-400. Correlational relationships between the instrumental and sensory attributes were established. ANOVA was used to establish the significance of relationships between the instrumental and sensory attributes. A strong correlation was observed between instrumental color and consumer-acceptable color. The instrumental b* value of the raw pulp was strongly correlated with consumer acceptable color liking (r=0.75) and overall acceptability (r=0.75). The b* value of the cooked matooke was also strongly associated with consumer color (r=0.78) and overall acceptability (r=0.77). The strong correlations between instrumental colour parameters and consumer liking can be used to predict acceptable color for matooke. In effect, instrumentation is time saving, inexpensive and unbiased.

Key words: Cooking banana, Matooke color, Consumer acceptability, Hybrids, Instrumental analysis

5.17 Detection and management of soil-borne pathogens in citrus using non-inorganic control practices under green-house conditions

Ronald Kisekka¹, Violet M. Namuyanja¹, Bernard Fungo¹, Miriam Masibo¹, Paul Balitta¹, Isaac Kiyingi¹, Hillary Agaba¹

¹National Agricultural Research organization (NARO), P. O. Box 295, Entebbe, Uganda

Corresponding Author: Ronald Kisekka; Email: ronald.kisekka@gmail.com

In Uganda, Citrus is among priority-crops and there is a growing need to produce it in large quantities for factory-use. However, production is constrained by several biotic-factors of which soil-borne pathogens are significant. Chemical-use to overcome these challenges has detrimental effects. An experiment was laid out in the green-house of National Forestry Resources Research Institute (NaFORRI) at Kifu-Mukonoin 2020-2021 to determine dominant soil and Citrus pathogens and test efficacy of different non-inorganic citrus pathogen control practices. A completely randomized block design was used with five treatments replicated thrice: boiled water, heated wet-soil, fumigated soil, solarized wet-soil, and untreated soil. They were integrated with cultural practices. Presowing treatment with sodium-hypochlorite-solution (1:7), sowing 30 Citrus seeds per variety tested in the treatments and monitoring disease responses were done. Soils from treatments were cultured on Potato-Dextrose-Agar and Nutrient-Agar. *Aspergillus niger* was the most dominant soil-borne pathogen identified in pure cultures. Others included *A. flavus*, *A. fumigatus*, *A. viridinutans*, *Penicillium chrysogenum* and *Fusarium oxysporum*. Ranking based on scores in: cost-effectiveness, leaf-health, chlorophyll-intensity and general-health of seedlings revealed solarization (35) as most effective technique for managing soil-borne pathogens, followed by boiling (33), heating (31), untreated soil (27) and lastly fumigation (26). Identified



pathogens induce aflatoxins in Citrus and lead to great losses during post harvest handling; they also cause root and fruit-rots. Solarization creates solar-radiation in a miniature green-house that kills pathogens. There is a need to study non-inorganic control practices of citrus pathogens under field conditions for improved yields in Uganda.

Key words: Citrus-production, soil-borne-pathogens, solarization, non-inorganic-control-practices, green-house

5.18 Effectiveness of Integrated Solarization Technology in managing soil-borne pathogens and weeds in Citrus seedlings under greenhouse conditions

Ronald Kisekka^{1,†}, Miriam G. Masibo^{1,†}, Samuel Ongerep^{1,†}, Emily Kamusiime^{1,†}, Sarah Musimenta and Bernadette Kabonesa^{1,†}

¹National Agricultural Research Organization, Plot 3, Lugard Avenue, Entebbe, P.O. Box 295, Entebbe, Uganda.

[†]National Forestry Resources Research Institute (NaFORRI), Kifu, Mukono-Kayunga Road, P.O. Box 1752, Kampala, Uganda.

Corresponding Author: ronald.kisekka@gmail.com

Solarization Technology utilizes solar radiation to kill soil-borne pests, diseases and weeds in an environmentally and eco-friendly way. In this study, we assessed the efficacy of integrating solarisation with sticky traps on two potting mixtures (sawdust and soil) for three Citrus species (*Citrus sinensis*, *C. reticulata* and *C. limoni*). Eight treatments were tested viz., non-solarized sawdust, non-solarized soil, solarized soil, solarized soil with sticky traps, non-solarized soil with sticky traps, non-solarized sawdust with sticky traps, solarized sawdust and solarized sawdust with sticky traps, each replicated thrice and were arranged in a randomized complete block design (RCBD). Thirty sterilized seeds of each Citrus species were sown per treatment and monitored for one year in 2019. ANOVA revealed a significant difference in weed control between the treatments at $p \leq 0.05$. Turkey's post hoc test showed weed growth differences between treatments with sawdust and ones with soil as media. More weeds grew in non solarized soil (32%), compared to non solarized soil with sticky traps (30%), solarized soil with sticky traps (21%), solarized soil (17%) and treatments with sawdust media did not allow weed growth (0%). A Kruskal Wallis test revealed a significant effect of treatments on the survival percentage of Citrus seedlings ($X^2 = 36.008$, $df = 7$, $p < 0.001$), mean of chewed leaves ($X^2 = 20.850$, $df = 7$, $p = 0.004$) and percentage levels of low chlorophyll ($X^2 = 21.073$, $df = 7$, $p = 0.004$) at the $p \leq 0.05$ level. Highest number of Citrus seedlings with folded leaves were observed in non solarized sawdust with sticky traps (mean rank = 119.50), followed by non solarized soil with sticky traps (112.22), and solarized sawdust (107.69), while the lowest in non solarized sawdust (90.96), solarized soil (90.91), non solarized soil (88.25), solarized sawdust with sticky traps (85.44) and lastly solarized soil with sticky traps (82.54). Citrus seedlings with sawdust media were observed to be nitrogen deficient (Mean ranks 118.43 - 141.63). Solarized soil with sticky traps had the least number of Citrus seedlings with leaf miner symptoms (Mean rank = 12.50). Therefore, solarized soil with sticky traps was the most suitable treatment for the control of soil-borne pathogens. Treatments with sawdust media effectively stopped weed growth while those with solarized soil media reduced their growth. Integration of sticky traps was very pivotal in the management of whiteflies and other honey dew secreting insects. We recommend a similar study under field conditions.

Key words: Integrated-solarization-technology, greenhouse, soil-borne-pests and diseases



5.19 Somatic embryo production in Ugandan elite cassava genotypes and genetic transformation using the enhanced green fluorescent protein gene

S.J Magambo², A. Nabatanzi¹, T. Alicai² and H. Wagaba²

¹College of Natural Sciences, Makerere University, P.O.Box 7062, Kampala, Uganda.

²National Crops Resources Research Institute, P.O.Box 7084, Kampala Uganda.

Corresponding authors: steven2magambo@gmail.com, hwagaba@gmail.com

Friable Embryogenic Callus (FEC) production is a prerequisite for genetic transformation of cassava (*Manihot esculenta* Crantz). However, its induction first requires generation of Organised Embryogenic Structures (OES). The production of OES and FECs in cassava is genotype dependent. The objective of this study was to optimise conditions suitable for somatic embryo production in the Ugandan farmer preferred cassava genotypes; NASE13, NASE19 and NAROCASS1, and demonstrate genetic transformation potential. Organised Embryogenic Structures were induced by initiating leaf-lobe explants on Murashige and Skoog (MS) media supplemented with 24D at varying concentrations of 5, 8, and 11 mg/L, half-strength MS containing 50 μ M picloram and MS full strength with 50 μ M picloram as the control. To produce FEC, resulting OES were established on Gresshoff and Doy media. These were then cultured on regeneration media (MS 5 μ M 1-Naphthaleneacetic acid (NAA) to determine regeneration frequencies of each genotype. Generated NAROCASS1 FECs were cocultured with OD600 0.05 of *Agrobacterium* suspension containing the enhanced green fluorescence protein (eGFP). There was a highly significant difference ($p < 0.001$) among media types in percentage response to OES formation. NASE 13 showed the highest regeneration frequency of 38.4% while NAROCASS1 had the lowest regeneration frequency of 10.5% recorded. The presence of eGFP gene in NAROCASS1 was confirmed by PCR analysis of transformed lines. These findings present opportunities to utilise elite Ugandan cassava genotypes already used by farmers to introduce desirable traits into the crop.

Key Words: Friable Embryogenic Callus, *Agrobacterium*, picloram, genetic transformation
Accept for oral. Minor revision

5.20 The Effect of Adoption of Improved Bean and Maize Technologies on Small holder Income and Food Security in Uganda

Sarah Mutonyi¹; D. Akwango¹, I. Kiyingi, ¹D. Magala¹, S. Adur¹, I. Obongo, S. Agundupu¹, R. Ariongo², A. Bua¹ & G. Lukwago¹

¹National Agricultural Research Organization (NARO)

²International Food Policy Research Institute (IFPRI)

Corresponding author: mutsarah@gmail.com

NARO has invested substantial resources in developing bean varieties; NABE15, NABE17, NAROBAN2 and others, and maize; LONGE5, LONGE10 and others. These varieties are widely used by communities. However, the impact of these crops on livelihoods in the country is not well documented. This study investigated the impact of the adoption of improved NARO bean and maize technologies on smallholder income and food security. Data were collected from adopters and non-adopters to estimate the impact of adoption on income and food security. A cross-sectional study design was employed using semi-structured and structured questionnaires, focus group discussions and key informant interviews. A total of 1,445



respondents were interviewed from 6 agro-ecological zones where beans and maize are grown for food and other purposes. The six zones were selected because both crops were grown as important for both subsistence and commercial purposes. Data were analyzed using Propensity score matching and Endogenous switching regression to assess the individual impact of NARO bean and maize technologies. Food security was computed using household diet diversity score.

The results show that the adoption of either improved beans or maize varieties led to increased household income and food security. The adoption of NARO bean technologies increased bean income, farm income & total household income by 80 percent, 37 percent & 36 percent, respectively. And the adoption of maize technologies increased maize income, farm income, and total household income by 65 percent, 54 percent & 48 percent, respectively.

Regarding food security, adoption of NARO bean technologies increased the Food Consumption Score (FCS) by 5.4 points, representing a 10 percent increase, which means technology adoption improved food security by 10 percent in relation to non-adoption. A comparable increase in FCS (4.7) was observed for adopters of improved NARO maize technologies. The increase in food security is attributed to the increased maize and bean yield and increased household income of technology adopters. The evidence reinforces the need for increased support for agricultural research and the dissemination of improved technologies.

Key words: Technology adoption, Impact evaluation, Beans, Maize, Livelihoods

5.21 New Variants of *Xanthomonas vasicolapv. musacearum* (Xvm) causing bacterial *Xanthomonas* wilt found in Uganda

Vicky Nabakooza¹, J. Kubiriba¹, A. Tugume², P. Namanya¹, W. K. Tushemereirwe¹

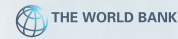
¹National Agricultural Research Laboratories (NARL), P.O. Box 7065, Kampala, Uganda.

²College of Natural Sciences, P. O. Box 7062, Makerere University, Kampala, Uganda

Corresponding address: ngorretivicky@gmail.com

Previous variability studies of *Xanthomonas vasicolapv. musacearum* (Xvm) which causes banana *Xanthomonas* wilt (BXW) reported homogeneity among Ugandan isolates sampled before 2010 despite the fact that BXW was very destructive and fast spreading, characteristic of pathogens that are highly heterogeneous. Later variability studies on Xvm based on SNPs and multi-locus variable number of tandem repeats (MLVA) analyses reported isolates from Rwanda, DR Congo and Ethiopia were more related but different from those collected from Uganda, Tanzania and Kenya. The current study examined the status of variability of Xvm among the isolates in Uganda, to determine whether the variants from Rwanda and DR Congo have spread to Uganda and/or whether isolates in Uganda have mutated. A multi-locus variable number of tandem repeats [VNTRs] molecular technique was used to determine the genetic variation in Ugandan isolates. Cluster analysis of VNTRs fragments and their genetic distances revealed four distinct Xvm variants with 1 and 2 spread along the south western border, variant 3 spread in western highlands while variant 4 is spread predominantly in the central region. AMOVA analysis revealed significant differences ($p=0.001$) being 72% within and 28% among Xvm populations respectively. Highly heterogeneous Xvm has implications for its BXW control. In order to guide subsequent multi-variant control strategies, greenhouse experiments are underway to establish whether the molecular variability observed translates into varying symptomatic expression. The virulence of the new variants will also confirm the stability and effectiveness of BXW transgenic resistance, conferred by Hrap and Pflp genes against formerly homogeneous Xvm.

Key words: Variant, banana *Xanthomonas* wilt



5.22 Response of potato to manipulation of row spacing, fertilizer use, and intercropping with beans in Uganda

¹Justine Nakibuule¹, Jeninah Karungi², Monica Kigambo², Johnny Mugisha², Jimmy Obala³ and Napoleon Heri Bahati Kajunju²,

¹National Agricultural Resources Research Institute (NaCRRI) - Namulonge– P.O.Box 7084, Kampala Uganda,

²Department of Agricultural Production, Makerere University, P.O. Box 7062, Kampala, Uganda

³Department of Agricultural Sciences, Lira University, P.O. Box 1035, Lira, Uganda,

Corresponding author: 0777177137, jazminetina@gmail.com

Southwestern Uganda is the leading potato producer contributing 60% of Uganda's national potato production. However, rapid population growth associated with land fragmentation has reduced arable land holding per household. Coupled with pests and diseases, lack of inputs, and inappropriate agronomic practices, potato yields have thus dropped from 7.5t/ha to 3.5t/ha since 2017 to date, lower than 25t/ha obtained under good management hence pathways to intensify productivity are urgently needed. The study intended to contribute to enhanced potato productivity by generating knowledge that would guide the development of a system of potato intensification through integrating crop management practices to suit farm resources and improve land use. The split-split plot Randomized complete block experiments with two replicates were established in Kabale, Rukiga, and Mbarara districts for two seasons (2018B and 2019A). The study investigated the effect of location, fertilizer use (NPK and No NPK), plant spacing (75x 30cm and 60x 50cm), and intercropping plant arrangements of potato and beans (in ratios of 1:1, 1:2, 2:2, sole potato and sole bean) on the performance of potato. It also investigated the effective plant arrangement in intercrop for efficient resource utilization. Potato leaf area (cm²), number of marketable and un-marketable tubers per plot, total tuber yield per plot (t/ha), and bean yield per plot (t/ha) were collected and subjected to Analysis of Variance (ANOVA) in Genstat 14th edition. Land use efficiency in crop mixtures was also determined. Potato leaf area was significantly ($p < 0.001$) influenced by the interaction of location, spacing, and plant arrangement. In Kabale and Rukiga, wider potato leaves for sufficient light interception were noted from one row of potato to one row of beans (1P:1B) and two rows of potato to two rows of beans (2P:2B) arrangements established at 60x 50cm respectively. Plant arrangement ($p < 0.001$) and the interaction between, spacing and fertilizer ($p < 0.05$) had a significant influence on crop yield. Maximum yields of potato, beans, and overall yield were achieved from fertilizer-treated intercrops of one row of potato to two rows of beans (1P:2B) established at 75x 30cm spacing. Plant arrangement by spacing ($p < 0.01$) and plant arrangement spacing and fertilizer significantly ($p < 0.05$) influenced marketable tuber yield. More marketable tubers were harvested from 1P:1B intercrops established at 60x 50cm but fertilizer treatment was fundamental for marketable yield in Mbarara. Moreover, the highest biological efficiency in crop mixtures was achieved from 1P:2B intercrops. Therefore intercropping potato and bean was highly recommended for potato intensification, precisely by adding NPK to 1P:1B arrangements of 60x 50cm spacing for commercial potato production. Whereas, adding NPK to 1P:2B intercrops maintained at 75x30cm spacing was highly recommended for ware potato production.

Key words: Potato, Spacing, fertilizer, intercropping, land equivalent ratio



5.23 Unlocking the industrial potential of the banana sector in Uganda

Authors: Priver Namanya Bwesigye, Jerome Kubiriba, Ali Kajubi, Yusuf Mukasa, Ronald Katwaza, Huudu Mutuba, Wilbeforce Tushemereirwe

National Agricultural Research Laboratories (NARL), P.O. Box 7065, Kampala, Uganda.

Corresponding address: bwesigyep@gmail.com

The banana value chain predominantly focuses on a food security crop. It is however, estimated that 73.6 million tonnes of banana biomass (80% of total biomass) comprising of peels, peduncles, leaves, fibres, pseudo-stem, remain unexploited. This biomass can be processed into numerous high value banana products, servicing but not limited to the following industries; packaging material, foods and beverages, beauty and fashion, textile, housing or interior design, hygiene and energy industries, much needed for spurring the budding agro-industry in Uganda and EAC region. NARO has prioritised a few flagship products including; banana fibre, green banana resistant starch,, industrial ethanol and natural dyes. The activities were kicked off by market studies in 2021. Banana fibre when processed into hair extensions, carpets and paper bags, can generate revenue estimated at USD 0.28 billion in local and USD 0.47 billion in the international market. Similarly, based on the price for existing green banana resistant starch products on the global market, the quantity of bananas lost during peak harvest that generates excess supply can be used to produce 3.8 tonnes of resistant starch worth USD 217 million/year. In addition, the potential local demand for ethanol in Uganda was estimated at 7.4 million litres worth USD 13.3 million. However, if only 27% of banana corms of Uganda was utilised, pilot processes developed at NARO would produce upto 304 million litres of ethanol. The food, textile and medicinal industry commonly utilise synthetic dyes, flavourants and colourants. Safer, natural dyes have been extracted from banana leaves, male buds, pseudostem and corms. These prototypes are being characterised for biophysical and biochemical suitability for different industrial applications.

There are a number of prototypes at various stages of development in the commercialisation pathway. They include green banana resistant starch (GBRS), natural banana hair extensions, industrial ethanol, banana yarn, natural banana dyes. The front runners are GBRS as a nutraceutical and and natural banana hair extension, now ready for marketing testing with the private sector. Sustainable production of raw materials, dynamic networks for processing and marketing will unlock the full industrial potential of the banana sector thereby accelerating achievement of Uganda's agro-industrialisation and transformation agenda.

Key words: Agro-industrialisation, banana value chain

5.24 Farmer Practices in Management of Oil Palm Weevil in Uganda

Nampeera, E.L.^{1,5}; Nankinga, C², Ddumba, G¹, Twaha, M¹, Mubiru, S³ and Ddamulira, G¹.

¹National Crops Resources Research Institute, NaCRRI, P.O. Box. 7084, Kampala

² Ministry of Agriculture, Animal Industry and Fisheries, MAAIF, 102, Entebbe

³Sow and Grow Foundation Group, P.O. Box. 16181, Kampala, Uganda

^{1,5} *Corresponding author; email; nampeerae@yahoo.com*

Introduction: The oil palm weevil *Rhynchophorus phoenicis* (Fabricius, 1801) is among the key pests of oil palm worldwide, affecting 71.4% of oil palm production areas in Uganda.



Methods: A baseline survey was conducted in Kalangala to identify oil palm production constraints and management practices used by farmers. The study was conducted among 200 oil palm farmers in four blocks, namely; Bbeta East, Bbeta West, Bubembe and Kagulube.

Results: Majority of farmers (66%) indicated insect pest problem as a major constraint and 86% ranked oil palm weevil as number one pest. Chemical insecticides was the major control method of oil palm weevils, with 42.4% of farmers using it in Bbeta West. Farmers used different types of insecticides to control oil palm weevils and the most used insecticide was Rokat, which was used by 23.7% of farmers that used insecticides in Bbeta West. Non chemical methods used by farmers to control oil palm weevils across the four blocks studied included; uprooting infected palms and burn, removal of rotten branches, recommended pruning, destroying wild palms and continuous inspection. Most farmers (97.5%) in the four blocks suggested a sex pheromone if identified to be used in the management of oil palm weevil.

Conclusion: These findings propose an opportunity for future research on IPM strategies against the oil palm weevil to reduce insecticide use and improve oil palm productivity among smallholder farmers.

Key words: oil palm, oil palm weevil, practices, insecticide, integrated pest management

5.25 Compliance in Farmers' Practices to Mitigate Pesticide Residues in Uganda Capsicum Exports to the EU

Nankinga, C.^{1,2}, Ssamula, A.,¹ Kisingiri, B.², Mutende, D.,³ Niyitegeka, B.,¹ Owiny, R.², Ekalu, S.,² Kasozi, G.,¹ Rukuba, D.,¹ Asimwe, R.,¹ Mukiibi, D.,¹ Nantongo, S.,¹ Muzira, F.,¹ Tugume, J.,¹ Musimenta, H.,¹ Mwambu, P.¹

¹National Agricultural Research Laboratories, P.O. Box. 7065, Kampala

²Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Department of Crop Inspection and Certification, P.O. Box 102 Entebbe

³Ministry of Internal Affairs, Directorate of Government Analytical Laboratories, P.O. Box 7003 Kampala

Corresponding author: cmnankinga@gmail.com

Interceptions due to excessive pesticide residues in Uganda horticulture exports of Capsicum (chillies and hot pepper) to European Union (EU) negatively impact market access to this lucrative market. In 2019, the EU amended its regulations to allow for increased inspections of produce entering EU that came into force January 2022. MAAIF-National Plant Protection Organization (NPPO) had to align its field operations to enhance compliance with the revised regulations, continue to facilitate trade while protecting the Uganda Capsicum market in the EU. A baseline study was therefore conducted in February and March 2022, the the NPPO semi-structured checklist and physical field inspection of the registered Capsicum farmers to assess the level of compliance of farmers' practices required to mitigate pesticide residues at the capsicum production sites. The checklist was administered on 174 farmers of which 117 (67%) grew chilli and 57 (33%) grew Hot pepper and sampled from 29 districts with highest percentage was located in the Lake Victoria crescent agro-ecological zone. A total of 41 samples of peppers were sampled and analyzed for the presence of 136 pesticides using the quechers multi-residue extraction, followed by gas chromatography-mass spectrometry (GC-MS). A total of 78% (136 farmers) were applying appropriate pesticides as recommended on the product label, 90% (157 farmers) could differentiate insecticides, fungicides, bactericides, and herbicides during



application, 63% (109) farmers were complying with the registered Pre-Harvest Intervals, while 37% (65) were not. 39% (68 farmers) had taken measures and actions aimed at meeting the MRLs of the market yet 61% (106) had not. Although 72% of the farmers were aware of the integrated pest management practices such as scouting and trapping, 21% of the Capsicum samples tested positive with exceeding levels Chlorpyrifos and Profenofos. The study highlights gaps to be addressed while designing strategies to mitigate pesticide residues. These may include massive awareness campaigns on pesticide safety practices, the need to adhere to recommended pre-harvest intervals, and developing Legislations for regular pesticide residues monitoring.

Key words: European Union, pesticide residues, Capsicums

5.26 Small size non-marketable tubers and Economic losses in Potato Production: Evidence from Smallholder Farmers in Southwestern Uganda

Nyirarukundo, M.,¹ Mugisha, J.,¹ Sanya, L.N.,¹ & Ntakyo, P.²

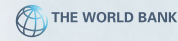
¹School of Agricultural Sciences, College of Agricultural and Environmental Sciences, Makerere University, P.O. Box 7062, Kampala Uganda

²Department of Agribusiness and Agricultural Economics, Faculty of Science, Kabale University, P.O. Box 317, Kabale, Uganda

Corresponding author: marirukundo@gmail.com

Tiny non-marketable potato tubers have an insufficient size which limits utilisation options and causes reduction in economic gains at the farm. This study examined economic loss associated with small size non-marketable potato harvests. A cross section survey was carried out among 237 potato farmers in Kigezi region of southwestern Uganda to determine the proportions and value of harvested small size non-marketable potatoes. Data was collected on 2019 potato production, utilisation and marketing. Descriptive statistics were used to determine the proportions of non-marketable potato harvests and value of the associated economic loss. The results indicate that non-marketable tubers accounted for an average of 37% of the total potato harvest per season. There were variations in the proportion of non-marketable potato tubers across seasons, variety, seed type and location. A reduction in the expected value per acre of non-marketable potato tuber harvests was estimated at an average of 53 and 60%, when the small tubers are sold as ware and seed potato, respectively. Potato farmers that use such non-marketable small tubers as seed experience reduced productivity which translates into economic loss that was estimated at 65 and 73% per acre in comparison with harvest value from use of marketable Non-Quality Declared Seed and Quality Declared Seed, respectively. The study results suggest that there is need for potato farmers to embrace production and management practices that contribute towards reduced proportions of non-marketable potato harvests such as use of quality seed and improved varieties rather than utilising the non-marketable potato tubers as seed. This can be achieved by implementing strategies that increase access to and enhance use of quality seed towards improved productivity and transformed production systems.

Key words: Economic loss, Non-marketable, Productivity, Quality seed



5.27 Hydropriming and Halopriming with Potassium Nitrate Solution to Improve Seed Germination and Vigour of Rice Cultivar KAFACI-287

MorishObura¹, Hillary Mireku Botey², Robert Kyambadde¹ and Jimmy Lamo¹

¹National Crops Resources Research Institute, P.O Box 7084, Kampala, Uganda

²CSIR - Crops Research Institute, P.O Box 3785, Kumasi, Ghana

Corresponding author: oburamorish100@gmail.com

Seed priming is one of the seed quality enhancement treatments for improving germination speed, germination uniformity, and seedling emergence. It is a physiological method of controlled hydration and drying that increases the pre-germinative metabolic process in the seed without radicle protrusion. Hydropriming and Halopriming with potassium nitrate solution have been widely applied to improve seed germination and vigour in many field crops. During the on-station trials at National Crops Resources Research Institute, poor and delayed seed germination was observed in a promising rice cultivar KAFACI-287. This phenomenon prolongs transplanting time, and increases production costs due to labour and seed needed for gap filling of direct seeded rice. This study therefore sought to investigate the effect of hydropriming and halopriming with potassium nitrate solution on seed germination and vigour of this cultivar. Hydropriming treatment levels involved soaking seeds in water for 12, 24 and 48 hours at 25°C, followed by air drying for 2 hours. Halopriming treatment levels involved soaking seeds in potassium nitrate concentrations of 0.5, 1, 2 and 3% for 12 hours. A standard germination test was done using top of paper method in a germination chamber at 20/30°C, and 16hr/8hr dark and light conditions for 10 days. Data was collected on germination capacity (GC), coefficient of velocity of germination (CVG), mean germination time (MGT), time to 50% germination (t₅₀), germination index (GI), germination rate index (GRI), seedling length (SL), seedling dry weight (SDW), seedling vigour index I (SVI-I) and seedling vigour index II (SVI-II). Data was analyzed using GenStat® 14th edition and treatment means were compared by Tukey's test at 5% level of significance. Results showed that seed priming improved seed vigour and germination characteristics of KAFACI-287 rice cultivar. Primed seeds germinated earlier than control and took less time to reach 50% germination for all the priming methods. For early and uniform seed germination in this rice cultivar, seeds should be hydroprimed for 24 hours or haloprimed with 1% potassium nitrate solution for 12 hours. However, hydropriming is a cheaper and more effective option compared to halopriming.

Key words: Hydropriming, Halopriming, Potassium nitrate, seed germination, seed vigour

5.28 Kernel morphometric characteristics and oil content among selected shea tree (*Vitellaria paradoxa*) genotypes in Uganda

Juventine Boaz Odoi^{1,3}, Clement Akias Okia², Samson Gwali¹, Thomas Lapaka Odong³, Hillary Agaba¹ and John Bosco Lamoris Okullo⁴

¹National Forestry Resources Research Institute, National Agricultural Research Organization, Uganda

²Department of Agroforestry and Natural Resources, Muni University, Uganda

³School of Agricultural Sciences, Makerere University, Uganda

⁴School of Forestry, Environmental and Geographical sciences, Makerere University, Uganda

Corresponding author: juventineboaz@gmail.com



Shea tree is very important as food, oil and industrial production of cosmetics, chocolate and other confectionaries traded upon worldwide. We studied seed morphometric characteristics and crude oil content in a commercially important oil tree species, *Vitellaria paradoxa* C.F. Gaertn. Subsp. *nilotica*. Five populations comprising of 16 ethnovarieties were selected from Eastern, Northern and West Nile Sub-regions of Uganda based on their attributes as judged by the farmers. The collected shea kernels were weighed using electronic balance to the nearest milligrams. Fresh kernel weight ranged from 2 ± 0.15 mg in the round fruited ethnovariety to 18.85 ± 1.87 mg in the soft pulped ethnovariety. Kernel weight increased with shea fruit weight ($y = 0.1499x + 6.1887$ $R^2 = 0.306$). Big-oval fruited, soft pulped and Sweet pulped ethnovarieties had heavier kernels whereas Round fruited, small fruited and Tinny seeded ethnovarieties had the lowest kernel weights. Katakwi district had the largest shea kernel size (11.67 ± 1.59 mgs) while Moyo district had the smallest shea kernel size (8.75 ± 0.32 mgs)

Oil content was determined on 150 selected tree samples between August and September 2020 using wet chemistry. Moyo district had the highest ($54.37 \pm 0.32\%$) while Amuru district had the lowest ($50.5 \pm 1.32\%$) oil content. Oil content decreased with increasing kernel size ($y = -0.4541x + 57.303$, $R^2 = 0.2116$) and dry matter content ($y = 0.635x - 9.863$ $R^2 = 0.011$). Oil content varied significantly between the ethnovarieties ($P=0.003$) and shea tree populations ($p \leq 0.001$) respectively. Tinny seeded (45.7% - 65.49%), Round fruited (45.41% - 65.91%), Dwarf tree (45.19 - 64.19) Elliptical fruited (45.32% - 64.19) and Soft pulped (42.16% - 69.77%) ethnovarieties had the highest oil content. Narrow sense heritability (h^2) for oil yield was 1.72, response to selection (R) was 16.48 with genetic gain (G_s) of 2.21% given 10% top selection intensity. While, Tinny seeded, Round fruited, Dwarf tree and Elliptical fruited ethnovarieties can be bred to generate high oil yielding shea tree varieties, larger ethnovarieties with high fruit to kernel ratio like Soft pulped, Sweet pulped and big oval fruited can be bred for sweet, bigger and fleshy fruits characteristics for food and nutrition security among the households in Uganda.

Key words: Kernel, Ethnovariety, Oil content, Descriptor, Wet chemistry, shea tree

5.29 Occurrence and damage/severity of coffee pests and diseases in central Uganda

Olango N.D.¹, Olal S.¹, Kagezi G.¹, Kucel P.¹, Ekwaru R.¹, Judith K.¹, Arinaitwe G.¹

¹National Coffee Research Institute (NaCORI), P.O. Box 185, Mukono, UGANDA

Corresponding author: Olango Nicholas David – olangonicholas@gmail.com

Central Uganda is the leading coffee producing region of the country, contributing 38% of total production. The region primarily produces Robusta coffee, albeit with production levels far below yield potential. This low productivity is substantially attributed to pests and diseases. According to the Uganda Ministry of Agriculture, by 2014, the country was losing at least 8 million USD annually due to coffee pests and diseases. Unfortunately there is no published statistic of their incidence and severity/damage in the region. A biological survey of coffee was conducted in the region on September, 2020 to determine the incidence and severity/damage of diseases and pests. Five coffee producing districts were selected at random, the selected districts were; greater Masaka, greater Mubende, greater Mpigi, Kayunga and Luwero districts. Within each district, at least 2 coffee growing sub counties were selected at random, within each sub-county, 5 coffee farms located at least 2 Km from each other were visited and evaluated. Disease severity was evaluated for all the diseases on a 1-5 scale while pest damage was expressed as a percentage of tissue damaged by the pest. Results showed significant differences in incidence and damage/severity of all the major pests and diseases across the districts except for foliage beetles. The most damaging pest was the BCTB with an incidence of between 15% and 26%. The other very damaging pests were the tailed caterpillars and Skeletonisers (*lepidoptera*), and Root mealybugs



(Hemiptera) with incidence of 20.4%, 16% and 11% respectively. The most important diseases of coffee were all of fungal origin, Red blister disease (*Cercosporacoffeicola*) with incidence and severity of 51.6% and 2.0 respectively was the most important. The incidence and severity of other key diseases were; Brown eye spot (*Cercosporacoffeicola*) 47% and 1.5, Coffee leaf rust (*Hemileiavistatrix*) 32% and 1.5 and Coffee wilt (*Fussariumxylaroides*) 2.5% (incidence only). No previously unreported economically important pests or diseases were discovered. The survey identified a strong relationship between Red blister and brown eye spot which suggests similarity of the pathogen strain responsible for both symptoms, further studies are recommended to confirm this and also to better understand factors proliferating the pests and diseases.

Key words: Robusta coffee, pests, diseases, incidence, severity

5.30 Genotype and environment effects on resistance to sweet potato weevil and stability of root neck length

Florence Osaru, Jeninah Karungi, Roy Odama, Doreen Murenju Chelangat, Paul Musana, Milton Anyanga Otema, Bonny Oloka and Benard Yada*

F. Osaru, R. Odama, P. Musana, D.M. Chelangat, M.A. Otema, B. Oloka, and B. Yada, National Crops Resources Research Institute (NaCRRI), Namulonge, P.O. Box 7084 Kampala, Uganda;

J. Karungi, School of Agricultural and Environmental Sciences (CAES), Makerere University, P.O. Box 7062, Kampala, Uganda.

Selection of sweetpotato for resistance to sweetpotato weevil (SPW) using morphological and biochemical resistance-predictors requires conducting several trials to account for location and seasonal differences in SPW population and damage. Therefore, this study aimed at understanding G×E effects on resistance to the weevils and stability of the key resistance-predictor, root neck length. Therefore, 30 genotypes comprising local collections, released varieties, and breeding lines were evaluated in a 6×5 alpha lattice design at three locations (Wakiso; NaCRRI, Serere; NaSARRI and Arua; AbiZARDI) with three replications per site and two seasons (2017A and 2017B) in Uganda. Data was collected on sweetpotato weevil damage and the key morphological weevil resistance-predictor trait; root neck length. Genotype means varied significantly for all the measured traits. Genotype by environment interaction effects were significant for weevil damage severity ($P < 0.05$) while the interaction effect was non-significant for root neck length. GGE Biplot graph analysis revealed one mega-environment for weevil damage severity. This study also pointed at NaSARRI B as the best test environment for screening for sweetpotato weevil resistance. It is especially useful for selecting specifically adapted genotypes and culling. The study thus revealed that environmental differences have significant effects on weevil damage on sweetpotato cultivars in Uganda. As such, efforts to breed for resistance to sweetpotato weevil in Uganda should therefore focus more on specific adaptation than broad adaptation.

Key words: Genotypes, GGE biplots, mega-environment, multi-environments, weevil damage severity

5.31 Five Years of *Sclerotium rolfsii* Research in Uganda: Prevalence, Pathogen Diversity, and Management of Southern blight on Common bean

Pamela Paparu¹, Allan Nkuboye¹, Fred Kato², Catherine Acam², Justine Nakibuule¹, Amos Acur¹, Samuel Erima¹, Michael Hilary Otim¹ and Clare, Mukankusi²

¹National Agricultural Research Organization - National Crops Resources Research Institute, Namulonge, P.O. Box 7084 Kampala, Uganda

²International Center for Tropical Agriculture (CIAT), P.O. Box 6247, Kampala, Uganda



Corresponding author: Pamela Paparu

pamela.paparu@gmail.com/Pamela.Paparu@naro.go.ug; <https://orcid.org/0000-0002-1279-6507>

Southern blight (*Sclerotium rolfsii* Sacc.) infects over 500 plant species, causing significant yield losses. Recently, southern blight became the most important root rot of common bean (*Phaseolus vulgaris* L.) in Uganda, with prevalence in all bean agroecologies. Isolates of *S. rolfsii* from common bean in Uganda have diverse morphology and virulence, with some causing 100% disease severity index. However, genotypic diversity of the isolates is unknown, despite this being important for management of the pathogen. The pathogen is difficult to eliminate from fields because it survives for long periods in the soil, on crop residue, volunteer crops and alternate hosts. Whereas the use of resistant host plants offers the most sustainable and affordable control option to smallholder common bean farmers, there is currently no single variety resistant to southern blight. Integrated management approaches such as crop rotation, fungicide seed treatment, soil fertilization and use of agronomic practices that give a healthy start are being promoted among smallholder farmers. In this review, we present an overview of southern blight disease, what is known and remains unknown about Southern blight disease of common bean in Uganda, and propose areas that need to be addressed to generate vital information for its management.

Key words: Dry bean, Pathogen diversity, Root rot disease management, Sclerotium root rot, Southern stem rot

5.32 Harnessing native rhizobia strains' nitrogen fixation capacity for enhanced pigeonpea productivity in Uganda

Sadina. B¹; Natabirwa.H²; Katende. S³; Amayo, R⁴; Apio. S²; Galu. A⁴; Akao.C¹, and Tumuhairwe. J.B³;

¹National Semi-AridResources Research Institute (NaSARRI) P. O. Box 56 Soroti

² National Agricultural Research Laboratories (NARL-Kawanda) P. O. Box 7065 Kampala

³Makerere University College of Agriculture and Environmental Sciences (CAES) P. O. Box 7062 Kampala

⁴Busitema University Faculty of Agriculture and Animal Sciences (FAAS)-Arapai Campus P. O. Box 236 Tororo

Corresponding author: sadina.beatrice@gmail.com mobile: 0782269022

Pigeonpea (*Cajanuscajan*) is one of the key legumes grown mainly in northern Uganda constituting 77.1% of legume production. Despite the high production levels in the region, the productivity has stagnated at 500kg/ha-1 far below the potential yield of 1500kg/ha-1. This is attributed to declining soil fertility and yet nitrogen fixation by rhizobia in legumes like pigeonpea account for about 65% of the N used in agriculture, it's a relatively cheap source of N for resource constrained farmers and has the potential to reduce the use of N quantities from external sources that are environmentally hazardous. To address the concern of low productivity, a screen house efficacy trial was conducted for 31 native rhizobia isolates to determine their nitrogen fixation ability. The isolates were also morphologically and biochemically characterized and hierarchical cluster analysis was carried out to ascertain possible morphological groups. The results showed that four native rhizobia isolates had higher average total (34.92 ± 11.25) and active (27.92 ± 8.49) nodule counts than the standard strain (12.0 ± 4.0 and 2.0 ± 2.0) for total and active nodule counts respectively. While five isolates had higher total average (1.04 ± 0.4g) and active (0.86 ± 0.52g) nodule weights than the standard strain (0.47 ± 0.47g active fresh nodule weight). Seven native



isolates had average chlorophyll content of (42.81 ± 5.78) higher than the standard strain (41.13 ± 8.70) . The isolates were also grouped into four clusters with varying characteristics. The findings indicate that the native rhizobia isolates have a higher ability to fix nitrogen and thus can be harnessed for production of a biofertilizer for improved pigeonpea productivity in Uganda.

Key words: Native rhizobia, Isolates, Nitrogen fixation and Efficacy

5.33 Occurrence and distribution of the Potato Cyst Nematode *Globodera* spp., on Potato in Uganda

Shahasi Yusuf Athman¹, Abubakar Sadik Mustafa¹, Prossy Namugga², Wasukira Arthur³ and Herbert Talwana⁴

¹College of Natural Sciences, Makerere University

²Kachwekano Zonal Agricultural Research and Development Institute

³Buginyanya Zonal Agricultural Research and Development Institute

⁴College of Agricultural and Environmental Sciences, Makerere University

Potato cyst nematodes (PCNs) are global quarantine pests and the most problematic pests of potatoes leading to severe yield losses. In Uganda, PCNs (*G. rostochiensis*) were first detected in 2019 from 17% of farms sampled in the southwestern and eastern highlands. We report the results of the first structured and comprehensive survey undertaken in 2020 and 2021 to assess the occurrence and distribution of PCN in three major potato growing regions of Uganda. A total of 200 soil samples were collected from farms from the western, central and eastern potato growing regions and assayed for the presence of PCN in the laboratory. PCNs were found in 100% of the farms sampled. The density of PCN in the soil varied between and across farms/regions and ranged from 7 to 500 cysts per 100g soil. This study showed that the occurrence and distribution of PCN in Uganda is wider than previously reported and the severity of infestation is higher than the recognized economic injury level of 10 cysts/100g soil. Identification of the species of PCN present in the farms is currently on-going. This information is necessary to map PCN species distribution and to understand the factors fueling dissemination and population build-up of PCNs in the country in order to guide decisions for developing effective management practices.

Key words: potato, potato cyst nematode, incidence, distribution

5.34 Silage quality of different tropical maize inbreds

John Bosco Ssempera^{1,2}, Julius Pyton Sserumaga^{2*}, Phinehas Tukamuhabwa¹, Tonny Obua¹, Abasi Kigozi², Robert Mwesigwa², Moses Matovu², Dennis Asizua², Jimmy Ssemakula², Mohammed Kiggundu², Clementine Namazzi², Shadia Nassejje¹, Stella Ayesiga Bigirwa¹, Douglas Ntwatwa¹, Habert Galinya^{1,2}, Abdallah Kawere² and Swidiq Mugerwa².

¹Department of Agricultural Production, School of Agricultural Sciences, Makerere University, P. O. Box 7062, Kampala Uganda, Tel: +256 414 533332, Fax: +256 414 534125.

²National Livestock Resources Research Institute (NaLIRRI), Nakyesasa of National Agricultural Research Organisation, Wakiso, Uganda. P. O. Box 5704, Kampala, Uganda. Tel: 0414 – 691047.

Corresponding authors: johnbosco7168@gmail.com, j.serumaga@gmail.com

Maize silage is the major source of energy and contributes about 60% in animal diets. In Uganda, the production of low - quality silage among dairy farmers is prevalent and largely attributed to the



lack of inbred lines for silage hybrid development. The available inbred lines have not yet been fully characterized for silage quality traits yet the demand for high - quality silage is high due to introduction and improvement in genetics of different dairy animals. This study was designed to assess the silage quality of different inbred lines where twenty genotypes were screened in a 5 x 4 alpha lattice design randomized with two replications for two seasons. Laboratory proximate analysis was carried out on Crude protein (CP), Ether extract (EE), Metabolizable energy (ME), Neutral Detergent fibre (NDF), Acid detergent fibre (ADF), Crude ash (CA), dry matter (DM) and crude fibre (CF). R software package was used to run the statistical analysis. Preliminary results reveal that CP among the genotypes varied from 10.3% to 12.8%, DM from 24.5% to 33.3%, NDF from 56.6% to 72%, ADF from 29.2% to 41.7%, CF from 27.4% to 34.8%, CA from 5.7% to 8.5%, EE from 0.9% to 1.9%, ME from 7.8 to 10.9 MJ/Kg. Genotypes including NML 88, POBLAC 28C9 and SFDM 6 showed superior performance in Metabolizable Energy (ME) and Crude Protein (CP) which are the important nutrients needed by dairy animals in high quantities and therefore recommended to be used as parents in maize silage breeding programs for high quality silage production.

Key words: Inbred lines, silage, Genotype, Milk stage, Ensiling.

5.35 Toward precision genome editing in banana: Present scenario and future prospects

Jimmy M. Tindamanyire, Frank Kalungi, Henry Mwaka, Jerome Kubiriba, Priver Namanya Bwesigye

National Agricultural Research Laboratories, Kawanda. P.O Box 7065, Kampala, Uganda.

Corresponding author: tindajm@gmail.com

Genome editing of crops is a novel and rapidly evolving technology where targeted mutations can be introduced into a plant genome in a highly specific and precise manner. The technology does not incorporate transgenic modifications, therefore has gained traction as a viable alternative to genetic engineering whose products face negative publicity, acceptability and complex regulatory environment, a hindrance to their approval for commercialisation. Genome editing by clustered regularly interspaced short palindromic repeats (CRISPR)/CRISPR-associated protein 9 (Cas9), [CRISPR/Cas9] has been precise, highly effective and versatile in plants. CRISPR/Cas9 system is characterised by the Cas9 endonuclease and a single guide RNA (gRNA), which includes a 20-nucleotide spacer sequence targeting the gene of interest and a non-variable Cas9 binding site. The sgRNA binds to Cas9 targeting it to the specific DNA sequences and a protospacer adjacent motif (PAM) limiting the possible target sequences in the gene of interest. Through targeting the carotenoid Phytoene Desaturase [PDS] gene of selected EAHB cultivar, a CRISPR/Cas9 genome editing platform is being developed specifically to (i) Develop genome editing capacity to build gene-editing constructs and (ii) Develop protoplasts, as the starting material for subsequent gene-edited products without the need for Agrobacterium mediation. With the readily available Banana Genome Hub (<http://banana-genome-hub.southgreen.fr/>), and full genome sequences for 2 Matooke varieties, the NARO Banana scientists are developing the novel and efficient genome editing platform beneficial for addressing abiotic and biotic banana constraints. Building capacity in such advanced/cutting edge technologies enables continuous development of more easily regulated biotech products by leveraging on NARO's current human and infrastructural capacity for now and the future.

Key words: Genome editing, CRISPR, banana, genetic engineering, regulatory, phytoene desaturase



Sub-theme 6: Managing Interactions among Agriculture, Fragile Ecosystems and Changing Environment

6.1 Impact of Tree Pruning on Water Use in Tree-Coffee Systems on Smallholder Farms in Eastern Uganda

Joel Buyinza^{ab}, Catherine W Muthuri^c, Matthew D Denton^a and Ian K Nuberg^a

^aSchool of Agriculture Food and Wine, The University of Adelaide, Waite Campus, Urrbrae, SA5064, Australia; ^bAgroforestry Research Programme, National Forestry Resources Research Institute (NaFORRI), Kampala, Uganda; ^cEastern and Southern Africa Region, World Agroforestry (ICRAF), Nairobi, Kenya

Tree pruning is an important tree management option for reducing shading effects and altering whole-tree water use in smallholder farming systems. In this study, sap flow meters (SFM1s) were used to monitor whole tree water use in *Cordia africana* (*Cordia*), *Albizia coriaria* (*Albizia*) and *Coffea arabica* (coffee) trees in two coffee agroforestry farms in Eastern Uganda. Overstorey trees were subjected to a 50% pruning regime at a 6-month interval over a period of 20 months (July 2018 - February 2020). Pruning altered the synchrony in the vegetative phenology of *Albizia* trees, as leaf cover changes occurred earlier in pruned trees than in unpruned trees. Pruned *Cordia* and *Albizia* trees respectively used 22.8% and 50.1% less water than unpruned trees whose average daily water use was 76.5L day⁻¹ and 133.7L day⁻¹ respectively. Episodes of reverse flows were observed in *Albizia* trees (pruned and unpruned) and the pruned *Cordia* during certain periods of the year. There was a statistically significant main effect of tree species, pruning, season and their interaction on daily tree water use ($P < 0.05$). Coffee used 0.1 to 4.3 litres of water per day over the 20-month period. While unshaded coffee used more water than shaded coffee, coffee growing under pruned trees used more water than coffee under unpruned trees. This could have resulted from more transpiration pull in coffee resulting from increased radiation with reduced shading. Subsequently, canopy pruning of what? reduced the water demand of the tree component and resulted in recharge in the crop-rooting zone, although this seemed to appear later following consistent pruning. The study findings demonstrate that tree canopy pruning can regulate water use in smallholder agroforestry systems, the benefits of other tree products notwithstanding.

Key words: Sap flow, Canopy pruning, *Cordia africana*, *Albizia coriaria*, coffee

6.2 Agronomic performance of two sets international wheat germplasm from ICARDA in Uganda's mid and low altitude environments

Bosco Chemayek¹, Daniel Kwemoi², Kenneth Walimbwa¹, Philip Idro³, Wuletaw Tadesse⁴, Lawrence Owere¹ and Geofrey Asea²

¹National Agricultural Research Organisation, Buginyanya Zonal Agricultural Research and Development Institute, P.O Box 1356, Mbale

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

³Operation Wealth Creation (OWC), Uganda

⁴Biodiversity and Crop Improvement Program, International Center for Agricultural Research in the Dry Areas (ICARDA), Rabat 10101, Morocco

Corresponding author: bchemayek@gmail.com



Wheat is one of the most important and strategic staple crops for food and industry in Uganda. This study was conducted to screen and identify high yielding improved bread wheat varieties adapted to the heat and drought prone mid-altitude (1400masl) and lowland (1000masl) areas of Uganda. A total of 100 elite lines from ICARDA's international wheat yield trials; 50 lines from 18th DSBWYT and 50 from 18th ESBWYT were evaluated at Bulegeni and Namulonge in a RCBD under rainfed conditions. Analysis of variance was performed to contrast the differences within the varieties based on agronomic and yield-related traits. The analysis revealed highly significant difference ($P < 0.001$) among the different wheat lines for days to heading, days to maturity, agronomic score and grain yield indicating a difference in the genetic makeup of the lines and adaptability levels. Based on the combined results entry VAR-27521 was the best yielder (1948 Kg/ha) from DSBWYT while VAR-29141 (1605 Kg/ha) from the ESBWYT. Results also showed a highly significant difference ($P < 0.001$) in sites for days to heading, days to maturity, agronomic score and grain yield indicating a different performance of bread wheat varieties in the different sites. The lines performed better in the mid altitude Bulegeni compared to the low altitude Namulonge suggesting the need for further assessment of these wheat lines for more seasons and multiple locations. The best performing lines identified and selected from the two trials for the different environments will be used by the national breeding program as donor parents.

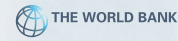
Key words: Bread wheat, Grain yield, Lowland, Rainfed

6.3 Tackling climate change effects in Robusta coffee by enhancing soil health through agroforestry

Judith S. Nantongo¹, Hillary Agaba¹, Joel Buyinza¹, Moreen Uwimbabazi¹, Herve Sanguin², and Bernard Fungo¹

¹National Forestry Resources Research Institute (NaFORRI), ²French Agricultural Research and Cooperation Organization (CIRAD)

Agroforestry's potential, especially in view of improving soil quality, has been widely recognized as a key climate change adaptive strategy. Among coffee farmers, climate change may pose severe challenges to sustain production and productivity levels. In Uganda, Arabica and Robusta are the two coffee species grown by approximately one million farmers. They are estimated to comprise 20% and 80% of the total production, respectively. Uganda accounts for 7% of global Robusta coffee exports. However, the quantity and quality of coffee, and hence incomes of coffee farmers, have been projected to be constrained by changing temperature, precipitation regimes and pests and diseases as well as the shrinkage of the suitable land area under coffee resulting from climate change. Currently, in Arabica growing areas in Uganda, for example, prolonged droughts, erratic and shorter rains have been associated with flower abortion, poor filling and increased pests and diseases. Yet, it has been indicated that the impacts of climate change will be more significant at low altitudes, suggesting that low land Robusta will potentially be more affected than Arabica. Many interventions have been suggested, such as irrigation. However, agroforestry - a land-use practice that intentionally links trees, crops, and/or animals under agroecological systems, is envisaged as a promising sustainable low-cost and green approach to mitigate and adapt Robusta coffee production to climate change and variability. Agroforestry's potential, especially to improve soil quality has been widely recognized although the impacts may vary according to the tree species involved, their management as well as other climatic and soil factors. Therefore, research activities have been designed at NaFORRI aimed at understanding the influence of specific locally preferred agroforestry trees on (1) soil organic carbon enrichment, (2) soil nutrient and soil fertility enhancement, and (3) soil microbial dynamics, which would positively influence soil and coffee health in low land Robusta-coffee agroforestry systems. The overall objective is to provide a scientific basis for selecting specific



agroforestry trees to mitigate different climate change scenarios e.g., drought. The presentation highlights the research design plus current knowledge and initial results on nutrient and water dynamics, including sap flow of the trees in Robusta coffee plus tree preferences as well as social-economic challenges associated with planting specific trees in Robusta coffee. Results will be a motivation for inclusion of agroforestry in Uganda's agricultural policies. Gaps for further research that need to be addressed for building climate resilient systems in Uganda are also identified.

Key words: Robusta coffee, climate change, Agroforestry, Resilience

6.4 Diversity and use of trees for food security in smallholder farming systems of Uganda's Mt. Elgon region

Fred Kalanzi¹, Isaac Kiyingi¹, Prossy Isubikalu², Florence Kyazze²,

¹National Forestry Resources Research Institute, Uganda

²Makerere University, Department of Extension and Innovation Studies

Agroforestry combines complementary tree species into cropping systems to increase spatial diversity. Because it combines trees and farming, agroforestry demonstrates how food production and nature can co-exist. However, smallholder farms have challenges to couple crop production and biodiversity conservation. This study assessed smallholder farms concerning their typology and tree species diversity. A cross-sectional survey of 277 randomly selected smallholder farmers who participated in the ACIAR-funded Trees for Food Security project was conducted. For each selected farmer, data on tree species diversity were collected on a plot with the most predominant agroforestry technology (boundary planting, intercropping and woodlot) and focused on deliberately integrated tree species. A cluster analysis was performed, and tree species diversity indices were computed and analysed according to each group. Two main groups of smallholder farmers could be distinguished: subsistence and semi-subsistence farmers. The tree species were distributed differently in the two identified groups. The tree species diversity was higher in subsistence farms than in semi-subsistence farms. Across the agroforestry technologies, tree species diversity was highest in intercropping, followed by boundary planting and woodlot. Subsistence farms showed a higher affinity to fruit tree species because they contribute directly to food security. In contrast, semi-subsistence farms were mostly dominated by trees of commercial value, such as Eucalyptus, mainly grown in woodlots. Therefore, we stress the critical role of smallholder farming systems in conserving on-farm diversity in the fragile eastern highlands of Uganda. The semi-subsistence farms may sell tree products to buffer their income and enhance access to food. However, tree species diversity for improving farming systems' resilience in the face of climate change remains low.

Keywords: Agroforestry technology, biodiversity conservation, food security, smallholder

6.5 Nutritional and antioxidant properties of stingless bee, *Meliponula bocandei* honey from two agro-ecological zones of Uganda

Chemurot Moses¹, Oromokoma Charles¹, Agnes S. Otim², Manugusho Gilbert³, Mwanga Victor⁴, Akite Perpetra¹, Matovu Moses² and Kasangaki Patrice²

¹Department of Zoology, Entomology and Fisheries Sciences, Makerere University Kampala.

²National Livestock Resources Research Institute (NaLIRRI) Nakyesasa, Wakiso District.

³Department of Nutritional Sciences and Dietetics, Kyambogo University

⁴Dr Ambrosoli Memorial Hospital-Kalongo

Corresponding author: Patrice Kasangaki 0772693241; patrice.kasangaki@naro.go.ug



Stingless bees are the most diverse group of social bees found throughout the tropical and subtropical regions of the world with at least 600 species. They contribute to food and nutrition security through pollination. Their honey, pollen and propolis are important food and medicinal resources for people. In Uganda, the stingless bee, *Meliponula bocandei* was recently domesticated to increase the production of its honey and propolis. In an effort to promote the use of the stingless bee honey as a food and medicine, this study was conducted to explore its nutritional and antioxidant properties. Selected nutritional and antioxidant properties (sugar content, mineral composition, total phenolic compounds, total flavonoids and DPPH) of the honey were determined following standard protocols. Results show the nutritional and antioxidant properties in the following ranges: sugar (50-76 mg/g), total phenolic compounds (7.21-95.38 gGAE/100g), total flavonoids (1.88-57.37 gCEQ/100g) and DPPH (2.07-18.04%). The total phenolic compounds and DPPH were significantly higher in honey samples collected during the dry season than the wet season. However, the honey samples collected during wet season had significantly higher total flavonoids than that of the dry season in both agro-ecological zones. The mineral elements recorded in the honey included P (132.12—5741.73ppm), Zn (0.46—41.42ppm), Ca (0—284.00ppm), Fe (9.61—52.78ppm), Cu (0—7.04ppm), K (9.05—490.03ppm), Mn (1.39—430.06ppm), Mg (7.64—291.56ppm) and Na (14.59—33.55ppm). Mean levels of these minerals were higher or within the limits of those reported in *Apis mellifera*. We recommend that people should embrace the consumption of stingless bee honey because it contains minerals and antioxidants that are vital for nutrition and health.

Key words: agro-ecological zone, antioxidants, meliponiculture, minerals

6.6 Effect of adding *Bacillus* species to the water of a coupled aquaponic system on the gastrointestinal microbiota of Mozambique tilapia, *Oreochromis mossambicus* (Peters, 1852)

Nasser Kasozi^{1,2}, Brendan Wilhelmi¹, Horst Kaiser³

¹Department of Biochemistry and Microbiology, Rhodes University, P.O. Box 94, Grahamstown 6140, South Africa

²Animal Resources Research Programme, Abi Zonal Agricultural Research and Development Institute, National Agricultural Research Organisation, P.O. Box 219, Arua, Uganda

³Department of Ichthyology and Fisheries Science, Rhodes University, P.O. Box 94, Grahamstown 6140, South Africa

Corresponding author: Nasser Kasozi, Nasser.Kasozi@naro.go.ug

A 90-day experiment was conducted to evaluate the effects of the addition of a probiotic mixture of *Bacillus subtilis* and *B. licheniformis* to a coupled aquaponic system on growth and composition of gastrointestinal microbiota of juvenile Mozambique tilapia, *Oreochromis mossambicus*. A total of 96 fingerlings (4.74 ± 0.01 g fish⁻¹) were randomly distributed into replicated independent aquaponic systems, with each containing 24 fish. Aquaponic systems assigned to the *Bacillus* treatment received 5.31 g of a commercial *Bacillus* mixture (Sanolife®PRO-W; 5.0×10^{10} CFU g⁻¹) twice weekly until the end of the experiment. The addition of the probiotic resulted increased weight gain, specific growth rate, feed efficiency and improved feed conversion ratio. Water quality remained within recommended ranges for tilapia culture, while free ammonia levels were reduced in the treatment systems. Microbial characterisation by IlluminaMiSeq sequencing of 16S rRNA gene amplicons showed that bacterial gut communities were dominated by the phylum Fusobacteria, specifically the species *Cetobacterium somerae*. Compared to the control, lower relative abundances of members of the family *Enterobacteriaceae*, represented by genera



Aeromonas, *Edwardsiella*, and *Klebsiella* were observed in the gut of *O. mossambicus* from the Bacillus treatment. The Shannon index values significantly decreased in the Bacillus treatment as compared with control, which suggests that the bacterial community was not modified to a large extent by the addition of *Bacillus* spp. This study establishes baseline data for probiotic trials in aquaponic systems.

Key words: Bacterial communities, probiotics, Next-generation sequencing

6.7 Introgressive hybridization levels of Tilapiine species in Lake Victoria basin, Kenya inferred from microsatellite and mtDNA genotyping based on next-generation sequencing

Gerald Kwikiriza^{ag*}, Thapasya Vijayan^a, Papius Dias Tibihika^b, Manuel Curto^{ca}, Gerold Winkler^d, Juliet Kattabi Nattabie, John Kariukif, Harald Meimberga

^aInstitute for Integrative Nature Conservation Research, University of Natural Resources and Life Sciences Vienna (BOKU), Gregor-Mendel-Straße 33, 1180 Vienna, Austria

^bNational Agricultural Research Organization, P.O. Box, 343, Jinja, Uganda

^cMARE-Marine and Environmental Sciences Centre, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal

^dInstitute of Hydrobiology and Water Management, University of Natural Resources and Life Sciences, Vienna (BOKU) Gregor-Mendel-Straße, 33 1180 Vienna, Austria

^eMakerere University Kampala, P.O. Box, 7062, Kampala

^fDepartment of Biochemistry, University of Nairobi, P. O. Box, 30197-00100, Nairobi, Kenya

^gNational Agricultural Research Organization P.O. Box, 421 Kabale

Corresponding author: Gerald Kwikiriza, gkwikiriza2@gmail.com

Institute for Integrative Nature Conservation Research, University of Natural Resources and Life Sciences Vienna (BOKU), Gregor-Mendel-Straße 33, 1180 Vienna, Austria

Introgressive hybridization levels of Tilapiine species in Lake Victoria basin, Kenya inferred from microsatellite and mtDNA genotyping based on next-generation sequencing

The study looks into use of modern molecular tools to understand the levels of tilapia hybridization level. But the abstract does not provide the objective and does not provide numerical evidence to suggest the stated conclusion. Authors should work on this and resubmit (accept after minor correction)

Despite their high abundance and species richness, the genetic structure of the tilapiines has been compromised by various factors especially overfishing, climate change, and un-controlled fish translocations. Fish translocations have negatively impacted native tilapiines populations through competition, predation, hybridization, and introgression leading to compromised genetic integrity. The hybridization levels of different tilapiines in the Lake Victoria basin remains relatively understudied. In the study to investigate hybridization signals and compare the genetic diversity of different tilapiines in Lake Victoria, Kenya, nuclear microsatellite and mitochondrial DNA (mtDNA) genetic markers were utilized using next-generation sequencing. Low levels of hybridization from *O. niloticus* into other *Oreochromis* species were detected by Bayesian clustering analysis and principal coordinate analysis (PCoA). The study contributes to the need for conservation measures of these fish species.

Key words: Tilapiines, Next-generation sequencing, Hybridization, Conservation



6.8 Host and Seasonal effects on the abundance of Bean Leaf Beetles (*Oothea spp.*) (Coleoptera: Chrysomelidae) in Northern Uganda

Moses Lutaakome^{1,2}, Samuel Kyamanywa¹, Pamela Paparu², Samuel Olaboro², Charles Halerimana³, Stanley Tamusange Nkalubo², and Michael Hilary Otim²

¹Department of Agricultural Production, College of Agricultural and Environmental Sciences, Makerere University. P. O. Box 7062, Kampala – Uganda

²National Crops Resources Research Institute – Namulonge, National Agriculture Research Organization. P. O. Box 7084, Kampala – Uganda

³National Coffee Research Institute, Kizuza, P.O. Box 185, Mukono, Uganda

Bean leaf beetles (BLBs) (*Oothea spp.*) are serious legume pests in Uganda and sub-Saharan Africa. In Uganda the beetles cause yield loss somewhere between 16.9% and 52.3%, but some aspects of their ecology are not well understood in order to design effective management strategies. We conducted field experiments in Arua and Lira districts, which are hotspots, to assess the effects of hostplants viz. common bean, cowpea, soybean, and influence of seasons on the density of adults and immature stages of BLBs. Overall, the number of adults, larvae, and pupae were higher in cowpea than common bean and soybean plots, respectively. The number of adults were highest on cowpea (29.5 adults/15 plants) in Arua during 2018A season. The number in 2017A did not differ significantly from that for 2018B season. Similarly, in Lira district, the highest number of adult BLBs was in cowpea (4.6), compared to common bean (2.7) and soybean plots, with peak at four weeks after planting (WAP). During 2018A, larvae of BLBs first appeared at five WAP and seven WAP, and peaked at 13 WAP and 11 WAP in Arua and Lira, respectively. The pupae were present in the soil after the harvest of crops during 2018A, but peaked at seven WAP and eight WAP in 2018B season in Arua and Lira, respectively. Occurrence of below-ground adults in 2018B followed peak abundance of pupae, however, delayed until six WAP in Arua compared to Lira. We conclude that cowpea was the most preferred by adults and larvae compared to common bean and soybean. Similarly, the first rain season (2018A) attracted higher abundance and damage than second rain seasons, which was also attributed to adequate soil moisture through the growing period.

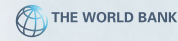
6.9 Isolation and Characterization of *Aeromonas hydrophilalytic* Bacteriophages Obtained from Selected Aquaculture Farms in Uganda as a safe antibiotic alternative biocontrol agent

¹Raphael Hans Lwesya, ¹Jesca L. Nakavuma, ¹Samuel P. wamala, ¹Claire M. Mugasa, ²John Walakira

¹College of veterinary medicine, animal resources and biosecurity, Makerere university

²National fishery resources Research institute-NAFIRRI, Uganda

Aeromonas hydrophila is one of the key pathogenic bacteria in aquaculture that results in huge losses all over the world. *Aeromonas spp.* are among the microorganisms that have developed into resistance to the majority of commonly used antibiotics in aquaculture, in addition to their inherent resistance to some medications like ampicillin. In Uganda, there isn't yet a reliable, affordable, or efficient alternative therapy for *Aeromonas* contamination or infection in aquaculture. This study aimed to develop a safe bio-control approach for therapy and decontamination for *Aeromonas hydrophila*. Specifically, the research objectives included the determination of the drug susceptibility of *Aeromonas* isolates from diseased tilapia; and the establishment of a stock of partially characterized *Aeromonas hydrophila* bacteriophages.



A total of 18 *Aeromonas* spp. isolates were tested for antimicrobial resistance against 10 antibiotics, using the Kirby Bauer disk diffusion method. Bacteriophage isolation, purification and characterization (host range and effect of temperature and pH on stability) were done using double agar overlay method and spot assay. Susceptibility of the isolates to various antibiotics was 100% for Ciprofloxacin and Gentamycin followed by 64.7%, 35.3%, 52.9%, 47.1%, 35.3%, 52.9%, 47.1% and 0% for Chloramphenicol, Penicillin, Tetracycline, and Nalidixic acid, Nitrofurantoin, Streptomycin, Trimethoprim/Sulphamethoxazole and Ampicillin, respectively. For bacteriophages, 19 crude preparations were obtained and three lytic isolates that had the highest host range (78.6% to 92.8%, n=28) were selected. Further characterization revealed a burst period of 20–40 minutes, a latent period that varied from 10 to 40 minutes; and burst size of 98–171 virions per infected cell. At a p-value of 0.05, there were no significant changes in phage titres on exposure at 40°C and 50°C for 60 minutes. However, a gradual decrease in the titres was observed at 60°C while a fast decline was noted at 70°C, 80°C and 90°C. At storage temperatures, the phage titres were reduced to 60% and 70% at 4°C and -20°C respectively. All phages demonstrated at least some activity in the pH range of 1–13, with optimum antibacterial activity observed in the pH range of 5–9. In water stability testing, the phages survived up to 22 days of experiment, with a sharp decrease of 1 log PFU/mL to have been encountered within the first 24 hours. The high phage host range, stability at temperatures and pH where they are likely to be applied in the management of the Aeromonas; and the high occurrence of drug-resistant *Aeromonas* spp. suggest the potential of developing the phage isolates for management of the disease in fish. Further characterization of the bacteriophages for absence of undesirable genes, which indicates their safety is recommended before bulk production for farm application is embarked on.

Key words: Bacteriophage, Phage application, aeromonas, Aquaculture, Bio-control

6.10 Juvenile tree seedlings' establishment in the dry lands of the Lake Albert Crescent Zone (LACZ) in Uganda, using hydrogels

Julius Masanyu^{1*}, Doreen Mugabi¹ and Joshua Nkosi¹

¹National Agricultural Research Organisation (NARO)–Bulindi Zonal Agricultural Research and Development Institute (BuZARDI) P.O. Box 101, Hoima, Uganda

Corresponding author: juliusmasanyu@gmail.com,

Dry lands in Uganda have problems of tree seedlings' establishment due to little moisture in the soils. This situation is getting worse with the extreme long periods of drought due to climate change. However trees are known to reduce vulnerability to climate change effects (ICRAF, 2013). For sustainable land management of these dry lands, we established an experiment of juvenile tree seedlings of *Cassia siamea*, *Eucalyptus camaldulensis*, (Neem) *Azadirachta indica* and *Melia volkensii* in three dry lands of Butiaba, Ngwedo and Kaiso Tonya within the Lake Albert Crescent Zone (LACZ) using hydrogels. The main objective was to determine the hydrogel concentration that produces maximum tree seedling growth during dry seasons. We therefore used varied hydrogel concentrations of 5, 10 and 15 grams together with a control of no hydrogels for each of the spp. Hydrogels can absorb water 400 times their weight and make it available to plants for uptake and use in the dry season (Agaba et al, 2014). The tree seedlings were planted at a spacing of 3m by 3m following a completely randomized block design. For each hydrogel treatment and each site 5 tree seedlings for each spp were planted. Data on tree heights was taken after 3 months and 6 months and analysed using R3.4.2 (R-Studio) for central tendency and significance testing. It was observed that in Butiaba and Kaiso Tonya all the eucalyptus seedlings without any hydrogels had dried after 3 months showing that without



hydrogel use, eucalyptus tree survival can be difficult if not impossible. After six months, all the control tree spp had dried up in all the sites except for *Cassia siamea* in Kaiso Tonya. It was also observed that the hydrogel concentration of 10 grams gave the maximum tree height establishment in Butiaba and Kaiso Tonya. In Kaiso Tonya, it was only *Cassia siamea* seedlings survived the dry season. For Ngwedo which is a little bit wet compared to others, the hydrogel concentration of 5 grams produced maximum growth of all the seedlings. It was concluded that hydrogel technology enhances tree seedling establishment in dry areas and should be recommended for uptake by farmers.

Key words: Hydrogel, tree seedlings, dry lands.

6.11 Impacts of the Victoria Nile Bujagali hydropower dam on fisheries and livelihoods.

Nduwayesu E¹., Basooma A¹., Sekiranda S.B.K¹., Balirwa J. S¹., Bassa S¹., Muhumuza E¹., Mugeni B¹., Mulowoza A¹, Musobya M.¹, and Nakiyende H.^{1*}

¹Capture Fisheries and Biodiversity Conservation Programme, National Fisheries Resources Research Institute (NaFIRRI), P.O. Box 343 Jinja, Uganda.

Corresponding author: nakiyende@yahoo.ie; Tel. +2567822168887

The Upper Victoria Nile (UVN) flows from Lake Victoria into Lake Kyoga, spanning 117 Km and supports a diverse aquatic fauna that sustains livelihoods of riverside communities. The UVN is habitat to critically endangered (*Labeovictorianus*), near threatened (*Oreochromis variabilis* and *Oreochromis esculentus*), and rare species (*Neochromissimotes*). Four hydro-power dams were built on UVN to provide energy for industrial and socio-economic development, notwithstanding consequential environmental and socio-economic impacts. The impacts of Bujagali Hydro-power (BHP) dam on the fisheries and livelihoods were assessed bi-annually (April and September) from 2006 to 2019, to contribute to biodiversity conservation. Data was obtained on the fishing effort indicators, species abundance, catch composition, and economic beach revenue at upstream, mid-reservoir, and downstream transects. The fishing boats increased from 31 in 2009 to 293 in 2019 and fishers from 83 to 500 over the monitoring period. Maximum annual catch of 461.4 t was recorded in 2014 and lowest of 54.2 t in 2009. In all transects, *Protopterus aethiopicus* and *L. victorianus* appeared least in the commercial catches and the use of *Mormyrus kannume juveniles* as bait for Nile perch fishery corresponded with increased catches from 3.3 t in 2009 to 148.2 t in 2019. Women mostly engaged in post-harvest activities such as fish drying, smoking and food vending. These observations could be a result of the coupling effects of the hydropower dam and ineffective fisheries management. We recommend a total ban on the harvest of wild stocks of *M. kannume* for bait and research into the aquaculture potential for this species. We further propose effective regulation of the escalating fishing intensity to avoid over-exploitation and implementation of conservation actions that mitigate potential biodiversity impacts from the hydropower dam operations and associated biodiversity net loss.

Key words: biodiversity conservation, fisheries management, *Neochromissimotes*, over exploitation, Upper Victoria Nile.



6.12 Establishment of *Psyllaephaus bliteus* Riek (Hymenoptera: Encyrtidae) as a bio-control agent for *Eucalyptus* pest *Glycaspis brimblecombei* Moore (Hemiptera: Aphalaridae) in Uganda

Violet M. Namuyanja¹, Ronald Kisekka¹, Peter Kiwuso¹

¹National Agricultural Research organization (NARO), P. O. Box 295, Entebbe, Uganda

Corresponding Author: Violet M. Namuyanja; Email: viomire12@yahoo.com

With an increase in global demand for timber and energy, trees like *Eucalyptus* that are fast-growing, high coppicing ability, and can be grown in most parts of the country, are preferred. However, invasive pests like the *Glycaspis brimblecombei* Moore (Hemiptera: Aphalaridae) (Redgum lerp psyllid) are threatening eucalyptus plantations globally. Elsewhere, classical biological control has been recommended as a successful intervention for managing Red gum lerp psyllid using *Psyllaephaus bliteus* Riek (Hymenoptera: Encyrtidae). This prompted its importation into Uganda. In the current study, we evaluated the establishment of this parasitoid in Uganda by assessing the parasitism by *P. bliteus* from release sites and beyond. Samples were collected from 10 release sites where 10 trees were randomly sampled per block each measuring 10*10 m across the country between August 2018 and December 2021. The sites were visited quarterly for three years (3years * 4 quarter). Infested leaf samples were obtained from the low, mid, and top sections of the *Eucalyptus* tree crown. Total number of *G. brimblecombei* nymphs on the abaxial and adaxial leaf sides was counted separately. Results indicate that mummified nymphs of *G. brimblecombei* were observed in all 10 release sites during the sampling period. Additionally, mummified nymphs of *G. brimblecombei* were recorded at least 179 km from the nearest release site four years after the initial release. Parasitized nymphs of *G. brimblecombei* were recovered in both plantations and on stand-alone trees. Our results also indicate that parasitism differences along the tree crown and on different leaf surfaces were not significant. These results demonstrate that *P. bliteus* has been established in field conditions in Uganda and since control is only possible after the establishment of natural enemies, this study infers substantial control of *G. brimblecombei* in Uganda. However, the social and economic impacts of the parasitoids need to be determined across the *Eucalyptus* enterprise.

Key words: Classical biological control, *Glycaspis brimblecombei*, *Psyllaephaus bliteus*, Uganda, *Eucalyptus*, Parasitoid.

6.13 Harnessing natural defences for maximizing productivity of trees and forests: lessons from pine species

J.S Nantongo¹, B. Potts², H. Fitzgerald² and J. O-Reilly Wapstra²

¹National Agricultural Research Organization/National Forestry Resources Research Institute,

²University of Tasmania

Forests are of immense importance to Ugandans. The NFA report of 2008 indicates that in 2004, the total economic value of Uganda's forests, including all marketable and nonmarketable values, was estimated at Uganda shillings (Ushs) 593.24 billion (Obua et al., 2010). Natural and planted trees are, however, subject to a wide range of pests and diseases, of which the most important causative agents are viruses, bacteria, fungi, oomycetes, and insect herbivores. Although, tree loss due to pest and diseases is underestimated, the increasing occurrence of native and non-native pests and diseases of trees is impacting rural livelihoods, economic development, and biodiversity across the continent of Africa (Graziosi et al. 2020), including Uganda. The conventional methods of controlling pests and diseases, such as the use of chemicals, are



costly and difficult to implement, especially in tree species that live long. Exploiting natural tree defence mechanisms can provide a sustainable and more convenient way of managing tree and forest pests and diseases. Using pine trees as a case study, we present results of different studies that examined the genetic variation, chemical diversity and molecular mechanisms associated with defence against herbivores. The lessons could be important given the significant pests and diseases on nationally important tree species like *Eucalyptus*. We examined the field variation in herbivory damage of structured pine populations to establish the quantitative genetic variation. We extracted DNA for genomic analysis of the variation. We also extracted non-targeted chemical compounds (terpenes, phenolics, sugars, fatty acids) that were analysed using chromatography to identify the specific chemical defences. RNA were also extracted and analysed for gene expression at different times following chemical inducers. The studies showed that there is genetic variation with moderate heritability ($h^2 \sim 0.2$) in susceptibility of trees to target herbivores. This genetic variation was attributed to specific terpenes (sesquiterpenes) and sugars, that were also under significant genetic control ($h^2 \sim 0.3$). The chemical phenotypes were associated with specific genes that remain unexploited in breeding for less susceptible trees. Overall, these different studies demonstrate the ability to select for less susceptible trees for enhanced productivity of trees. Such knowledge could be useful in managing other biotic and possibly abiotic stresses in both indigenous and exotic tree species in the region.

Key words: Pests and diseases; natural defences; trees

6.14 Effect of *Metarhiziumanisopliae* on non-target predator arthropods in farm land

Gerald Ongodia¹, Philip Nyeko², Benon M. Sekamatte³ and Hillary Agaba¹

¹National Forestry Resources Research Institute (NaFORRI), P.O Box 1752 Kampala, Uganda

²College of Agricultural and Environmental Sciences, Makerere University, P.O Box 7062 Kampala, Uganda

³Joint Energy and Environment Projects (JEEP), P.O.Box 4264, Kampala, Uganda

Corresponding author: byanagirado@yahoo.com, ijerad92@gmail.com, +256 772 695262

The use of biological methods to manage pests of economic importance, notably use of fungi to manage termites in farming is gaining prominence. Losses to productivity in farming as a result of termite attack to a variety of crops in east Africa are projected to range between 50 and 100%. Of particular concern are termites of the sub family Macrotermitinae that have been estimated to cause damage of up to 90% to crops, trees and structures. Natural termite control methods, although potent, may have effects on organisms not targeted yet may play an important role in the ecosystem. This study sought to understand the effect of *Metarhiziumanisopliae* fungus application for control termite attack on *Grevillea robusta* seedlings on useful arthropods often found preying in farmland. Arthropods were trapped in two phases; at pre-application (APP_0) i.e. control; and at 12 and 28 weeks (APP_{12} and APP_{28} respectively) post application of *M. anisopliae* fungal granules to the root collar area of *Grevillea robusta* tree seedlings planted in farmland. Trapping was done using 16 cm depth and 14.5 cm diameter pit fall traps installed into the ground to their full depths at known trapping zones (3 m and 6 m) from the *M. anisopliae* treated seedlings. This study was conducted in six different farms in Magada sub county, Namutumba district in eastern Uganda. The trapped specimens were transported to Makerere University, School of Forestry Environmental and Geographical Sciences (SFECS) pathology lab and cultured on sterile petri dishes lined with moist filter paper on a sterile lamina floor at room temperature. The cultures were inspected every 48 hours and the arthropod cadavers observed to show a characteristic green muscardine mycosis from *M. anisopliae* fungus counted and recorded. Pre (APP_0) and post (APP_{12} and APP_{28}) application of *M. anisopliae* to *G. robusta* had



no mycosis effect on arthropod cadavers. There was a non-significant effect of *M. anisopliae* infection pre (APP₀) and post (APP₁₂ and APP₂₈) application of fungal granules to *Grevillea* in the 3m ($F_{(2, 89)} = 0.559, p = 0.574$) and 6m ($F_{(2, 61)} = 1.216, p = 0.306$) zones. The effect of *M. anisopliae* infection on non-target arthropod orders (*Hymenoptera, Dermaptera, Coleoptera, Orthoptera* and *Araneae*) was non-significant in the 3m ($F_{(4, 89)} = 1.137, p = 0.346$) and 6m ($F_{(4, 61)} = 2.031, p = 0.106$) trapping areas. *Metarhizium anisopliae* fungus has no effect on non-target arthropods when applied in soil as an eco-friendly approach to manage pestiferous termites attacking *G. robusta* trees in agroforestry.

Key words: Pestiferous, Mycosis, Arthropod, *Metarhizium anisopliae*, Cadavers.

6.15 Integrated weed management in conservation agricultural systems

Otim Godfrey Anyoni^{1,2}, Obong Samson¹, Otim Bosco¹, Abdoulaye Fofana Fall², Obia Alfred⁴, Tumwebaze Susan³ and Laban F. Turyagyenda¹

¹Ngetta Zonal Agricultural Research and Development Institute, National Agricultural Research Organization, P.O.Box 295, Entebbe, Uganda.

²Uganda Martyrs University, P.O. Box 5498, Kampala, Uganda.

³Makerere University, P.O.Box 7062, Kampala

⁴Gulu University, P.O.Box 166, Gulu.

Corresponding Author: Otingw@gmail.com

Weeds cause a significant economic impact more harmful than insects and fungi. An integrated weed management approach is more effective than a single control. Decades of herbicide use as a single weed control method have caused the rise of herbicide-resistant weeds. Weeds are more difficult to manage in Conservation Agriculture (CA) than in conventional agriculture. Yet CA offers several benefits among which are increased soil quality and biological activity and reduced soil erosion among others. In Uganda CA farmers only adopted two of the three principles minimum tillage and crop rotation. Soil cover by mulching is not practiced due to the difficulty in obtaining mulch. Minimum tillage under CA may also lead to a change in the microenvironment leading to a shift in weed flora intensifying the weed management problems. A diverse weed management system will require a better understanding of weed biology and ecology; these are regionally specific. To investigate an appropriate method to estimate the soil seed bank among the three commonly used methods (Floatation, Cloth bag, and Greenhouse), weed seed bank composition and diversity were determined at soil depths (0–30 cm). Weed management practices were evaluated using a split-plot experimental design with two tillage practices (tillage₁, and tillage₂) as the main plot treatment and five soil cover practices (Soilcover₁, Soilcover₂, Soilcover₃, Soilcover₄, and Soilcover₅) as the subplot treatments established for 3 years (4 rainy seasons) on a sandy loam texture (ferrosols) in Lira, Uganda. Maize crop acted as the test crop and soybean provided soil cover (intercrop). The diversity of weed species was high for the Greenhouse method (Shannon diversity index $H = 1.0309$) compared to the Floatation ($H = 0.6538$) and cloth Bag ($H = 0.5428$). For the total soil depth sampled (0–30 cm), the weed seed population was significantly greater under tillage₂ (119 weeds m²) compared to tillage₁ (99 weeds/m²). For the effect of soil cover practices on weed diversity, there were no significant differences ($P > 0.05$) between the five soil cover practices. A combination of tillage practice and soil cover was more effective in suppressing weeds, especially broad-leaved weeds.

Key Words: Tillage, integrated weed management, soil cover, conservation agriculture, soil seed bank



6.16 Occurrence and severity trends of fusarium wilt disease in oil palm plantations in Kalangala

Otuba, M. A., Idd, R., Asiimwe, A., Akullo, R., Ddumba, G., Masika, F.B. and Ddamulira, G.

National Crops Resources Research Institute (NaCRRI), National Agricultural Research organization (NARO).

P O. Box 7084, Kampala, Uganda 27 Km Gayaza –Zirobwe road, Namulonge, Wakiso district, Uganda

Fusarium wilt (*Fusarium oxysporum f. sp. elaeidis*) is among the most devastating diseases of oil palm in Africa's commercial oil palm producing countries including Uganda. The first Fusarium wilt symptomatic oil palms in Uganda were observed in late 2018 in Kalangala. A study to monitor the trend of the disease in different production blocks in Kalangala was initiated to understand spread for application of sustainable management strategies. Quarterly surveillance on marked Fusarium wilt infested plots over a period of 30 months was done. Currently, results show that the disease was more prevalent in Kagulube block with an average plot severity of 3.5 and percentage plot incidence of 15.8% compared to other blocks such as Bbeta West that has an average plot severity of 1 and percentage plot incidence of 0% over a period of 30 months. The soils in the high prevalence plots in Kagulube are typical sandy compared to other areas. Sandy soils have poor nutrient retention capacity and are easily washed away under poor soil cover accelerating spread of the disease in the affected areas. The occurrence of Fusarium wilt of oil palm in Kalangala poses a potential threat to the growing oil palm industry in Uganda and East Africa in general, where oil palm production is expected to avert over dependency on imported crude palm. Hence fusarium wilt resistant oil palm hybrids in combination with integrated disease management practices stand to offer better alternatives for Fusarium wilt control. In Uganda where oil palm breeding is at its initial stages, comprehensive testing for resistance to the local strains of fusarium wilt and adaptability for imported disease resistant hybrids may offer a short-term solution to Fusarium wilt disease problem in Uganda.

Key words: Oil palm, Fusarium wilt, Spread, Kalangala

6.17 Predicting future heat stress in the pastoral rangelands of Uganda: Implications for milk production

Owoyesigire, B.^{1,2} D. Mpairwe¹, and P. Ericksen³

¹Department of Agricultural Production, School of Agricultural Sciences, College of Agricultural and Environmental Sciences (CAES), Makerere University, P. O. Box 7062 Kampala, Uganda

²Buginyanya Zonal Agricultural Research and Development Institute (BugiZARDI), Uganda

³International Livestock Research Institute ILRI, P.O Box 37009, Nairobi, Kenya

Heat stress is considered among the most important impacts of climate change on livestock production. The main objective of the study was to predict future heat stress and derive implications on milk production for cattle reared in the pastoral rangelands of Uganda. Temperature Humidity Index (THI) was used as an indicator of heat stress. Daily temperature and relative humidity data from 1960-2013 were used for computation of THI values. ARIMA models in SPSS Expert modeller were used to predict futuristic trends of heat stress. Best ARIMA model selection was made using Akaike information criterion (AIC) and Bayesian information criterion (BIC). ARIMA (1, 1, 0) (0, 0, 0)₁₂ was found the best fit model as it could perfectly produce an excellent match with THI values. Predicted THI values revealed increasing trends of heat stress at a rate of 0.079 per year. By 2030 the predicted THI will be above 72 maximum threshold beyond



which lactating cows begin to suffer heat stress. This will most likely impact negatively on milk production especially for cattle in open grazing lands. Therefore the current drive of farmers improving to high grade animals like pure Friesians is most likely not to be sustainable unless appropriate interventions are adopted. Therefore, there is need to keep livestock genotypes that are tolerant to increasing heat stress like indigenous long horned Ankole or their F1 crossbreds. There is also a need to adapt strategies like planting of trees to provide shade in open grazing lands and construction of shades to effectively minimize heat stress in the pastoral rangelands.

Key words: Heat stress, Temperature humidity index, rangelands

6.18 The potential of Joint crop-animal clinics in strengthening Agricultural Extension Service delivery in Uganda

Patience B. Rwamigisa¹, Angella Namyenya¹, Christine Alokit², Solveig Danielsen², Caroline Aliamo², and Idah Mugambi²

¹ Department of Agricultural Extension and Skills Management, Ministry of Agriculture, Animal Industry and Fisheries, Entebbe, Uganda; Email: rwamigisa@gmail.com ; namyenyamigadde@gmail.com

² Centre for Agriculture and Bioscience International (CABI) Uganda. Email; C.Alokit@cabi.org; S.Danielsen@cabi.org; C.Aliamo@cabi.org; I.Mugambi@cabi.org

Agricultural extension is one of the main drivers of agricultural transformation, and applies a wide range of methodologies for transfer of knowledge, information and technologies to farmers and other value chain actors. The Plantwise Programme aimed to establish and strengthen a sustainable Plant Health System in through use of plant clinics approach to give farmers advice. The approach was adopted in the national agricultural policy that enabled resource allocation and expansion of plant clinics to districts, as well as the inclusion of plant clinic tasks in the formal job descriptions of Central and Local Government officers. Smallholder farmers practice mixed farming and a study revealed that they also sought advice on animal health management from plant clinics however, veterinary staff were unavailable at such sessions. The pilot joint crop-animal clinics is intended to explore benefits of 'One Health added values' in aspects of improved cost-efficiency of joint service delivery to address major health and productions problems affecting crops, livestock, food safety and enhanced knowledge and awareness of farmers on the inter-dependence of crops and livestock for productivity, health, food safety and the environment. Uganda one health strategy is applied in management of zoonotic and environment issues and the joint crop-animal clinics offer potential for practical one health action. A quantitative research approach was used whereby joint clinics were setup in four pilot districts of Uganda with agriculture and veterinary staff attending to farmers at one location each time. The clinics were widely advertised for farmers to come and consult and detailed guidelines on how to conduct the clinics designed and applied. Farmers' queries were captured using data sheets and analyzed using descriptive statistics with Excel. Findings revealed that farmers sought information beyond crop pest management. An average farmer attendance per session of about 15 was recorded at 83 clinic sessions from the four districts. Farmers presented 59% crop related queries of which 90% were on pests and diseases, 10% on management practices and 41% animal related queries of which 73% were on vectors and diseases and 27% on husbandry practices. Previous plant clinic evaluation results indicated that seeking plant health advice from plant clinics led to crop-based productivity and income increase of between 12 and 30%. These findings demonstrate that joint crop-animal clinics approach has potential to improve agricultural extension service delivery and needs to be explored for recognition at agricultural policy and strategic levels as potential sources of knowledge, information and technologies.

Key words: Joint crop-animal clinics, Agricultural extension, Agricultural Policy.



6.19 Community structure and distributional patterns of Pelecypoda upstream and downstream of Bujagali Hydropower Project along the Upper Victoria Nile

Stephen B.K. Sekiranda^{1*} Pabire W. Ghandi¹ and Vincent Kiggundu¹

¹National Fisheries Resources Research Institute (NaFIRRI), Plot 39-45 Nile Crescent, P. O. Box 343, Jinja, Uganda.

Corresponding author: sekirandastephen@yahoo.com, Tel. 256-752480212/0787808067

Pelecypoda (Bivalvia) are mainly bio-filter feeders that improve water quality of where they live because as they feed, they filter organic matter, phytoplankton, zooplankton, bacteria etc., suspended in the water and excrete fine particulate matter. In the Upper Victoria Nile (UVN), the community dynamics of bivalves is largely unknown. Bivalvia community structure changes of the UVN were biannually examined using proxies of Shannon-Weaver Diversity Index, Simpson's Dominance Index, Pielou's Evenness Index and spatial-temporal abundance from April 2006 to April 2021 at three transects: upstream (Kalange-Makwanzi), mid-reservoir and downstream (Buyala-kikubamutwe). Biannual (April and September) abundances of Pelecypoda were obtained by a ponar grab in pool areas of the transects to determine variations in the assemblage structure in relation to Bujagali Hydropower Project (BHP). The pelecypod community consisted of nine bivalve species in the zoobenthos belonging to five families, namely; Unionidae, Iriniidae, Etheriidae, Cyreniidae and Sphaeriidae. Three of these families (Unionidae, Iriniidae and Etheriidae) were of the order Unionida (freshwater mussels). Both Unionidae and Etheriidae were represented by one freshwater mussel species, *Coelatura sp.* and *Etheria elliptica* respectively. The Unionida family Iriniida was represented by two species, *Aspatharia sp* and *Mutela sp.* Two orders of freshwater clams, namely; Sphaeriida and Venerida were encountered. Venerida was represented by one family, Cyreniidae with only one species, *Corbicula africana*. Sphaeriida too was represented by one family, Sphaeriidae which consisted of four species, namely; *Pisidium victoriae*, *Byssanodonta parastica*, *Sphaerium victoriae* and *Sphaerium stuhlmanni*. Freshwater clams (Unionacea) were the most characteristic and widespread riverine pelecypods. Freshwater mussels on the other hand were poorly distributed and much less diverse. These mussels can be raised in culture tanks and restocked in the river to boost their populations.

6.20 Host-plant Preference and Oviposition Responses by the Sorghum Midge on Grain Sorghum

¹Wandulu A. J, ²Talwana H.

¹National Semi Arid Resources Research Institute (NaSARRI), P.O. Box 56, Soroti, Uganda Tel: 07724444767, 0753444767 Email: josephwandulu@gmail.com

²Makerere University, P.O.Box 7260, Kampala, Uganda Tel: 0772521685

Corresponding Author: haltalwana@gmail.com, haltalwana@caes.mak.ac.ug,

Sorghum *Sorghumbicolor* is increasingly becoming an important food crop, feed, and industrial raw material. It is drought tolerant and adapted to grow under harsh conditions. Sorghum midge *Stenodiplosis sorghicola*, is the most important pest of grain sorghum worldwide. Host-plant resistance is an important control measure for sorghum. To-date no information on sorghum reaction to midge has been done. A study was therefore, conducted to assess sorghum midge host preference, oviposition and damage of *S. sorghicola* under choice and no choice situations in the field in a randomized complete block design. Female sorghum midge flies preferred to infest and oviposit on some sorghum germplasm, while others were not preferred for infestation and oviposition. Significantly ($P < 0.05$) fewer adult female midge flies 1.38 – 3.8 infested sorghum accessions AS21, AF28, GA08/103, IS8884, IESV94023SH, SEREDO, SEKEDO, with corresponding



less yield loss and fewer larvae observed, categorized resistant to midge infestation and damage. Genotypes GA010/010 and MACIA were significantly ($P < 0.05$) most infested and damaged with corresponding high yield loss and more larvae, categorised as susceptible to midge. Flies frequented susceptible germplasm for oviposition compared to resistant ones. The higher the pest pressure the more damage caused to sorghum irrespective of the resistance status. Sorghum floral morphological parts were partly responsible for expression of resistance or susceptibility to the midge fly. Resistant genotypes, IESV94023SH, AF28, AS21, AS25, MACIA and WAD had significantly ($P < 0.05$) longer floral glume lengths ranging 5.57–4.16mm, compared to the susceptible germplasm GA010/010 (4.53). Floral style length ranged 2.26 – 0.98mm, resistant genotypes AF28, AS21, AS25, GA07/84, Seredo, GA08/103 had significantly ($P < 0.05$) shorter style lengths compared to GA010/010 which is susceptible. Promising sorghum genetic materials identified with unique floral morphological traits can be used in breeding for resistance against midge.

Key words: *Stenodiplosis sorghicolar*, host-resistance, antixenosis, antibiosis



Sub-theme 7: Modernizing Post-Harvest Management and Food Safety Systems

7.1 Taking Stock of farmers participation in the eVoucher agricultural subsidy program in Uganda

Adong A.

This article examines farmers to participate (registration, ordering and redemption) in the e-voucher program and in different cycles. We used secondary datasets namely: the e-voucher data base and the cohort data. Our results reveal that although the requirement was that in each household, only one household member should be enrolled in the e-voucher system, results shows that there have been incidences in which more than one household member gets enrolled in the e-voucher system. About 22 percent of households had more than one beneficiary within the household. The correlation with the number of seasons that household has ordered for inputs is only 13 percent suggesting that this can be an avenue of farmers getting around the limitation that the e-voucher program supports only inputs worth one acre per household and ensuring that all members within the household have access to the program for equity purposes. These households are usually wealthy owning many farms equipment and assets for transportation. Youth and women headed households are less likely to have more than one member enroll in the e-voucher and this shows how the targeting of the youth is not achieved due to the leakages.

Transition to the subsequent cycles beyond one cycle are very low at less than 2 percent: 97 percent of farmers enroll in the first cycle, and only some two percent proceed to the second cycle, and less than one percent proceed to cycle three. Also, a higher proportion of male farmers (59 percent) enroll in the e-voucher system compared to 41 percent of female farmers. People who participate beyond cycle one besides being wealthy also agree that they have a clear understanding of the requirements of the e-voucher system and take pride in the co-funding of inputs.

Not all registered farmers order inputs. From the e-voucher data base, between 45 to 70 percent registered farmers order inputs. Those who order inputs are wealthier and have a higher level of education. They also take pride in the co-funding of inputs which is a key element of the eVoucher program. Youth and women are more disadvantaged when it comes to the ordering and redemption of inputs: Youth are also more likely to redeem only one input because of the lack of resources. Also, women headed households are less likely to order inputs compared to their male counterparts which may be attributed to the lack of liquidity.

Ordering and the redemption of inputs is influenced by the wealth status of the household, availability of transport facilities, a clear understanding of the requirements of the e-voucher program, the pride one takes in the co-funding of inputs between farmers and the Government and training. Generally, farmers in cluster 6 and cluster 11 are more likely to redeem more inputs than farmers in cluster 1. Farmers who have redeemed inputs from other sources are less likely to redeem more inputs and this suggest the complementarity that other input providers such as OWC have with the e-voucher program. Those who don't clearly understand the requirements of the e-voucher program are also more likely to order one input. Similarly, those who have received training are less likely to order one input. Therefore, clearly articulated information and training are important components for households to participate in the program.



7.2 Consumer Experiences with Processed Bean Products

Immaculate Babirye¹, Florence Nakazi³, Jackline Bonabana², Gabriel Elepu², Stanley Nkalubo¹, and Michael Ugen⁴

¹National Crops Resources Research Institute, Legumes Department

²Makerere University College of Agriculture and Environmental Science, Department of Agribusiness and Natural resource Economics

³Economic Policy Research Center Kampala-Uganda,

⁴National Semi-Arid Resources Research Institute

Abstract of a paper prepared for oral presentation at the NAROMAK conference 2022.

Consumption of processed foods is becoming an increasingly important component of the food system as more of the working class chooses to dine out rather than prepare meals at home. This comes along with changes in what they choose to buy to reduce the time for cooking. However, in the bean subsector in East Africa, there has been limited value addition to meet the changing demand and preferences for value-added bean products. To meet the growing demand for processed and quick-cooking beans, there have been efforts by the National Agricultural Research Organization (NARO) and the Kenya Agricultural and Livestock Research Organization (KALRO) to introduce quick-cooking bean products “precooked beans” on the Ugandan and Kenyan markets. However, consumers’ perceptions and experiences with processed bean products have never been assessed. Data were collected by following up with 60 processed bean consumers of which 36 were subjected to direct interviews and later data weighted to adjust for non-responsiveness by some consumers. A two-way MANOVA and multivariate regression were employed to examine the various processed bean attributes including safety, pricing, nutrition, energy-saving, proper packaging, time-saving, fair pricing, and ease of serving. Study findings reveal that baked and canned beans were perceived to be more energy and time-saving but were perceived as non-nutritious. In terms of place of sale, processed bean products sold at the retail shops were relatively cheap (\$0.66 less) compared to those sold in supermarkets. Aspects such as safety and nutrition should be considered by the food processing companies and deliberate efforts made to sensitize consumers on these aspects.

Key words: Value addition, Processed Beans, MANOVA, Nutrition, Food Processing.

7.3 Post-harvest Handling and Loss Mitigation in Common Beans in Selected Districts of Uganda

Immaculate Babirye^{1*}, Michael Hilary Otim¹, Pamela Paparu¹

¹National Agricultural Research Organization – National Crops Resources Research Institute (NARO-NaCRRRI)

Abstract of a paper prepared for Oral presentation at the NAROMAK conference 2022.

Theme: Innovations for Enhancing Productivity, and Agro-industrialization

Subtheme 2: Modernizing Post-Harvest Management and Food Safety Systems

Post-harvest handling of common beans has remained a key challenge among bean farmers and traders in Uganda, leading to quantitative, qualitative, and financial losses. A study was therefore conducted to determine the level of post-harvest losses and document the major



common bean post-harvest technologies among farmers in the districts of Arua, Oyam, Nakaseke, Sironko, and Hoima. Farmers in the study districts carried out up to 12 post-harvest activities including threshing (98%), winnowing (91%), drying pods (82%), and drying grain (80%). Significant losses are recorded at all these stages mainly because the activities take several days to complete. Grain loss was recorded to start at the time of harvest with 84% of farmers harvesting beans after completely drying, a practice that results in shattering and rotting of beans in the field. The greatest losses were recorded during harvesting followed by sorting, on-farm storage, threshing, and transporting. At these stages, farmers reported mean losses of 10 kg, 8kg, 8kg, 6kg, and 5 kg per 100kg of harvest. Farmers mainly used rudimentary technologies such as uprooting during harvest, threshing with sticks, and sorting by hand. Over 70% of the farmers reported hiring labor to carry out postharvest activities. Some farmers employed techniques such as tie-dry-thresh where farmers tie uprooted physiologically mature beans up to dry and thresh them from the same place, the use of light plastics to develop sheaves and winnowing material instead of metal and wood, as well as the use of tarpaulin during winnowing. In this paper, we discuss the implications of the findings.

Key words: Innovations, Postharvest, Technologies, Farmers, Losses

7.4 The Provision of Agro-inputs in Uganda, who are the influential actors and what are the governance challenges: A case of Uganda

Ilukor J., Opoloth N.,

In this paper, we examine the process of delivering or accessing inputs using the eVoucher program under the ACDP program. A Process Net-Map tool is used to map the consecutive steps of the process accessing in input through the eVoucher, identify relevant actors and assess their influence in the delivery or provision of agricultural inputs as well as challenges and potential solutions for addressing these challenges. The key influential actors are extension officers, farmer group leader, eVoucher provider and agro-input dealers among others. The main challenges were unstable network often leading to system failures, limited political will, late delivery of inputs because of slow expansion of the agro-input network often leading to partial deliveries; weak client service, limited ICT capacity for government staff, and delays in replenish the government contribution. The possible solutions to the addressing these problems are improving functionality of the of the eVoucher systems, building capacity of government staff in ICT, and expansion of the agro-input markets.

7.5 Effect of nixtamalization on mycotoxin levels and sensory properties of maize products in Uganda

Archileo N. Kaaya^{1*}, Naggayi Maureen¹, Clare Narrod² and Joy H. Kauffman³

¹Department of Food Technology & Nutrition, Makerere University, P.O. Box 7062, Kampala; Corresponding Author; email: archileo.kaaya@mak.ac.ug;

²Joint Institute for Food Safety and Applied Nutrition, 2134 Patapsco Building, College Park, MD 20742-5551 USA; ³Farm Stew International, 470 Adams St. Tiskilwa IL 61368, USA

This study analyzed the effect of nixtamalization on mycotoxin content and consumer willingness at village level, to consume products made from nixtamal maize. Fifty (50) kg of maize grain were nixtamalized using 1% slaked lime (Ca(OH)₂) and 1% wood ash, dried in an electronic dryer, milled into flour and used by consumers in Iganga and Mubende districts, to make porridge



and posho. Both districts are among those where maize is highly produced and consumed in Uganda. Porridge and *posho* were subjected to sensory evaluation by panelists representing village consumers in these districts. Prior to and after nixtamalization, the maize was tested for aflatoxin and fumonisins to ensure consumption of safe products. Nixtamalization using both slaked lime and ash significantly ($P < 0.05$) reduced aflatoxin and fumonisin content below East African regulatory levels (10 ppb and 4 ppm respectively) making the products safe. Overall, both porridge and *posho* from nixtamal maize were liked by the panelists for all the sensory attributes tested (General appearance, colour, aroma, thickness, taste, aftertaste and overall acceptability). For porridge, consumers could not differentiate between the colour of the control and that made from nixtamal maize. These results imply that communities in Uganda are likely to accept products made from nixtamal maize and thus, nixtamalization technology could be scaled up in the country.

Key words: Nixtamal maize, consumer acceptability, safety

7.6 Analysis of the quality of bean and maize seed at key points along the seed value chain – implications for upgrading the seed system

Letaa E., Erongu M.

Recent studies suggest that seed systems in Uganda undermine farmer productivity and resilience by supplying them with planting material of inferior quality. This evidence base is however fragmented, less representativeness and thus cannot inform policy and institutional design aimed at enhancing resilience of seed system. Using a nationally representative sample we sample bean and maize seed at key points between breeders and farmers. Physical seed quality parameters – germination percentage and moisture content are tested for seed collected at each of the key points in beans and maize seed system. Additionally, genetic purity of the samples is analyzed, against the genetic make-up of the breeder seed of the selected varieties, using a high-density genotyping assay.

7.7 Acceptance of bio-degradable Stoverpack among agricultural products market actors in Kampala and Wakiso districts

Stephen Lwasa¹, Adam Charlton², Florence Miremadi³, Naila Khairallah³, Jalia Packwood², John Baptist Kirabira¹, Andrew Ayor¹, Davis Bariho⁴, Esther Mugambe⁵, Carol Bukirwa Nakato¹, Leticia Katiiti¹, Pamela Matovu¹, Rusia Oririkiza⁴, and Grace Mbabazi¹

¹Makerere University, Uganda, ² Bangor University, United Kingdom, ³ Nafici Environmental Research, United Kingdom, ⁴ Oribags Innovations (U) Limited, Uganda,

⁵MusaBody (U) Limited.

Corresponding Author: Stephen Lwasa, Makerere University, P. O, Box 7062, Kampala, Uganda

The biodegradable stover packs are designed to reduce post harvest losses, improve shelf life of food products and prevent food spoilage, and are tradable. The study aimed at creating awareness and assess acceptance of a new value proposition for biodegradable packs manufactured from waste maize stover in Uganda. This was achieved through assessing the different types of packs market actors majorly use, its acceptability, and how much more THEY are willing to pay for the biodegradable packs. A descriptive cross-sectional study was conducted among 84 consumers, 42 processors and 90 traders. Results revealed that consumers, processors and traders mostly used polythene bags. They were willing to purchase the new biodegradable packs at a higher price (in the range of \$0.1 – 0.27). Age, sex, education, annual income, access,



quantity of produce traded, amount of produce transported to the market that gets damaged during transportation were significant influencers of willingness of market actors of agricultural produce, to pay more for the new biodegradable stover packs. Therefore, awareness creation and acceptance of the biodegradable packs, as a solution to environmental degradation and as a cheaper solution were pursued and achieved in this study. These are critical pre-requisites in the viability of the stover based biodegradable packs among market actors.

Key words: biodegradable packs, market actors, maize stover.

7.8 Mitigation Measures for Reducing Tomato Post-Harvest Losses at Farmer Level in the Lake Victoria Crescent Agro-Ecological Zone

Damalie Babirye Magala¹, Jerry Egessa², Jackie Atim³, Godfrey Sseruwu⁴, Teopista Namirimu⁵

¹ National Agricultural Research Organisation (NARO), Mukono Zonal Agricultural Research and Development Institute (MUZARDI),

² National Agricultural Research Organisation (NARO), Mukono Zonal Agricultural Research and Development Institute (MUZARDI),

³ National Agricultural Research Organisation (NARO), Mukono Zonal Agricultural Research and Development Institute (MUZARDI),

⁴ National Agricultural Research Organisation (NARO), Mukono Zonal Agricultural Research and Development Institute (MUZARDI),

⁵ National Agricultural Research Organisation (NARO), Mukono Zonal Agricultural Research and Development Institute (MUZARDI),

Globally, tomato (*Solanum lycopersicum*) is one of the major vegetable crops due to its nutritional, health and economic importance (Guan et al., 2017). In Uganda, tomato is widely cultivated by small-scale producers on less than 2 hectares. The attained yields are much lower than the potential due to pests and diseases, lack of irrigation facilities and insufficient information on sustainable agronomic practices (Atuhaire et al., 2016). Further, tomato production is constrained by post-harvest losses, which limit the volumes of quality produce that reaches the market. Substantial research effort has been geared towards tomato post-harvest losses at market level but limited investigation has been done to document practical measures to reduce their effects at farm level. A study to better understand the farmer mitigation measures was conducted in Wakiso and Luwero as some of the major tomato growing districts in Central Uganda. A purposive sampling technique was used to select the study areas and respondents. Data were collected using a pre-tested semi-structured questionnaire with four focus group discussions consisting of 55 respondents. Data was analyzed by content analysis. Results indicated that Asla F1 Hybrid was the most common variety grown due to its firmness and long shelf life and pest and disease resistance. To manage post-harvest losses, farmers practiced staggered planting to avoid over production and supply sufficient volumes to markets. Also tomato was harvested mainly at mature-green stage in morning and evening hours. Due to lack of technical know-how, there was no deliberate effort for post-harvest technological treatments nor mandatory body for produce inspection which affected the quality. After harvesting, farmers applied pesticides to reduce fruit rotting. Majority of the farmers sold their produce individually and lacked standardized measurements which caused exploitation by middlemen. To enhance farmer's capacity, the study recommends farm level training in appropriate postharvest handling.

Key words: tomato, post-harvest losses, innovative, Central Uganda



7.9 Use of photovoice technique to analyse factors that influence peanut product quality and safety along the value chain in Uganda

R. M. Mirembe^{1*}; A. N. Kaaya¹; D. Male¹, S. Lwasa²; D. Kemigisha², D. K. Okello³, D. Musoke⁴, A. Carter⁵, T. Gill⁵; D. R. Ader⁵; C.A. Stephens⁵

^{1*}Department of Food Technology and Nutrition, Makerere University, Kampala, Uganda; Corresponding Author, email: mruthmartham@gmail.com;

²Department of Agribusiness and Natural Resource Economics, Makerere University, Kampala, Uganda;

³National Agricultural Research Organization (NARO), NaSARRI;

⁴Department of Disease Control and Environmental Health, Makerere University, Kampala, Uganda;

⁵Department of Agricultural Leadership, Education and Communications, University of Tennessee, USA.

The quality and safety of peanuts has been highly compromised along the value chain due to inadequate handling. Assessment of quality and safety has proved to be very expensive in Uganda, necessitating a cheaper alternative technique that can be used. This study aimed at using photovoice, a community participatory research technique to evaluate on-farm and postharvest handling practices that influence the quality and safety of peanuts along the value chain. Thirty (30) rural youth farmers aged 18-35 years in Nwoya and Tororo districts of Uganda were trained in photovoice technique and provided with smart phones to take photos of what they understood by peanut quality and safety attributes over two growing seasons. Qualitative data from the focus group discussions with the youth conducted every two months was analysed using content analysis in Atlas ti version 6. Rural youth farmers were able to use photovoice for two peanut seasons to assess pre- and post-harvest handling practices that influenced peanut quality and safety under five broad categories; agronomic practices, pests and diseases, storage, processing and marketing. Photovoice was able to identify and assess the risk factors that exposed peanuts to adverse contamination levels which can be prevented and controlled in communities. Results further indicated that the peanut quality and safety burden in Uganda is still high and needs urgent and appropriate interventions especially at postharvest level. This study recommends photovoice as a technique that can be used by farmers to assess quality and safety in resource limited communities, used as a training tool for pre- and postharvest handling in rural communities and should be disseminated in the country.

Key words: photovoice, value chain, quality and safety, peanut, Uganda

7.10 A Systems Approach to Exports of Quality Capsicums from Uganda into the European Union

Nankinga, C.M.¹, ²Kisingiri, J.B., ¹Ssamula, A., ¹Ekaru S., ¹Owiny, R., ¹Okwiri, R.B., ¹Mwambu, P.¹

¹National Agricultural Research Laboratories, P.O. Box. 7065, Kampala

²Ministry of Agriculture, Animal Industry and Fisheries, Department of Crop Inspection and Certification, P.O. Box 102 Entebbe

Corresponding Author: cmnankinga@gmail.com, Tel: +256 772524642

Between 2015 and 2019, an astounding 497 interceptions of horticultural export consignments from Uganda were recorded in the European Union (EU). These were due to presence of *Thaumatotibialeucotreta* (Meyrick) commonly known as False Codling Moth (FCM) and Fruit flies in horticultural exports of Peppers, Garden eggs, Mangoes, Soursop and Roses. Further, an EU Audit during 2019 for Uganda's phytosanitary controls revealed high FCM prevalence and incidence



in production places. Though official controls were in place, the findings signified high phytosanitary risk to import such commodities into the EU. To foster phytosanitary compliance and reduce incidence of quarantine pests on exported produce, the National Plant Protection Organization (NPPO) proposed to private sector, utilization of a Systems Approach based on the International Standard for Phytosanitary Measures (ISPM) 14. This system integrates several pest mitigation measures along the commodity value chain including; farmer, exporter and pack-house registration, growers implementing integrated pest management, and continuous review of evidence of growers' crop protection practices in reducing FCM incidence. Additional measures include regular official inspections for post-harvest practices in packhouses facilities exporting Capsicum, commodity and notification traceability, exit inspection and issuance of electronic phytosanitary certificates. Stakeholders in the fruit and vegetable value chain ought to embrace the systems approach for management of pests on commodities, as documented in the Uganda Capsicum technical dossier submitted to and approved by the European Union.

Accept for oral. Minor revision

Key words: System Approach, ISPM 14, Capsicums, European Union,

7.11 Utilization of orange fleshed sweet potatoes in production of noodles

Natocho J., Muyonga J., Mugabi R.

Department of Food Technology and Nutrition, Makerere University, P.O. Box 7062, Kampala, Uganda

Corresponding author: natochoj1@gmail.com

Sweet potato (*Ipomoea batatas* L. Lam) is the fourth most important food crop in Uganda, with respect to production volume, with annual production of 1.8 million MT. The crop is widely grown and consumed in the country and contributes significantly to food security. In recent years, orange-fleshed sweet potato (OFSP) varieties have been recognised for their potential to contribute to the alleviation of vitamin A deficiency, due to their high beta-carotene content. High post-harvest losses, limited value addition and low farm-gate prices limit the benefits from sweet potatoes in Uganda. Currently, the crop is mainly marketed in form of fresh roots and consumed in steamed, boiled, fried, or roasted state. To expand sweet potato markets and improve benefits to farmers and other value chain actors, there is need for improved post-harvest handling and value addition. This article describes a study on the utilization OFSP as an ingredient in production of nutrient enriched instant noodles. In this study, noodles were made by partially substituting wheat flour with raw OFSP and biofortified beans. Response surface methodology (RSM) was used to develop an optimal formulation and process to produce OFSP-based noodles. Independent variables considered included content of wheat, OFSP and bean powder, as well as dough thickness, drying temperature and time. The moisture content, hardness, protein, dietary fibre, iron, and zinc content for the nutrient enriched noodles produced using the different experimental runs conditions were found to range from 6.1 to 35.9 (%), 0.1 to 26.5 (N), 7.8 to 34.5 (%), 2.4 to 22.1 (%), 11.1 to 84.9 (ppm), and 20.6 to 59.1 (ppm), respectively. Reduced quartic models were found to adequately represent relations between data for the different variables (with $p < 0.05$). Optimal protocol for production of nutrient enhanced OFSP-based noodles were determined using RSM to include formulation consisting of wheat (83.0 g), OFSP (24.5 g) and beans (6.2 g); dough thickness of 2.0 mm; and drying temperature and time of 80.0 °C and 143.4 minutes, respectively. These conditions yielded noodles with 5.9 (%) moisture, 11.0 (N) hardness, 34.5 (%) protein, 11.9 (%) dietary fiber, 86.9 (ppm) iron and 50.53 (ppm) zinc with a desirability function of 0.82.

Key words: Noodles, Orange fleshed sweet potatoes, wheat, beans, biofortified



7.12 Farmers Practices, Trends, and Incomes from Citrus Production in Teso Region in Eastern Uganda

Obongo Isaac¹, KisemboLindah², Semalulu Onesmus², Ddamulira Gabriel¹, Atim Barbara², Driciru Patricia³, Park Taeseon³, and Adriko John²

¹National Crops Resources Research Institute (NaCRRI), Kampala, Uganda;

²National Agricultural Research Laboratories (NARL), Kampala, Uganda; ³Korean Program on International Agriculture (KOPIA), Uganda Centre.

Citrus has high market potential locally and internationally, providing opportunities for enhancing employment and incomes, and household nutrition among smallholder households in Uganda. Despite this market potential, citrus production and productivity, market value and export volumes have remained low. This study aimed to benchmark farmers' production, post-harvest handling practices, profitability and market dynamics in Teso region in Uganda. A survey was conducted on 120 farmers and 12 Key informants in Soroti, Ngora and Kumi districts and data analyzed using SPSS software version 23. The study revealed that citrus production was male (92.4%) dominated, grown on small scale (0.78 Ha), with average of 225 trees that were 8.7 years old. The major varieties planted were Valencia (28.7%), Hamlin (28.7%), Washington Navel (23.8%), Tangerines (9.0%), Lemons (7.4%) and local varieties (2.5%). The major citrus field pests reported included; fruit flies (31.2%), rust mites (28.6%) aphids (20.3%), leaf minors (15.0%), and scales (4.9%) while the major diseases were pseudocercospora (36.9%), anthracnose (19.0%), black spot (17.2%), sooty blotch (14.5%), melanose (12.3%). The nine major field agronomic practices reported by farmers were weeding (18%), spraying pesticides (15.2%), intercropping (14.5%), pruning (13.6%), digging basins around trees (13.2%), orchard sanitation (8.0%), mulching (7.4%), excavation of trenches (6.1%) and minimum tillage practices (3.9%). Citrus farmers incurred a TVC of UGX 1,872,567 (\$212) per hectare per annum; reported Total Revenue and Gross Margin of UGX 2,635,828 (\$732.2) and UGX 763,567 (\$212) per hectare per annum. Farmers reported an average yield of 9,000 Kilograms per hectare lower than the yield potential of 17-25 MTs per Ha reported by NARO (Idd, 2018). Farmers sold 72.14% of their production as fresh fruits on-farm (91.7%) at UGX 293/Kg. The major constraints reported by farmers included; high pest and disease burden (25.0%), high input costs (19.6%), low fruit market prices (18.9), limited fruits market 13.3%, water stress (12.8%), and theft (10.4%). These research findings have provided a foundation for designing appropriate interventions to enhance citrus value chain profitability in the Teso region

Key words: Citrus varieties, diseases, production practices, productivity, market prices, profitability and constraints

7.13 Input choices and Productivity effects

Opolot D.

Sheahan & Barrett, (2017) found that synergistic use of modern inputs at the household level was very limited for example inorganic fertilizer using farming households are not likely also to use an organic fertilizer in Uganda because they are viewed as substitutes instead of complements. In addition, users of improved seed varieties are less likely also to use inorganic fertilizer while agro-chemicals and inorganic fertilizers are not used together at the household level in Uganda and Niger. At the plot level, they find less joint use of inputs compared to at the household level. In this section, we examine the farmers input choices and use under the eVoucher system and the productivity effects. We analyse the factors that affect farmers choice and use of multiple inputs



under the e-voucher program. Results show that less than a quarter of those who registered and redeemed inputs used one input (22.4%), 15.9% redeemed and used two inputs, 9% used three inputs, 4.7% redeemed and used four inputs while less than 1% used all the five inputs. The results also showed that multiple use of inputs had significant effect on crop productivity than single use of input.

7.14 The effect of the e-voucher program on household's farm productivity and food security

Rukundo E.

In this paper, we assess the impact of the e-voucher on households' farm productivity and food security. We use the household food insecurity access scale (HFIAS) and the Food Consumption Score as the main tools for assessing food insecurity. The benefit of this tool is that it provides a measure of both severe food insecurity as well as mild food insecurity that measures fears and worries about not having enough food or eating undesired food. Both naïve and matched differences-in-differences regressions show that participation in e-voucher reduces household food insecurity. The main pathway seems to be through higher harvests of target crops. The majority of farming households who are targeted by this programme is subsistence rural households who depend on their production for food supply. This implies that a lot of household food availability depends on (1) harvest and (2) home storage and (3) to some extent, reducing wastage. Our results show that participation in e-voucher increased maize harvest by 222 kilos per acre for households that cultivated maize. These results point policy in the direction that to increase food security among rural households, the provision of inputs and input subsidies needs to be intensified and scaled up to regions where it not yet is.

7.15 Response Surface Methodology and Mixture Experiments for optimizing factors affecting the value-addition of agricultural products and for formulating nutritious food products

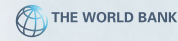
Tessema Astatkie, Ph.D., P.Stat. (SSC), P.Stat (ASA)

Professor of Statistics, Faculty of Agriculture, Dalhousie University, Canada

Corresponding author: astatkie@dal.ca

ORCID: 0000-0002-9779-8789

Post-Harvest Management (PHM) can be broadly defined as the practices and technologies used for the retention of, or improvement of, the quality of harvested plant or animal products through technologies or improved practices in production, harvesting, handling, storage and distribution until purchase or consumption. Value-addition, processing, packaging, and marketing of agricultural products, as well as the effective use, treatment and/or disposal of all associated wastes in an environmentally and economically sustainable manner are also key components. At the different stages of PHM, modern statistical methods can be utilized to modernize PHM and food safety systems. Two of these useful methods are Response Surface Methodology (RSM) and Mixture Experiments. RSM is an advanced statistical method that allows the determination of optimum settings of numerical factors and process variables when adding value to agricultural products. The most efficient experimental design used in RSM is Central Composite Design (CCD). For example, grape seed extract (GSE) is a rich source of condensed flavonoid tannins that interact with proteins and have beneficial effects on animal and human health. We conducted an experiment using a CCD to determine the optimum settings of three factors (temperature, ethanol concentration, and microwave extraction time) to maximize the health benefits of GSE.



Mixture Experiments are used to determine the optimum proportion of the ingredients when formulating food products. The optimum settings and proportions can be chosen to maximize desired characteristics such as nutritional contents or to minimize undesired characteristics that can compromise food safety and cause environmental damages. In this presentation, these two methods will be briefly described, and their PHM application examples will be shared.

Keywords: process optimization, food formulation, value addition, Central Composite Design, Mixture experiments

7.16 A Qualitative Assessment of the impact and scalability of the electronic agricultural voucher subsidy

Tinker J

This evaluation sought to find out the extent to which the current e-Voucher program can be scaled. Scaling is a deliberate attempt to reach more people with an innovation by expanding its scope or geographic reach. With this scalability analysis, we specifically addressed the primary questions: Should the eVoucher be scaled and how would the e-voucher component of the ACDP be expanded, replicated, or adapted in any way to reach other parts of Uganda? Some of the questions among others that we specifically sought clarity on include: (i) does the e-voucher system successfully create the “mindset change” necessary to get farmers to pay full price for fertilizers? (ii) Will the e-voucher system successfully create the “mindset change” necessary to get farmers to pay full price for fertilizers? (iii) Should the size of the farm be increase from the current one acre? Is the business relationship between input providers and farmers developing, and will it be durable after the program ends? Do we see a robust ecosystem taking shape, or will these connections only exist if the ACDP provides support?

The study has shown evidence that the e voucher program is a highly rated program amongst all stakeholders including farmers, agro input dealers, local district authorities and government officials at the Ministry of Agriculture, Animal Industry and Fisheries. Most of the evidence supports its scaling with the need to urgently address the implementation challenges found at pilot phase. Specifically, the study found: (1) Consensus amongst the beneficiaries and other stakeholders that the e-voucher addresses a felt need and creates credible and observable benefits; (2) The e-voucher program is superior to other alternatives like Operation Wealth creation because it does more to increase input quality by allowing the farmers to reach the suppliers directly and allowing farmers to have a say in the type of inputs that they receive; (3) The e-voucher results in better use of inputs and more impacts distributed across the value chain. Despite these clear advantages, the interviews flagged several areas where implementation needs to be improved: communication, coordination between government and private sector actors, training, dispersing funds to input suppliers, and technology (e-voucher system). Can this be sufficiently improved for the program to succeed at scale? We think it is fundamentally about government capacity and political will. While we can present recommendations on making certain improvements and suggest which ones are critical, ultimately, the assessment of political will and ability to improve government capacity will need to come from decision-makers within Uganda and the World Bank.

7.17 Postharvest loss measurement along the cassava value chain in Eastern Uganda

Samuel E. Tinyiro^{1*}, David Bamwirire¹, Aditya Parmar² and Tanya Stathers²

¹ National Agricultural Research Organization (NARO), Kampala, Uganda

² Natural Resources Institute (NRI), University of Greenwich, Chatham, UK

Corresponding author: samuel.tinyiro@naro.go.ug or stinyiro@yahoo.com +256782711277



Cassava is an important food security crop in Uganda contributing up to 60% of the food and income requirements in the East, North and West Nile regions. Root and tuber crops have been reported to have high post-harvest losses in Sub-Saharan Africa (13-29%) however, most of these are estimates devoid of empirical data. Measuring losses is the first step towards their management or mitigation by understanding where, how much, and why they are occurring. The main objective of the study was to establish post-harvest losses along the fresh and processed cassava value chain using the load tracking method involving direct measurement (weighing) of losses from farm to retail market in Soroti, Kumi and Serere districts. In addition, for storage losses, a visual scale was also used. Post-harvest loss measurements began at harvest with in-situ field measurements in farmers' gardens (10 x 10m Plot). This entailed determination of yield potential before harvest followed by determination of unharvested and rejected produce in the field. Losses were also measured during transportation, trading (markets), primary processing (dried chunks), storage (6 months) and milling. The study involved 19 farmers, 6 primary processors, 38 traders and 3 millers. The losses at harvest varied from 8.6 to 25.3% while trader losses varied from 9.6 to 16.4%. Losses during cassava processing were; peeling (1.3 – 3.8%), chunking/chipping (0.8 – 2.1%), drying (1.4 – 13.1%) and milling (1.7 – 2.7%). Storage losses of dried chunks after 6 months were 14.5 – 54.7%. Losses at harvest were highest in Soroti and associated with poor yields resulting from cassava brown streak disease that afflicted the Migeera/Nigeria variety cultivated by 57% of farmers surveyed. Pre-harvest, drying and storage are critical stages to mitigate cassava post harvest losses and should be targeted for interventions.

Key words: Post-harvest losses, load tracking, cassava

7.18 Effect of Training on Farmers' Awareness and Use of NARO-Promoted Packages for Managing Black Coffee Twig Borer and Coffee Wilt Disease on Robusta Coffee

¹Tumuramye, Kellet, ^{2*}Kagezi, H. Godfrey, ³Fungo, Bernard, ⁴Nassimbwa, Florence, ⁵Sseruwu, Godfrey, ⁵Atim Jackie and ²Wagoire W. William.

¹Faculty of Agriculture, Uganda Martyrs University, P. O. Box, 5498, Kampala, Uganda.

²National Coffee Research Institute (NaCORI)/National Agricultural Research Organisation (NARO), P.O. Box 185 Mukono, Uganda

³National Forestry Resources Research Institute (NaFORRI)/National Agricultural Research Organization (NARO), P. O. Box 1752, Kampala, Uganda

⁴African Centre of Excellence in Agro ecology- Uganda Martyrs University, P. O. Box, 5498, Kampala, Uganda.

⁵Mukono Zonal Agricultural Research and Development Institute (MuZARDI)/National Agricultural Research Organization (NARO), P. O. Box 164, Mukono, Uganda

Corresponding author: gkagezi@gmail.com

Although, the Black Coffee Twig Borer (BCTB) and Coffee Wilt Disease (CWD) are among the major factors limiting production and productivity of Robusta coffee in Uganda, their management is still a challenge. National Agricultural Research Organisation (NARO) therefore developed packages consisting of five different cultural practices for managing each of these pests, but also including chemicals for BCTB. These packages are currently being promoted mainly through training and skilling. We therefore conducted a study in Kayunga district to establish whether training of farmers enhanced awareness and usage of these packages and the resultant effect on damage on Robusta coffee. A structured questionnaire was administered to 136 purposively selected farmers in four sub-counties (two of them had received training while the other two



had not). Additionally, incidence and damage of BCTB and CWD were assessed on 10 and 30 coffee trees, respectively along a diagonal in 20 coffee gardens in each of the trained and untrained sub-counties. Chi square analysis was used to relate trained and untrained farmers while, logistic analysis was used to establish how farmers' demographic characteristics influenced use of NARO-promoted packages. Results showed that the number of farmers who considered BCTB and CWD as a problem was not significant ($p \geq 0.05$) different for trained and untrained. Trained farmers were significantly ($p \leq 0.05$) more aware of these packages than untrained. Also, significantly ($p \leq 0.05$) more trained than untrained farmers were using these packages, except chemicals for managing BCTB, and, uprooting and burning for CWD. Furthermore, sex significantly ($p \leq 0.05$) influenced using trimming and burning of infested materials, elimination of alternative hosts and chemicals while, age significantly ($p \leq 0.05$) influenced using clean planting materials and chemicals for managing BCTB. For CWD, age significantly ($p \leq 0.05$) influenced uprooting and burning of infected materials and planting of CWD resistant varieties. However, gender did not ($p \geq 0.05$) influence all practices for managing CWD whereas, level of education did not significantly ($p \geq 0.05$) influence using all practices for managing BCTB and CWD. At plot level, an average of 4.1% of the primary branches had been infested by BCTB and this infestation was significantly ($p = 0.004$) higher in coffee gardens of untrained (4.9%) as compared to trained (3.2%) farmers. However, CWD incidence in coffee gardens of trained farmers was higher (2.2%) than for untrained (0.8%). In conclusion, farmers consider BCTB and CWD as important pests of Robusta coffee regardless of being trained or not. Training was also observed to enhance awareness and usage of NARO packages for managing BCTB and CWD. However, this resulted into reduction in damage caused by BCTB but not CWD. This therefore calls for more research to establish and address the cause.

Key Words: Cultural-practices, Damage, Diseases, Pests, Skilling



Abstracts: Posters

Socioeconomic and institutional drivers for uptake of potato (*Solanum tuberosum* L.) crop intensification initiatives in Southwestern Uganda

R.R. Ainebyona¹, J.G. Agea¹, S.L. Nasirumbi¹, G. Karubanga¹ and J. Mugisha²

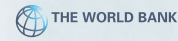
¹Department of Extension and Innovation studies, Makerere University P.O. Box 7062
Kampala-Uganda

²Department of Agribusiness and Agricultural Economics, Makerere University P.O. Box 7062
Kampala-Uganda

Corresponding author: ainebyoonar@yahoo.com

Potato yield in Uganda (7.5 t ha⁻¹) continues to lag below 20 t ha⁻¹ which is reportedly achievable on research stations. This has been attributed to limited access to quality seeds, fertilizers, and poor farming practices. Potato crop intensification is an innovation known to increase yield, and ultimately improve household income with improved seeds, fertilizers, and recommended agronomic practices such as spacing, intercropping, and sole cropping. However, there is little data on farmers' decision-making to take up and sustainably use potato crop intensification initiatives in Uganda. This study examines the factors that influence farmers' decision to adopt and take up potato crop intensification initiatives introduced by Community Action Research Programme Plus (CARP+) implemented by Makerere University in Southwestern Uganda. Data were collected from 265 randomly selected smallholder potato farmers who had participated in CARP+ project activities using a pre-tested questionnaire between January and March 2022 using a pre-tested questionnaire and analyzed using a binary logistic regression model. The mean age of farmers was 46.0 (SD=12.7) years, with a median household size of five persons with at least 50% having attained primary education and owning at least 2.65 acres of land (SD=1.7). Findings revealed that uptake of potato crop intensification initiatives by smallholder farmers was more adopted as a package of at least two (2) intensifications initiatives increased from about two percent (2%) to about 63% by the third potato growing season (2020A) while use of conventional practices decreased sharply from 51.3% to about four percent (4%) during the same period because of the CARP+ intervention. Relatedly, apart from, potato sole cropping whose uptake increased sharply from seven percent (7%) to about 40% within the first season of CARP+ intervention but later reduced and remained constant at about 21% throughout the intervention period (2019A -2020B), the use of improved seed obtained from Kachwekano Zonal Agricultural Research Development Institute (KAZARDI), the use of NPK fertilizer, and use of recommended spacing (75 cm X 30 cm) almost remained constant at 8%, 4% and 2% respectively before and during the CARP+ intensification intervention period. Our data showed that the farmer's age (>45 years), level of education (at least primary education), household monthly income (\geq 150,000 UGX), and distance to the available agricultural markets (<5km) are associated with improved uptake of potato crop intensification innovations. This data supports the role and need for interventions aimed at engaging farmers in continuous agricultural educational programs, particularly for elderly. Our data also indicates a vital need to mobilize and avail close-to-reach agricultural markets, commercial community outlet centers and stores for smallholder potato farmers to easily access output markets, improved seed and fertilizers.

Key words: Combination, conventional practices, farming practices, quality seed



Evaluation of the Effects of Local Feeds and Environmental Quality Parameters on the Growth and Economic Performance of Different Fish Species for Culture in Uganda's Mid Altitude

Constantine Chobet Ondhoro¹, Ismail Kagolola¹, Gerald Osipa¹, Robinson Odong², Godfrey Kawooya Kubiriza² and Lawrence Owere¹

¹National Agricultural Research Organization (NARO) Buginyanya zonal Agricultural Research and Development Institute. P.O.Box 1356, Mbale (Uganda)

²Makerere University School of Biological Sciences Department of Entomology and Fisheries Sciences. P.O.Box 7602 Kampala (Uganda).

Corresponding author: occonstantine88@gmail.com

Uganda's high-altitude areas remain ecologically challenging to the growth of tropical fish species; the Nile tilapia and African catfish, yet the potential for coldwater fish (Rainbow trout) culture remains unexploited. This study evaluated the effects of environmental quality parameters; temperature, dissolved oxygen and turbidity as well as local feeds on the growth (body weight gain and Nile tilapia, Mirror carp and Rainbow trout condition) and economic performance (profitability) of selected species along the slopes of Mountain Elgon.

Juvenile stocks ($n = 2400$) of Nile tilapia, Mirror carp and Rainbow trout were stocked at a rate of 4 fish per m^3 each in triplicate in prepared earthen ponds each $200 m^3$. The mean biomass carrying capacity and initial weights (\pm SE) were 2, 2 and 4 kg m^{-3} and 1.5 ± 0.1 , 17.9 ± 2.2 and 2.0 ± 0.2 g of Rainbow trout, Nile tilapia and Mirror carp respectively. Water quality and growth data were collected daily and monthly respectively. Performance parameters (fish growth and profitability) were computed and analyzed using one-way ANOVA and regression analysis in SPSS20.

The mean body weight gain ($g \text{ day}^{-1}$) ($P < 0.001$) between Rainbow trout and Nile tilapia (mean diff 0.079, $P < 0.001$) and Mirror carp (mean diff 0.087, $P < 0.001$) and between Rainbow trout and the two species combined (mean diff 0.016, $P = 0.006$) were different. The highest weight gain ($4.8 g \text{ day}^{-1}$) overall was by Mirror carp. The mean relative condition (K_n) for respective species ($P < 0.05$) were all < 1 . The Mirror carp was the most profitable, with UGX 4,130,463 (44.9%) of total sales, generating highest economic performance with highest gross profit compared to Rainbow trout which incurred over 92.1% (UGX -3,974,994.5) losses.

The observed growth patterns were consistent with temperature variation and feed quality. Cold temperatures caused poor growth performance in tilapia, while Rainbow trout growth was mainly affected by poor feed quality which limited visibility and feed intake. However, Mirror carp performed well on the experimental feed under low temperatures.

Key words: Fish species, suitability, environmental conditions suitable feeds

Morphological, Pathogenic and Molecular Characterization of Fusarium Species Causing Common Bean Root Rot in Uganda

Samuel Erima¹, Richard Edema,² Allan Nkuboye¹, Justine Nakibuule,¹ Dalton Kanyesigye¹ and Pamela Paparu¹

¹National Agricultural Research Organization - National Crops Resources Research Institute, Namulonge, P.O. Box 7084 Kampala, Uganda.

²Department of Production, Makerere University, Kampala, P.O. Box 7062 Kampala, Uganda



Fusarium root rot (FRR) of common bean is an economically important disease in Central America, South America and Africa with yield losses attributed to it reaching up to 86%. There is limited information on the distribution, pathogenicity and diversity of *Fusarium* species causing root rot disease in common bean in Uganda. Surveys were conducted in seven agroecologies of Uganda to determine the prevalence and incidence of the disease. The recovered isolates were characterized based on colony morphology and microscopic features. The pathogenicity of isolates was studied in a screenhouse while the genetic diversity was determined using molecular techniques. The prevalence and incidence of FRR varied across agroecologies ($X^2 = 46$, $P = 0.0001$ and $X^2 = 231$ and $P = 0.0001$, respectively). *Fusarium* spp. isolates differed in growth rate on culture media, colony color and shape of microscopic structures. The isolates evaluated were pathogenic on common bean and caused root rot and wilting of seedlings. PCR amplification of Inter Simple Sequence Repeats showed a high genetic diversity among the isolates. BLASTn search of TEF-1 α gene partial sequence revealed several *Fusarium* spp. such as *solani*, *oxysporum*, *falciforme*, *incarnatum*, *brachygibbosum*, *duofalcatisporum*, *equiseti*, *delphinoides*, *fredkrugeri* and 15Ar047 as the causal agents of FRR/wilt in the surveyed areas. The finding that several *Fusarium* species are pathogenic on common bean and cause root rot has significant implications on breeding for resistance to *Fusarium* root rot. For example, these pathogenic *Fusarium* species may have different avirulence genes for which different resistance genes will have to be introgressed. Similarly, screening for resistance will have to utilize all the known pathogenic species of *Fusarium* from Ugandan common bean agroecologies.

Key words: Common bean, *Fusarium* root rot, genetic diversity, Pathogenicity, Disease incidence, Disease prevalence

Opportunities and challenges for enhancing *Persea americana* (avocado) production in Uganda

Phiona Kwaga^{1,2}, Bernard Fungo^{1,2}, John Bosco Lamoris Okullo³, Susan Nansereko^{1,2} and Joel Buyinza^{1,2}

¹National Agricultural Research Organisation (NARO) P.O. Box 925, Entebbe, Uganda

²National Forestry Resources Research Institute P.O. Box 1752, Kampala, Uganda

³Makerere University College of Agricultural and Environmental Sciences,

Corresponding author: kwagaphiona@gmail.com

Avocado (*Persea americana* Mill. (Lauraceae)) is a fruit tree native to Central America. It is widely cultivated in the tropical and Mediterranean regions for pharmaceutical, nutritional and cosmetics among other values. Avocado production in some of its native countries like Mexico and Chile has become challenged because of drought while Uganda's unique climate and fertile soils, make it perfect for avocado growing. Predominantly produced in home gardens and compounds for subsistence uses in most regions of the country; the Ugandan government is currently promoting commercial avocado growing for export. However, meeting the required export standards is a great challenge affecting the avocado enterprise in Uganda. As such a study was conducted to understand challenges affecting avocado production and how to address them in Masaka and Mpigi districts in Central Uganda; A structured questionnaire was used to interview a total of 120 respondents and data analyzed in the Statistical Package for Social Sciences (SPSS V. 16) to run descriptive statistics. Results indicated that most avocado production was highly affected by pests (51 %) especially fruit flies (43.2 %), epiphytes (24 %), diseases like root rot (19.2 %), market failure (33.2%) but also least affected by small sized fruits (1.6%). It is therefore worth noting that as the farmers grow avocado, technical guidance



needs to be provided on the good agricultural practices such as pests and disease control, appropriate pre- and post-harvest operations that meet the global food safety requirements among others. Such technical guidance will not only boost avocado production but also widen the market opportunities for Ugandan avocados overseas thereby enhancing the country's foreign revenues and livelihoods.

Key words: Fruit trees; Good Agricultural Practices, *Persea americana*, Pre- and Post-Harvest Losses, Commercial farming, Agroforestry

Exploring farmers' awareness and willingness to accept Climate Smart Agricultural (CSA) Technologies in Uganda – A Case of 2022 Summer School in Alebtong

Enock Lubogo M¹ and Patrick Bamanya¹, Jackline Bonabana², Vegard Martinsen³, Samuel Kyamanywa²

^{1&2} School of Agricultural Sciences, College of Agriculture and Environmental Sciences, Makerere University.

³Norwegian University of Life Sciences, Faculty of Environmental Sciences and Natural Resource Management.

Agricultural productive capacity of Uganda is below its potential with vital yield gaps apportioned to climate change and insubstantial use of modern farming technologies. To combat the likely outcomes from such calamities, CSA technologies have been introduced in many districts such as Conservation Agriculture (CA) involving Rip lines and planting basins, then CA+Biochar. However, these have had little success due to low acceptance by farmers. A descriptive study was undertaken during a four weeks' summer school course in Owelo and Adongi B villages, Amugo Subcounty, Alebtong district, to examine farmers' awareness and willingness to accept CA and CA+Biochar, also to assess the cost per kilogram incurred during production of biochar. The researchers together with community members produced 220.65kgs of wet biochar from 407.05kg of pigeon pea feedstock at an average cost of 1001.6 Ugx/kg. Also 250 semi-structured questionnaires were administered randomly to farmers and analyzed using STATA 17 to obtain descriptive statistics, Awareness was 12.7% for planting basins, 19.9% for riplines, 13.2% for biochar. Willingness to accept was 49.7% for basins, 46.4% for riplines and 45.3% for biochar. 44.7% were willing to accept planting basins+ biochar while 43.1% riplines+ biochar. For sustainable food production under changing environments therefore, knowledge gaps, labor and input limitations should be bridged to advance the erratic uptake patterns of CSA technologies.

Key words: Biochar, Riplines, Planting basins, Farmers' awareness, Willingness to accept.

Farmers' knowledge and impact associated with the invasive papaya mealybug in Uganda

*Nankinga Caroline M^{1,4}, Nampeera Esther², Magala Damali³, Sammula Alexander⁴, Kisingiri Brenda⁴, Robert Solar Lakidi⁴, Kamulegeya Patric⁴, Aool Winnfred¹, Kirongo Patrick⁴, Mukasa Yosia⁴, Owiny Raphael⁴, Ogom P⁴, Namasa Emanuel John⁴, Nampeera Florence¹, Lubega Victor¹, Nasaazi Sharron¹, Rware Harrison⁵, Fernadis Makale⁵, Monica Kansiiime⁵, Rwomushana Ivan⁵, Byantwale T. Stephen⁵, Ogwang James M. Okidi⁶, Mwabu Paul⁴

¹National Agricultural Research Laboratories, P.O. Box. 7065, Kampala,

²National Crops Resources Research Institute, P.O. Box. 7084, Kampala,



³Mukono Zonal Agricultural Development Research Institute, P.O. Box 164, Mukono,

⁴ Ministry of Agriculture, Animal Industry and Fisheries, MAAIF, 102, Entebbe,

⁵CAB International, P.O. Box 633-00621, Nairobi, Kenya,

⁶FAO, Uganda, P O Box 521 Buganda Rd, Kampala.

Corresponding Author's Email: cmnankinga@gmail.com, Tel: +256 772524642

The invasive Papaya Mealybug (*Paracoccus marginatus*) was detected in Uganda and reported to the IPPC in 2021. This polyphagous pest has potential to significantly affect production and quality of papaya and other host crops; and decrease incomes. A survey was conducted in July 2022 to assess farmer's knowledge, perceptions and practices regarding the pest; to be used in designing integrated management strategies. Seventeen Focus Group Discussions were conducted using semi-structured questionnaire with 333 papaya fruit growers (264 males; 69 females), from nine (9) key papaya growing sub-counties in Mukono, Kayunga, Luwero and Lira districts as guided by the district and sub-county agricultural extension. Farmers were shown photos of papaya mealybug symptoms of damage, asked, when they observed the pest for the first time, estimate the proportion of plants affected and the management practices used to cope with the pest. Descriptive analysis was done by calculating frequencies, percentages and means. In addition to papaya several crops were affected since its first observation between 2017 and 2019 with more than 80% perceiving it as a serious pest causing 70 to 100% potential crop losses in Kayunga, Mukono and Luwero areas. At least 77% male and 17% female respondents were conversant and described the mealybug symptoms as whitish cottony appearance on the fruit and leaves (nick-named 'Kipamba' or 'kikubavvu' in Kayunga, 'Ebola apapalu' in Lira), yellowing of leaves, reduction in flowering, fruit abortion, and tasteless fruits. The most devastating papaya damage was attributed to the associated viral disease ('kigenge') which causes leaf mosaic symptoms, die back, wilting and completely kills the tree. Farmers reported that papaya now yields as little as one million shillings from 6-8 million per season per acre of 500 trees with tree life reducing from 5 years to hardly 2 years due to infestation by this pest and diseases. Pesticide sprays were the most common management practices though reported ineffective. Other coping practices included extending planting to new fields, shifting cultivation, manure application, and indigenous practices. Planting recycled and diseased seed was mentioned as the main cause for rapid spread of the diseases. Findings highlight the need for an integrated strategy for management of the papaya mealybug and the associated disease complex.

Key words: Invasive, Papaya mealybug, *Paracoccus marginatus*

Adaptation and agronomic performance of horsegram, mothbean and mungbean genotypes in the semi-arid region of Uganda

Obuo John Emdiaits, Wandulu Joseph, Tabisha Tino and Okello Emmanuel

National Semi-Arid Resources Research Institute (NaSARRI), P.O. Box 56, Soroti

Corresponding Author: johnobuo@gmail.com

National Semi-Arid Resources Research Institute (NaSARRI) is located in the north-eastern region of Uganda and it handles research for the semi-arid regions of Uganda. The study was carried out during the first rainy season of 2020 using 50, 50 and 50 genotypes of mungbeans, horsegram and mothbeans, respectively. Prolonged drought is one of the major constraints faced by farmers engaged in cultivation of stressed tolerant orphan legumes in Uganda. The



aim of the study was to evaluate their adaptability and yield performance in the semi-arid regions of Uganda. The standard checks Narogram 1 and Narogram 2 (released greengram varieties) were used for comparison. The experiment was laid out using an augmented block experimental design. Data were collected on growth and yield attributes and data were analyzed using the Statistical Package for Augmented Design software (SPAD). Means and variance were obtained using MS Excel computer software.

For horsegram genotypes, the ground mean yield per hectare was 473.3 kg/ha and genotypes that gave high yields were; VL-Gahat-38 (1125kg/ha), Bhilangna local Himala (1125kg/ha), VL-Gahat-37 (1113kg/ha), VL-Gahat-39 (1086kg/ha) and IC-312383 (1009kg/ha), these genotypes gave yields that were higher than the two standard checks (control) and the least was IC-342971 (21kg/ha). While for mothbean genotypes, the best performing genotypes were; RMB-25 (284 kg/ha), Maru moth (209.9 kg/ha), RMO-3-5-70 (206.8 kg/ha) and RMM-12 (194.4 kg/ha), these were significantly different from the rest of the genotype, however, their yields were lower than the checks; Narogram-1 (614.2 kg/ha) and Narogram-2 (848.8 kg/ha) and the least was RMB-00 (9.3 kg/ha). For mungbean, only one genotype (Sweta) gave a grain yield of 986.1 kg/ha which was significantly higher than the standard check Narogram-1 (814.8 kg/ha), the rest of the genotypes performed less than the check (Narogram-1). Five horsegram and 1 mungbean genotypes performed better than the standard checks (Narogram-1 and Narogram-2) and appear to be adaptable to the semi-arid region of Uganda.

Key words: adaptability, horsegram, mothbean, genotype.

Livestock production and the role of community pasture seed production and delivery systems in Uganda's south eastern agro ecological zone

Owoyesigire, B¹, R. Gidoi¹, L. Buyi¹, F. Kitiyo², D. Nampamya³, L. Owere¹ and J. Park³

¹NARO/Buginyanya Zonal Agricultural Research and Development Institute, P. O. Box 1356 Mbale, Uganda.

² District Production Office, Bukwo District Local government, P.O Box 1 Bukwo

³KOPIA Uganda Center, National Agricultural Research Laboratories (NARL), Kawanda P.O Box 7065 Kampala.

Corresponding author: bowoyesigire@naro.go.ug

The objective of this study, was to characterize emerging livestock production systems and explore community pasture seed supply systems and marketing opportunities in Uganda's south eastern agro-ecological zone. Data were collected from 240 respondents through household interviews using a pre-tested questionnaire. Households that participated in the study were randomly selected. Data were cleaned, coded, and entered into SPSS software and analysed using descriptive statistics. Most households kept indigenous cattle genotypes for socioeconomic and cultural reasons. Exotic genotypes were majorly kept as sources of income. There was a positive correlation ($r=0.361$) between total land size and the number of cattle kept per household. The number of cattle owned per household was positively correlated with improved pasture use ($r=0.82$). Confined grazing systems were predominantly emerging in Bukwo and Sironko districts. Extensive grazing systems existed in all districts. Herding cattle was mainly a male responsibility. Bukwo district had the highest proportion of children herding cattle. Tethering goats was a family responsibility, although children, especially boys played a key role. Majority of farmers' sourced pasture seeds from informal systems as there were hardly any pasture seed



stockist. Informal seed delivery systems operated mainly at individual farmer initiatives within a community. Formal pasture seed system involved NGOs and NARO research institutes. It was found that huge market opportunities exist both locally and beyond for pasture seed and forage products such as hay and silage to offset the pasture demand-supply gaps. Therefore, increasing livestock productivity in USEAEZ requires well-planned, managed, market-oriented, intensified production systems coupled with a strengthened community pasture seed business (CSB) model.

Key words: Community, pasture, seed markets and Uganda

Profitability of selected Climate Smart Technologies and Practices for maize-beans production in drought-prone areas, Uganda

Semalulu, O¹., P. Kibaya², S. Kyebogola³ E. Mworozzi², N. Sewankambo² and B. Gebru⁴

¹National Agricultural Research Organisation (NARO). P.O. Box 7065, Kampala, Uganda.

²Jinja District Local Government, P.O. Box 1551, Jinja, Uganda

³Uganda Chartered Healthnet. P.O Box 16571, Kampala, Uganda, Kampala, Uganda.

⁴Connecticut Avenue 1825. Washington, DC 20009, USA

Corresponding author: o.semalulu@gmail.com

Climate change increasingly affects farm-level decisions on when to plant and which climate smart agriculture (CSA) options to use. This study was conducted to determine the productivity and profitability of different CSA technology options for maize-bean production in drought-prone areas of Uganda. It was conducted on-farm in Rakai and Nakasongola districts during 2020 and 2021. Variables included: planting date (early vs late); varieties (common beans: NABE 4 and NAROBAN 2, and maize: Longe 5 and Bazooka); intercropping versus pure stand; and fertiliser use (manure, DAP or combination). The experimental design was split-split plot, replicated six times. Over two years, partial budget analysis showed that early planting caused 16% and up to 46% higher yields of maize and beans, respectively, than late planting, resulting in 14-28% and 18-43% higher B/C ratio for maize and beans, respectively. Intercropping reduced maize and beans yield by 16-25% and 52-57%, respectively. The B/C was highest for pure maize, though intercropping was more profitable than sole beans. Fertilizer (DAP) was most profitable when Bazooka was early-planted as sole crop followed by intercrop. For late planted-crop, manure was better. These practices were more beneficial when applied simultaneously for both crops excluding bean variety. Thus, CSA practices are more profitable when promoted in combination.

Key words: Climate change adaptation, cost-effectiveness, decision making; integrated soil fertility management, technology adoption



✉ naromakconference.caes@mak.ac.ug

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🐦 @NaroMakConf

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