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icipe CORE ANNUAL REPORT

PROGRAMMATIC REPORTING BASED ON RESULTS BASED MANAGEMENT (RBM) WITH THE AID OF THE LOGICAL FRAMEWORK APPROACH (LFA)

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List of Acronyms

AAT	Animal African Trypanosomosis
ACIAR	Australian Centre for International Agricultural Research
AGriDI	Accelerating inclusive green growth through agri-based digital innovation in West Africa project
AHIs	African Hosted Institutions
AHUs	African Host Universities
AIRCA	Association of International Research and Development Centres for Agriculture
ARPPIS	African Regional Postgraduate Programme in Insect Science
BA	BioInnovate Africa Programme
BecA-ILRI	Biosciences east and central Africa- International Livestock Research Institute
BSF	Black soldier fly
CABI	Centre for Agriculture and Bioscience International
CBFAMFEW	Community-based Fall Armyworm Monitoring, Forecasting, Early Warning and Management
CBID	Capacity Building and Institutional Development
CGIAR	Consultative Group on International Agricultural Research
CIFF	Children's Investment Fund Foundation
CIRAD	French Agricultural Research and Cooperation Organization
COP26	The 2021 United Nations Climate Change Conference
DAAD.	German Academic Exchange Service
DRIP	Dissertation Research Internship Programme
EASTECO	East Africa Science and Technology Commission
EU	European Union
F&A	Finance and Administration
FAW	The Fall Armyworm, *Spodoptera frugiperda*
FCDO.	Foreign, Commonwealth & Development Office
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (German Development Agency)
GOHi	Ohio State University Global One Health initiative
GPFS	Global Programme Food Security
IDDRSI	IGAD Drought Disaster Resilience & Sustainability Initiative
IGAD	Intergovernmental Authority on Development
INSEFF	Insects for Food, Feed and other uses
IPM	Integrated Pest Management
ISFs	Insect-specific flaviviruses
KEPHIS	Kenya Plant Health Inspectorate Service
MiRNAs	MicroRNAs
MOYESH	MOre Young Entrepreneurs in Silk and Honey programme
PASET	The Partnership for Skills in Applied Sciences, Engineering and Technology
RBM	Results Based Management
RCU	Regional Coordination Unit
RSIF	Regional Scholarship and Innovation Fund
SDC	Swiss Agency for Cooperation and Development
SDGs	Sustainable Development Goals
SEI	Stockholm Environment Institute
SHNR	Shimba Hills National Reserve
Sida	Swedish International Development Cooperation Agency
SNNP	Southern Nations, Nationalities, and Peoples' Region, Ethiopia
SSA	Sub-Saharan Africa
SwECCA	Sida Regional Hub for Environment and Climate Change in Africa
TDR	Special Programme for Research and Training in Tropical Diseases
TRC	Tsetse repellent collar
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
VBD	Vector borne disease
WRB	Waterbuck repellent blend
WTP	Willingness to pay
YESH	Young Entrepreneurs in Silk and Honey project
YF	Yellow fever

EXECUTIVE SUMMARY

***icipe* 2021 Results Based Management Report**

icipe's 2021 Results Based Management (RBM) Report presents evidence of *icipe's* continued commitment to pioneer global innovations in insect science and related fields to improve the well-being and resilience of people and environment to the challenges of a changing world. *icipe*'s accomplishments are through innovative and applied research, alongside deep exploratory study, impact assessment, evaluation and sustainable capacity building. Despite the continued challenges of COVID-19, in the year 2021, *icipe* has achieved significant progress across all its interlinking research for development (R4D) activities (discovery; proof-of-concept; piloting; scaling) for implementation of its new Vision and Strategy (V&S) (2021 to 2025). *icipe* is contributing to sustainable development goals (SDGs) through advances in R4D efforts on insect science, technology and products to transform global food, nutrition and health systems in the face of a climate crisis.

Selected highlights of the Centre's fascinating R4D activities are described in Section 2 and these are aimed at developing and disseminating tools, technologies and management strategies to control crop pests and disease vectors and protecting biodiversity and the environment while contributing to various national policies. Major highlights are: (i) a tool developed for harnessing data science for field monitoring of Fall armyworm in Africa; (ii) a breakthrough in managing potato cyst nematodes in east Africa through wrap-and-plant technology; (iii) an advance in implicating warthogs as important reservoirs of tsetse-borne trypanosomes affecting cattle health; and (iv) mass release of natural enemies was achieved to control the highly destructive *Tuta absoluta*, a tomato leafminer, and the Fall armyworm (FAW), *Spodoptera frugiperda*, as part of the Centre's innovative approaches for managing invasive species. Other highlights include gender-based malaria risk in reducing income and productivity, antimicrobial activity of insect-based chitin and chitosan to manage bacterial wilt diseases, and some solutions to both technical and economic issues of edible insect farming.

During 2021, *icipe's* contribution and recognition within the scientific community is evident, with 271 peer reviewed journal articles published and 65 conference presentations. Sixty percent (60%) of the publications of the Centre were first-authored or co-authored by postgraduate and postdoctoral fellows. *icipe* also managed 22 BioInnovate Fellows and 184 PhD scholars supported by the Regional Scholarship and Innovation Fund (RSIF) from 21 African countries. Women represent 47% of the cumulative total 509 scholars, fellows and research interns training at *icipe*. Capacity Building and Institutional Development (CBID) Programme of *icipe* conducted more than 180 training events and trained 66,875 individuals (62% women) from 27 African countries.

Commensurate to the R4D achievements, *icipe* appeared in over 700 media items, published and broadcast, locally and internationally in 275 publications and in over 50 countries. The media houses/publishers with the highest number of news items mentioning *icipe* were Springer (32 articles), Multidisciplinary Digital Publishing Institute; MDPI (17 articles), AllAfrica.com (10 articles), Nature (7 articles), Standard Digital News (7 articles) and CABI (6 articles). The Centre also got approximately 6,626 mentions on social media, predominantly on Twitter (about 5,404 mentions) within the same time.

The challenges of the Coronavirus pandemic continue to be felt across the world especially in health and economies. *icipe* organised COVID-19 vaccination efforts across all its campuses; and prevention measures, regardless of vaccination status, are strictly adhered to. The Centre remains committed to implementing successful interventions for food and health even in these uncertain times.

icipe continues to demonstrate that creativity and innovation in insect and arthropod related science can provide nature-based practical solutions for the rural problems of millions of smallholder farmers and promote food security and sustainable livelihoods in the face of climate crisis. We look to a more resilient future to continue to deliver evidence-based One Health approaches for solving the rural problems of millions of smallholder farmers and for improving their food and nutritional security, and income generating opportunities through protection of plant, animal, human and environmental health. One Health is a holistic and integrated framework aimed to improve the overall well-being of communities in Africa, with sustainable development as its basis.

Signed:

Segenet Kelemu, PhD
Director General & CEO
Date: 31 May 2022

icipe – International Centre of Insect Physiology and Ecology

SECTION 1: INTRODUCTION

icipe Centre-wide Themes/Programmes and brief on its Results Based Management (RBM) Framework

icipe adopted RBM as a project planning and monitoring tool in 2011 and has had RBM framework covering the implementation periods of 2011 - 2013; and 2014 - 2020 and now 2021 – 2025: http://www.icipe.org/publications/corporate-publications/results-based-management. *icipe*'s use of RBM has been very strategic and useful in maximizing project and programme achievements by continuously learning from success as well as failure and making adaptations based on the lessons learned. At *icipe*, this is an annual activity led by the Centre's Director General (DG). To closely monitor *icipe*'s RBM, in 2018, *icipe* institutionalised its Planning, Monitoring, Evaluation and Learning (PMEL) Strategy. The Strategy emphasizes the fostering of stronger partnerships with other local and international institutions with expertise in PMEL. The Strategy is based on a self-assessment of *icipe's* current M&E system by *icipe* scientists and support staff and their shared vision of the M&E system that they would like to see in place by 2025. The evolution of the PMEL Strategy at *icipe* was based on the Centre's RBM.

icipe's continuing journey of RBM with the aid of the Logical Framework Approach (LFA)[1] supports the Centre's Strategic Priorities, Policies and Guidelines for research and development (R&D) of insect science. Each of *icipe's* core activity area has a specific RBM framework. All project-based activities go through a cycle of knowledge management and continuous learning. The RBM-LFA is indeed a strategic management approach that ensures *icipe*'s R&D activities are implemented in collaboration with our partners to contribute to a logical chain of results that provide knowledge-based solutions aimed at equipping the communities in Africa to sustain livelihoods within a rapidly changing global environment.

With keen pursuit of its 2021 – 2025 V&S as well as RBM, *icipe* continues its mandate as Africa's principal insect and arthropod research institute through the following 4-H themes and special programmes:

Plant Health Theme: This Theme conducts multidisciplinary research using a One Health concept, working with a range of partners to benefit smallholder agriculture, nutrition, health and the environment in Africa. Its strategic objectives include basic and applied research on native and invasive, below- and above- ground, pre- and postharvest pests, under changing climate and habitats. The Theme harnesses the synergies in plant-insect-soil interactions through integrated pest management (IPM) options that are ecologically sustainable and economically feasible. Its focus is on biological control using predators, parasitoids, microbes and habitat management strategies. Further, the Theme discovers, develops and pilots technological innovations, products and applications for pest management. It disseminates research results, transfers technologies, influences policies and empowers communities through partnerships with national agricultural research organisations, the private sector and other stakeholders. The theme builds excellence in plant health research in Africa through training of students and scientists. A major thrust has been on invasive pests, increasingly using a systems approach, including modelling and forecasting using big data analytics. Research is aimed at developing integrated pest management (IPM) products (push-pull technology, biopesticides, attractants), to lessen damage to staple crops, horticulture, and plantation crops.

Animal Health Theme: This Theme aims to develop effective solutions to improve the health, productivity and sustainable farming of livestock in Africa. Its main research niche is disease transmitting insects and arthropods, primarily tsetse flies (vectors of human and animal trypanosomosis), biting flies and ticks. Through a 'One Health' and multisectoral approach, its activities are geared towards profound understanding of the biology and population ecology of arthropod disease vectors; vector–host and vector–parasite interactions; and the epidemiology of vector-borne diseases. The Theme develops locally-adapted technologies to manage vector-borne diseases, conducts operational research for vector-borne livestock diseases, and supports capacity building and extension services. It has taken a research approach on vector ecology, behaviour and population ecology of the arthropods that transmit some of the most important livestock diseases of the region, thus leading to greater availability of meat and milk, hides and draught power and thereby assisting livestock owners to get out of the poverty trap.

Human Health Theme: This Theme contributes to the reduction, elimination and eradication of vector-borne diseases. It aims to achieve this goal by generating knowledge and developing sustainable tools and strategies that

[1]Ortengren, K. 2016. A guide to Results-Based Management (RBM), efficient project planning with the aid of the Logical Framework Approach (LFA). Swedish International Development Cooperation Agency (Sida), Stockholm, Sweden, 42p. https://www.sida.se/contentassets/9d257b83f4124113a324c61715150722/21920.pdf

control vectors, break the cycle of transmission, and that can be integrated into other disease management efforts. Its most prominent programme has been pursuit of the malaria control through a focus on mosquito ecology, behaviour and the transmission of the malaria-causing *Plasmodium* parasites. The scientists working in the Theme have also targeted other important vector-borne diseases including dengue, Rift Valley fever, leishmaniasis, schistosomiasis (together often labelled "neglected tropical diseases" [NTDs]).

Environmental Health Theme: The focus of this Theme is to broaden knowledge on arthropods and their diversity and role in ecosystems, contribute to conservation and sustainable use of biodiversity, and develop strategies for climate change mitigation and adaptation. The Theme's research thrusts include: bee research; beneficial and commercial insects; bioprospecting, particularly for plant-based biopesticides and medicinal products; and habitat management to support biodiversity, pollination ecosystem services, and alternative hosts for pests and diseases. The research emphasis has been on monitoring biodiversity and building understanding of key ecosystem services related to plant-pollinator systems with a focus on bees and stingless bees. The development at scale of community-based enterprises that produce commercial honey, wax and raw silk, and on bee ecology and health, an issue of major concern globally is a key priority of the Theme. Integral to this work is youth entrepreneurship, where insect-based production systems provide the platform for youth to gain the expertise, finance and networks to get started on their own small enterprises.

To foster more interdisciplinary and inter-theme interaction and synergy, *icipe* has adopted the **'One Health'** concept as a Centre-level, strategic framework. The concept envisions the integration of research across all 4-H themes through a social-ecological systems framework targeted to specific problem areas.

Insects for Food, Feed and other uses (INSEFF) Programme: The Centre has established itself as a leader in the globally emerging insects for food, feed and other uses research agenda providing proteins in livestock feed, minerals, vitamins, antioxidants and oils. This programme aims to translate the latent benefits of insects in transforming the food system into a more sustainable and vibrant circular economy. Insects have a better ecological footprint and lower greenhouse gas emissions. Insects are an alternative, more affordable and nutritious source of food for people and livestock; are efficient in bioconverting waste; and are also a basis of organic fertiliser and pest control products.

Capacity Building and Institutional Development (CBID) **Programme:** Building the capacity of people and institutions to respond to arthropod-related developmental needs in Africa is a major commitment of *icipe*. This objective is achieved through: world-class postgraduate and postdoctoral training; nurturing and strengthening of African research and development organisations and institutions; dissemination of technologies to national agricultural and health research and extension systems. This programme continues to deliver new knowledge and outcomes for Africa and other parts of the world. Its longstanding focus on building research capacity across Africa is one of its sustained achievements.

The Centre's special programmes **- BioInnovate Africa** and **RSIF-PASET** – have sustained commitment to capacity building. BioInnovate Africa Programme (supported by Sida) enables scientists and innovators in eastern African universities, research institutes and firms to commercialise biological based ideas, inventions and technologies. *icipe* is the Regional Coordination Unit for the RSIF of the PASET program which is an African-led initiative. As a competitive grants scheme, the mission of RSIF is to strengthen the institutional capacity for quality and sustainable doctoral training, research and innovation in sub-Saharan Africa. RSIF is established to fill gaps in knowledge that are critical for African growth and development by increasing the number of PhD and post-doctoral opportunities in Applied Sciences Engineering and Technology (ASET) as well as increase the capacity of scientists and innovators to translate innovative biological science-based ideas and technologies into practical application in society and build functional innovation ecosystems.

SECTION 2. ADVANCES IN RESEARCH AND DEVELOPMENT (R&D) OUTPUTS AND OUTCOMES

Highlights of major advances in research for development (R4D) are provided below.

2.1 PLANT HEALTH THEME

2.1.1 Prediction of potential distribution of Fall Armyworm (FAW) in Africa and beyond

The Fall Armyworm, *Spodoptera frugiperda* (FAW) first invaded Africa in 2016 and has since become established in many areas across the continent where it poses a serious threat to food and nutrition security. The existing CLIMEX model was re-parameterized to assess the FAW global invasion threat, emphasizing the risk of transient and permanent population establishment in Africa under current and predicted future climates, considering irrigation patterns. Future predictions suggest that FAW invasive range will retract from both northern and southern regions towards the equator. However, a large area in eastern and central Africa is predicted to have an optimal climate for FAW persistence. These areas will serve as FAW 'hotspots' from where it may migrate to the north and south during winter seasons and then pose an economic threat. These projections can be used to identify countries at risk for permanent and transient FAW-population establishment and inform timely integrated pest management (IPM) interventions under present and future climate in Africa. (Publication link: https://www.researchsquare.com/article/rs-196606/v1).

2.1.2 Harnessing data science to improve integrated management of fall armyworm

After five years of its first report on the African continent, fall armyworm (FAW) is considered a major threat to maize, sorghum, and millet production in SSA. Despite the rigorous work already conducted to reduce FAW prevalence, the dynamics and invasion mechanisms of FAW in Africa are still poorly understood. This study applied interdisciplinary tools, analytics, and algorithms on a FAW dataset with a spatial lens to provide insights and project the intensity of FAW infestation across Africa. The data collected between January 2018 and December 2020 in selected locations were matched with the monthly average data of the climatic and environmental variables. The tool developed from this study provides a framework for field monitoring of FAW in Africa that may be a basis for a future decision support system. (Publication link: https://doi.org/10.1016/j.gecco.2022.e02056).

2.1.3 Bioecology of FAW and its management and potential patterns of seasonal spread in Africa

Community-based FAW Monitoring, Forecasting, Early Warning and Management (CBFAMFEW) initiative was implemented in six eastern African countries (Ethiopia, Kenya, Tanzania, Uganda, Rwanda and Burundi) for effective monitoring and a better understanding of the bioecology to inform management. Results showed that the abundance of FAW adult and larval infestation significantly varied with crop phenology, with infestation being high at the vegetative and reproductive stages of the crop, and low at maturity stage. This study provided an understanding on FAW bioecology, which should be vital in guiding the deployment of FAW-IPM tools in specific locations and at a specific crop developmental stage. The outcomes demonstrate the relevance of community-based crop pest monitoring for awareness creation and management among smallholder farmers in sub-Saharan Africa (SSA). (Publication link: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0249042).

2.1.4 Managing FAW using *Desmodium intortum*, *Brachiaria* sp. and *Phaseolus vulgaris* in maize

The mechanisms of how push-pull controls FAW were investigated further. Larval host preference, feeding and survival rate when exposed to four host plants commonly used in push-pull and legume intercropping were assessed. Maize (*Zea mays* L.) was the most preferred oviposition, larval orientation and settlement and was most consumed by FAW larvae, followed by beans, desmodium and lastly, brachiaria. *Brachiaria brizantha* cv Xaraes, which received more eggs than maize, could be a promising alternative to *B. brizantha* cv Mulato II for the control of FAW. (Publication link: https://onlinelibrary.wiley.com/doi/full/10.1002/ps.6261).

2.1.5 Post-harvest disinfestation treatment facilitates market access for mango into EU

Hot water disinfestation treatment protocol against invasive fruit fly species, *Bactrocera dorsalis* has been developed for Tommy Atkins mango to achieve full security level building on protocol earlier developed by *icipe* for Apple mango. This treatment has no negative impact on fruit quality. *icipe* protocol developed earlier for Apple mango variety has been duly recognized as an effective post-harvest treatment by the European Union, facilitated the much-awaited re-access of Kenyan mangoes into EU market. To this effect, *icipe*, Kenya Plant Health Inspectorate Service (KEPHIS), and the private sector (Fresco Freshpro Limited, Kenya) collaborated to send a pilot shipment of treated mango to Italy in July 2021. The consignment passed and satisfied all phytosanitary requirements as expected and the EU market is ready for more treated mangoes.
(Publication link: https://www.youtube.com/watch?v=jEOPdXVqAcA).

2.1.6 Climatic projections for classical biological control of fruit flies

The braconid parasitoid *Diachasmimorpha longicaudata* is one of the most important natural enemies in classical biological control programs against tephritid fruit flies worldwide. In light of the spread of the invasive fruit fly species, *Bactrocera dorsalis* in Africa and beyond, there is a need to implement classical biological control. Results indicate that *D. longicaudata* could successfully establish in tropical and sub-tropical regions under current and future climatic conditions. However, a slight change in the suitable areas is expected by the year 2050 due to a slight and gradual rise in temperature. These findings provide important information for further release of this parasitoid in Africa as well as designing pest management strategies to limit the spread and reduce the impact of fruit flies sustainably. (Publication link: https://doi.org/10.1371/journal.pone.0255582).

2.1.7 Managing *Tuta absoluta,* an invasive pest of solanaceous vegetables

Endophytic fungi live within plant tissues without causing any harm to the host, promote its growth, and induce systemic resistance against pests and diseases. Fifteen endophytic fungal isolates from five different genera were screened for efficacy against *Tuta absoluta* host plants, *Solanum lycopersicum* and *Solanum scabrum* through artificial seed inoculation. The results indicated that *Trichoderma asperellum* M2RT4, *Beauveria bassiana* ICIPE 706 and *Hypocrea lixii* F3ST1 have high potential to be developed as endophytic-fungal-based biopesticide for the management of *T. absoluta*. (Publication link: https://doi.org/10.1038/s41598-020-78898-8).

2.1.8 Odour composition of field versus laboratory desert locust populations

Olfaction plays an important role in the behavioural ecology of the desert locust *Schistocerca gregaria*. Different locust life stages and sexes use olfactory cues for different behaviours such as grouping, mating, oviposition, feeding, maturation and gregarization, which can be exploited for management of the desert locust. However, the full spectrum of the chemistry of volatiles released by the desert locust remains unknown. This study compared the volatile emissions of different life stages of a natural wild population reared in the laboratory for one generation with those of a population that has been reared in the laboratory for seven generations. The results demonstrate the composition and variation in odours of field and laboratory populations of the desert locust, and that the discriminating odours warrant further investigation to determine their roles in the bioecology and management of this locust species.

(Publication link: https://www.sciencedirect.com/science/article/abs/pii/S0022191021001062).

2.1.9 Mitogenomic analysis of diversity of key whitefly pests in Kenya

Whiteflies are devastating agricultural pests of economic importance vectoring pathogenic plant viruses. Knowledge on their diversity and distribution in Kenya is scanty, limiting development of effective sustainable management strategies. This study identified four whitefly species, *Aleyrodes proletella*, *Aleurodicus dispersus*, *Bemisia afer* and *Trialeurodes vaporariorum*, the latter being the most dominant species across all agroecologies in Kenya. Use of prediction spatial models indicated high climatic suitability of *T. vaporariorum* in Africa, Europe, Central America, parts of Southern America, parts of Australia, New Zealand and Asia. This study provides information to guide biosecurity agencies on protocols to be adopted for precise identification of pest whitefly species in Kenya to serve as an early warning tool against *T. vaporariorum* invasion into unaffected areas and to guide appropriate decision-making on their management. (Publication link: https://www.nature.com/articles/s41598-021-85902-2).

2.1.10 Field performance of the third-generation push-pull in western Kenya

In five counties of western Kenya, we evaluated field performance and farmer opinions of practicing a third-generation push-pull technology (PPT) with newly selected companion plants. This third generation PPT was compared with the earlier version of climate smart PPT, and also with farmers' own practices of growing maize in controlling stemborers, fall armyworm (FAW) *Spodoptera frugiperda*, and striga weeds. We assessed infestation on striga, stemborers, and FAW, and yield performance of these three cropping systems. Both PPT plots recorded lower striga count, FAW, and stemborer damage, and higher grain yield than those from plots that followed farmers' own practices. There were no differences between the two PPT plots except for stemborer damage for which the third generation PPT recorded higher damage than the climate-smart PPT. Farmers preferred the third generation PPT owing to improved mite resistance, biomass yield and drought tolerance of the forage grass cultivar *Xaraes* together with 'very good' seed production and drought tolerance of legume, *Desmodium incanum*. This third generation PPT therefore presents a better option to upscale the technology and meet different needs of farmers, especially in arid and semi-arid conditions. (Publication link: https://doi.org/10.1017/S0014479721000260).

2.1.11 Intensity of adoption of integrated pest management practices in Rwanda

The push-pull technology (PPT) is considered as an alternative integrated pest management strategy for the control of fall armyworm (FAW) and stemborer, among smallholder maize farmers in sub-Sahara Africa (SSA) to conventional pesticides. However, the extent of PPT use in Rwanda where the technology was introduced in 2017 remains largely unexplored. We employed a fractional logit model to assess the factors influencing the intensity of adoption of PPT among smallholder maize farmers in Gatsibo and Nyagatare districts of Rwanda using survey data obtained from 194 PPT adopter households that were selected using a cluster sampling technique. Our results show that the perceived benefits of PPT, its perceived effectiveness in pest control, group membership, livestock ownership, and gender of the farmer had significant effects on the intensity of adoption of the PPT in Rwanda. These findings provide compelling evidence to recommend that development initiatives should give emphasis on creating awareness on the perceived benefits of PPT adoption using group approaches that are gender disaggregated. (Publication link: https://doi.org/10.1016/j.heliyon.2022.e08735).

2.1.12 Wrap-and-plant technology for managing potato cyst nematodes in East Africa

Potato production in East Africa is under increasing threat from the invasive and highly destructive potato cyst nematode (PCN) pest. *icipe* and its partners have developed an organic technology developed from banana plant waste material. This technology is known as 'wrap and plant', and the solution involves enclosing potato seed before planting, in a thick absorbent paper that is made from the fibre of banana plants. This innovative technology provides a protective barrier for plants against damage from the invasive and highly destructive PCN. This breakthrough in PCN control demonstrates an environmentally friendly way to counter disruptions in sustainable food systems. (Publication link: https://rdcu.be/cHVSg).

2.1.13 Biocontrol potential of chitin and chitosan from black soldier fly to control bacterial wilt

Globally, *Ralstonia solanacearum* (Smith) is ranked as one of the most destructive bacterial pathogens inducing rapid and fatal wilting symptoms on tomatoes. Yield losses on tomatoes vary from 0 to 91% and most control measures are unaffordable to resource-poor farmers. This study investigated the antimicrobial activities of chitin and chitosan extracted from black soldier fly (BSF) pupal exuviae against *R. solanacearum*. Morphological, biochemical, and molecular techniques were used to isolate and characterize *R. solanacearum* for *in vitro* pathogenicity test using disc diffusion technique. We found that BSF chitosan significantly inhibited the growth of *R. solanacearum* when compared to treatments without chitosan. This study has demonstrated that BSF pupal shells are an attractive renewable raw material for the recovery of valuable products (chitin and chitosan) with promising ability as a new type of eco-friendly control measure against bacterial wilt caused by *R. solanacearum*. Further studies should explore IPM options that integrate insect-based chitin and chitosan to manage bacterial wilt diseases to increase tomato production worldwide. (Publication link: https://doi.org/10.3390/microorganisms10010165).

2.1.14 The dynamics and role of gender in high-value avocado farming in Kenya

This study used two-wave panel data obtained from avocado growers in Murang'a County in Kenya to examine, through the perspective of gender, the dynamics of farmers' participation in avocado production and marketing organizations (PMOs), and test whether understanding group dynamics is important for analysing contract farming. Results from this study reveal heterogeneity with regard to household, farm, and resource characteristics across categories of farmers and between gender groups. Besides, the results reveal that group and contracting dynamics are related and ignoring the former leads to biased estimates of the determinants of contracting dynamics. Policy efforts should focus on supporting women farmers to enhance their participation in PMOs, which ultimately affects contracting. Improving access to high-yielding avocado varieties and building capacity in orchard management would enhance women's decision-making including group participation, contracting, and marketing. Low-cost agricultural credit may also improve women's ownership of improved avocado trees and hence their participation in high-value markets. (Publication link: https://doi.org/10.1057/s41287-021-00484-z).

2.2 ANIMAL HEALTH THEME

2.2.1 Farmer perceptions and willingness to pay for tsetse repellent collar in Kwale County in Kenya

Tsetse-transmitted Animal African Trypanosomosis (AAT) is one of the most important constraints to livestock development in Africa. *icipe* and partners have developed and implemented a novel tsetse repellent collar (TRC) applied on animals to limit contact of tsetse flies and livestock, thereby reducing AAT transmission. The TRC has now advanced to commercialization. A household-level survey involving 632 cattle keeping households was conducted in Shimba Hills region of Kwale County to assess farmers' knowledge, perception, and practices towards the management of tsetse flies, their willingness to pay (WTP) for the TRC, and factors affecting the WTP. Sixty-three percent (63%) of the farmers were willing to pay for the TRC at the same cost they spend treating an animal

for AAT. On average, farmers were willing to pay KES 3,352 per animal per year. Wider dissemination and commercialization of the herd-level tsetse control approach (TRC) should be encouraged to impede AAT transmission and thus enhance food security and farm incomes among the affected rural communities. Besides the uptake of TRC can be enhanced through training, especially among women farmers.
(Publication link: https://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0009663).

2.2.2 Economic benefits of controlling trypanosomiasis using waterbuck repellent blend (WRB)

Trypanosomiasis is a significant productivity-limiting livestock disease in sub-Saharan Africa (SSA), contributing to poverty and food insecurity. The waterbuck repellent blend (WRB) is a new technology that pushes trypanosomiasis-transmitting tsetse fly away from animals, improving animals' health and increasing meat and milk productivity. The study estimated the benefits of WRB on the production of meat and milk using the economic surplus approach. Findings showed that the adoption of WRB in 5 to 50% of the animal population would generate an economic surplus of US$ 78–869 million per annum for 18 African countries. The estimated benefit-cost ratio (9:1) further justifies an investment in WRB. The technology's potential benefits are likely to be underestimated since our estimates did not include the indirect benefits of the technology adoption, such as the increase in the quantity and quality of animals' draught power services and human and environmental health effects. These benefits suggest that investing in WRB can contribute to nutrition security and sustainable development goals.
(Publication link: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0254558).

2.2.3 Role of zebra skin-derived compounds in the host seeking behaviour of tsetse fly vectors

The riverine tsetse fly *Glossina fuscipes fuscipes* is a major vector of trypanosome pathogens causing African trypanosomiasis. This study evaluated a three-component blend comprising 6-methyl-5-hepten-2-one, acetophenone and geranyl acetone (blend K), previously identified as a repellent for savannah tsetse flies in zebra skin odour, on *G. f. fuscipes* populations. Results showed that, blend K significantly reduced *G. f. fuscipes* catches compared to the control trap alone. Of the individual compounds, geranyl acetone solely significantly reduced catches. This study indicated that geranyl acetone accounts for the repellent effect of blend K on the riverine tsetse fly, *G. f. fuscipes*, demonstrating the ecological importance of animal skin odours in the host-seeking behaviour of medically important tsetse fly vectors.
(Publication link: https://www.sciencedirect.com/science/article/abs/pii/S0001706X20316582?via%3Dihub).

2.2.4 Antennal enriched odorant binding proteins are required for odour communication

Odorant binding proteins (OBPs) are soluble proteins found in sensillum lymph. Their role in olfactory processing is still controversial. For the first time at *icipe*, we used RNA interference (RNAi) gene silencing coupled with molecular dynamics and behavioural assays to demonstrate that OBPs expressed in the antennae are of critical importance for *Glossina fuscipes fuscipes* olfaction. The study demonstrated the possibility of the use of RNA interference (RNAi) silencing method to understand the role of gene in insect-odour communication and opening new avenue to study the function of genes in non-model insects. The biological simplicity of OBPs as compared to odorant receptors, but at the same time their interaction with specific odorants and their involvement in olfactory behaviour, can facilitate the discovery of behaviour modifying odours and for the development of sensors.
(Publication link: https://www.mdpi.com/2218-273X/11/4/541).

2.2.5 Supplementing blood diet with plant nectar enhances egg fertility in stable flies

This study demonstrated that stable fly, a known vector of various livestock pathogens interacts and feeds on various plants. The host plants on which stable fly fed on in nature were identified from the habitats of this vector using chloroplast DNA sequence accepted marker for plant barcoding. Results from this study also showed that female stable fly performs a fertility treatment to her eggs by supplementing her diet with plant nectar. Nectar supplementation significantly increased larval emergence, as compared to those eggs obtained from stable fly that fed on only blood. Volatile organic compound analysis demonstrated that each plant had diverse odours represented by signature odour(s), for which behavioural response of stable flies under field conditions varies from attractive (γ-terpinene and ocimene) to repellent (butanoic acid, linalool oxide, methyl benzoate) that has potential to develop as vector control tools. (Publication link: https://www.frontiersin.org/articles/10.3389/fphys.2021.646367/full).

2.2.6 Demonstration of the potential of camel ked, *Hippobosca camelina* as a vector of anaplasmosis

Anaplasmosis, caused by infection with bacteria of the genus *Anaplasma*, is an important veterinary and zoonotic disease. Transmission by ticks has been characterized but little is known about non-tick vectors of livestock anaplasmosis. This study investigated the presence of *Anaplasma* spp. in camels in northern Kenya and whether the hematophagous camel ked, *Hippobosca camelina*, acts as a vector. Results showed that *Anaplasma*-positive camel keds could transmit '*Ca.* Anaplasma camelii' to mice and rabbits via blood-feeding. Competence was demonstrated in

pathogen transmission and subsequent infection in mice and rabbits. For the first time, this study demonstrated the potential of *H. camelina* as a vector of anaplasmosis. This key finding provides the rationale for establishing ked control programmes for improvement of livestock and human health.
(Publication link: https://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0009671).

2.2.7 Ticks and tick-borne pathogens associated with dromedary camels

This is the first detailed molecular study on tick species infesting camels in northern Kenya and on the tick-borne pathogens (TBPs) in blood and ticks from these camels and co-herded sheep. The study showed the occurrence of the similar pathogens, mainly zoonotic including the zoonotic *Coxiella burnetii*, *Rickettsia africae*, and *Ehrlichia chaffeensis*, as well as major livestock pathogens such as *Ehrlichia ruminantium,* circulating in camel herds and their ticks. These findings form a basis for strategic frameworks for research and the development of novel control strategies needed to protect camels from the threats that TBPs pose.
(Publication link: https://cgspace.cgiar.org/handle/10568/114173).

2.2.8 Molecular characterization of *Trypanosoma vivax* in tsetse flies confirms the presence of the virulent *Tvv4* genotype in Kenya: Potential implications for the control of trypanosomiasis in Shimba Hills

Trypanosoma vivax is a pathogen of livestock transmitted by tsetse flies (in Africa) and mechanically by biting flies in Africa and South America. Understanding genotypes in circulation in any locality is important to determine genotype-associated risk (e.g., pathogenicity), and effective management. However, information regarding *T. vivax* diversity remains limited in many endemic countries in Africa. Two-gene conventional-PCR-sequencing and phylogenetic analysis were employed to characterize *T. vivax* genotypes in tsetse flies collected around Shimba Hills National Reserve between November 2018 and September 2019. More than 80% of *T. vivax* isolates from tsetse flies clustered within the virulent *Tvv4*-genotype clade, previously described wildlife in Mozambique. Using multiple genes we also detected three closely related haplotypes within the *Tvv4*-clade. These findings highlight the value of vector control in limiting transmission of highly pathogenic genotypes of trypanosomes to livestock.
(Publication link: https://doi.org/10.1016/j.meegid.2021.104953)

2.2.9 Satellite-based modelling of potential tsetse breeding and foraging sites

African trypanosomiasis, which is mainly transmitted by tsetse flies (*Glossina* spp.), is a threat to public health and a significant hindrance to animal production. Tools that can reduce tsetse densities and interrupt disease transmission exist, but their large-scale deployment is limited by high implementation costs. This is in part limited by the absence of knowledge of breeding sites and dispersal data, and tools that can predict these in the absence of ground-truthing. In Kenya, tsetse collections were carried out in 261 randomized points within Shimba Hills National Reserve (SHNR) and villages up to 5 km from the reserve boundary between 2017 and 2019. *Glossina pallidipes* flies were caught in 47% of the 261 traps, with teneral (young) flies accounting for 37% of these traps. The models predicted that 63% of the potential tsetse breeding area was within the SHNR, but also indicated potential breeding pockets outside the reserve. Modelling tsetse occurrence data disaggregated by life stages with time series of satellite-derived variables enabled the spatial characterization of potential breeding and foraging sites for *G. pallidipes*. Our models provide insight into tsetse bionomics and aid in characterising tsetse infestations and thus prioritizing control areas.
(Publication link: https://parasitesandvectors.biomedcentral.com/articles/10.1186/s13071-021-05017-5).

2.2.10 The developmentally dynamic microRNA transcriptome of tsetse flies

MicroRNAs (MiRNAs) are single stranded gene regulators of 18-25 bp in length. They play a critical role in regulating several biological processes in insects. However, the functions of miRNA in *Glossina pallidipes* tsetse flies, one of the biological vectors of African animal trypanosomosis in SSA, remain poorly characterized. This bioinformatics-based research study investigated how miRNA profiles change during the development of *Glossina pallidipes* tsetse flies. The results provide the first repository of G. *pallidipes* miRNAs across developmental stages, many of which appear to play crucial roles in tsetse fly development. This study provides a better understanding of tsetse biology and a baseline for exploring miRNA genes in tsetse flies.
(Publication link: https://doi.org/10.1093/bioadv/vbab047).

2.2.11 Warthogs as important reservoirs of tsetse-borne trypanosomes affecting cattle health

Trypanosomes are endemic and retard cattle health in Shimba Hills, Kenya. Wildlife in the area act as reservoirs of the parasites. However, wild animal species that harbor and expose cattle to tsetse-borne trypanosomes are not well known in Shimba Hills. We screened 696 trypanosome-infected and uninfected tsetse flies for vertebrate DNA using multiplegene PCR-High Resolution Melting analysis and amplicon sequencing. Results revealed that tsetse flies fed on 13 mammalian species, preferentially *Phacochoerus africanus* (warthogs) and *Bos taurus* (cattle). Some tsetse flies showed positive cases of bloodmeals from multiple hosts, including warthog and cattle. Importantly, tsetse flies

that took bloodmeals from warthog had significant risk of infections with *Trypanosoma vivax, T. congolense,* and *T. brucei sl.* These findings implicate warthogs as important reservoirs of tsetse-borne trypanosomes affecting cattle in Shimba Hills and provide valuable epidemiological insights to underpin the parasites targeted management in Nagana vector control programs in the target area.
(Publication link: https://www.mdpi.com/2076-0817/10/11/1501).

2.2.12 Molecular prevalence and risk factors associated with tick-borne pathogens in cattle

Tick-borne pathogens (TBPs) are of global importance, especially in SSA where they represent a major constraint to livestock production. Their association with human disease is also increasingly recognized, signalling their zoonotic importance. We set out to identify TBPs present in cattle and to determine associated risk factors in western Kenya, where smallholder livestock production is important for subsistence and market-driven income. Tick-borne pathogen infections in blood samples collected from cattle at livestock markets and slaughterhouses between May 2017 and January 2019 were identified by high-resolution melting analysis and sequencing of PCR products of genus-specific primers. Of the 422 cattle sampled, 30.1% were infected with at least one TBP, while 8.8% had dual infections. *Anaplasma* spp. (19.7%) were the most prevalent followed by *Theileria* (12.3%).
(Publication link: https://doi.org/10.1186/s12917-021-03074-7).

2.2.13 Detection of species substitution in the meat value chain using PCR-HRM analysis

Substituting high commercial-value meats with similar cheaper or undesirable species is a common form of food fraud that raises ethical, religious, and dietary concerns. Measures to monitor meat substitution are being put in place in many developed countries. However, information about similar efforts in SSA is sparse. We used PCR coupled with high-resolution melting (PCR-HRM) analysis targeting three mitochondrial genes—cytochrome oxidase 1 (*CO1*), cytochrome b (*cyt b*), and *16S* rRNA—to detect species substitution in meat sold to consumers in Nairobi, Kenya. Out of 107 meat samples representing seven livestock animals, 11 (10.3%) had been substituted, with the highest rate being observed in samples sold as goat meat. Our results indicate that PCR-HRM analysis is a cost- and time-effective technique that can be employed to detect species substitution. We propose that this approach has broad applications in the protection of consumers against food fraud in the meat industry in developing as well as developed countries. (Publication link: https://doi.org/10.3390/foods10123090).

2.3 HUMAN HEALTH THEME

2.3.1 Malaria transmission blocking

The possibility of controlling malaria using a newly discovered microbe that blocks transmission of the disease from mosquitoes to people has moved closer to reality with advanced findings by *icipe*. We have demonstrated that the microbe, *Microsporidia MB,* can be transmitted sexually between mosquitoes, in addition to being passed from mother mosquitoes to their offspring, as reported in the Centre's previous study. This breakthrough will allow the efficient spread of the microbe through mosquito populations, thus limiting their ability to infect people with the parasite that causes malaria. (Publication link: https://www.frontiersin.org/articles/10.3389/fmicb.2021.647183/full).

2.3.2 Invasive plants-mosquito disease vector interactions

Invasive plants can impact disease spread by influencing aspects of vector biology and ecology. The potential effect of allelochemicals from the invasive plant *Parthenium hysterophorus* was tested on the bionomics of the African malaria vector *Anopheles gambiae*. This mosquito vector is known to preferentially feed on this plant in nature for sugars. Findings demonstrated that: (i) the plant root exudate volatiles modulate egg-laying behaviour of gravid *An. gambiae*; and (ii) offspring that emerged as adults from breeding sites containing the root exudates exhibit extended lifespan, which is a critical determinant of pathogen transmission potential. These results improve our understanding of the risk and benefits of oviposition site selection by gravid *An. gambiae* females and the role root exudate allelochemicals could play on anopheline bionomics, with potential implications in malaria transmission.
(Publication link: https://www.nature.com/articles/s41598-021-94043-5).

2.3.3 A survey of mosquito-borne and insect-specific viruses in hospitals and livestock markets

Aedes aegypti and *Culex pipiens* complex mosquitoes are prolific vectors of arboviruses that are a global threat to human and animal health. Increased globalization and ease of travel have facilitated the worldwide dissemination of these mosquitoes and the viruses they transmit. To assess disease risk, the frequency of arboviruses was determined in western Kenyan counties. Insect-specific flaviviruses (ISFs) were also evaluated. Dengue or chikungunya viruses were not detected. However, one *Culex poicilipes* female was positive for Sindbis virus, which causes febrile illness in humans. The presence of Sindbis virus in a single mosquito from a population of mosquitoes with ISFs calls for further investigation into the role that ISFs may play in blocking transmission of other arboviruses in this region.

(Publication link: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0252369).

2.3.4 Plant feeding ecology of the dengue vector *Aedes aegypti*

A fundamental understanding of plant sugar feeding behaviour in vector populations can lead to the development of ecologically effective vector monitoring and control strategies. Despite several previous studies on mosquito-plant interactions, relatively few studies have been conducted on the dengue vector *Aedes aegypti.* By analysing field caught *Ae. aegypti* from Kilifi (dengue-endemic) and Isiolo (dengue non-endemic) areas, this study found that plant feeding in this mosquito species: (i) varies by sex, and season; (ii) results in acquisition of diverse plant-derived sugars, iii) is associated with diverse host plants mostly in the families Fabaceae and Malvaceae; and (iv) females are associated with a greater diversity of sugars and host plant species more than males. Plants thus constitute an integral ecological resource in this vector paving the way for further elucidation of its impact in dengue transmission dynamics as well as olfactory basis for host plant attraction towards development of tools on vector monitoring and control. (Publication: https://doi.org/10.1111/mve.12514).

2.3.5 Vector competence of *Aedes simpsoni sl* from Kenyan coast for BUNV and NGIV viruses

Bunyamwera (BUNV) and Ngari (NGIV) viruses are arboviruses of medical importance globally and are endemic in Africa. *Aedes (Ae) aegypti* and *Anopheles (An) gambiae* mosquitoes are currently competent vectors for BUNV and NGIV, respectively. Both viruses have been isolated from humans and mosquitoes in various ecologies of Kenya. A total of 379 (255 BUNV and 124 NGIV) *Ae. simpsoni sl* were orally exposed to infectious blood meal. The results showed that *Ae. simpsoni sl.* is a laboratory competent vector for BUNV since it was able to transmit the virus through capillary feeding while NGIV infection was restricted to midgut infection and disseminated infection. These findings contribute to the knowledge on the epidemiology of the viruses and vector control plan.
(Publication link: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0253955).

2.3.6 Role of plant nutrients in reproductive fitness of the dengue vector *Aedes aegypti*

A recent study using DNA barcoding, identified the plants fed upon by four Afro-tropical mosquito species that vector dengue, malaria, and Rift Valley fever. Herein, this study was extended by investigating the role of three plants, *Pithecellobium dulce* (Fabaceae), *Leonotis nepetifolia* (Lamiaceae), and *Opuntia ficus-indica* (Cactaceae), on the survival, fecundity, and egg viability of the dengue vector *Aedes aegypti.* With an initial blood meal, females fed on *L. nepetifolia* laid 1.6-fold more eggs while those fed on the other two plant diets laid fewer eggs compared to those fed exclusively on blood meals. Hatching rates of the eggs laid varied with the diet. Mass spectroscopic analysis of gut contents of mosquitoes exposed to the different diets showed qualitative and quantitative differences in their amino acid levels. These findings highlight the central role of plant nutrients in the reproductive fitness of dengue vectors, which may impact their disease transmission potential.
(Publication link: https://parasitesandvectors.biomedcentral.com/articles/10.1186/s13071-020-04519-y).

2.3.7 Plant-derived volatile organic compounds control leishmaniasis sandfly vectors

Leishmaniasis is a neglected tropical disease of public health importance in tropical areas of the world especially in eastern Africa. Few options exist to control the disease targeting the vectors. This study tested using laboratory assays, the responses of the sand fly *Phlebotomus duboscqi* vector of cutaneous leishmaniasis (CL) in Kenya, to some selected plant-derived compounds (linalool oxide, ocimene, *p*-cymene, *p*-cresol, and *m*-cresol). The compounds were previously isolated from Acacias (Fabaceae) being Afrotropical sandflies' preferred host plants. The study identified candidate kairomones that could be used as attractants in the management of this CL vector.
(Publication link: https://onlinelibrary.wiley.com/doi/10.1111/mve.12541?af=R)

2.3.8 SPEAR$_{pesticides}$ bioindicator as a tool for cost-effective pesticide monitoring in streams

Detecting pesticide pollution in streams requires the expensive monitoring of peak concentrations during run-off events. Alternatively, exposure and ecological effects can be assessed using the SPEAR$_{pesticides}$ bioindicator that quantifies pesticide-related changes in the macroinvertebrate community composition. SPEAR$_{pesticides}$ technology has been developed in Central Europe and validated in other parts of Europe, Australia and South America. This study evaluated its performance in East African streams. Results from this study indicated that increasing contamination was associated with considerable changes in the macroinvertebrate community composition. Thus, pesticides need to be better regulated in developing countries and SPEAR$_{pesticides}$ provides a straightforward and cost-efficient tool for the required monitoring of pesticide exposure in small to medium streams.
(Publication link: https://enveurope.springeropen.com/articles/10.1186/s12302-021-00497-9).

2.3.9 Contribution to antimalarial drugs policy through molecular research

Plasmodium falciparum (Pf) resistance to antimalarial drugs is a major impediment to malaria control. The Pf.Kelch 13 (PfK13) gene has been largely reported to be associated with artemisinin resistance. However, recent studies have shown artemisinin resistance without Kech13 mutations, suggesting the implication of other genes in artemisinin resistance. In this study, we focused on mutations in Pf.actin-binding protein coronin, Pf.cysteine desulfurase and Pf.plasmepsin 2 gene, three putative candidates that were recently reported to be involved in artemisinin, lumefantrine and piperaquine resistance, respectively. We found that Mutations R100K, and G50E involved in reduced artemisinin susceptibility were detected in Pfcoronin. These findings indicate the presence of mutations associated with reduced artemisinin susceptibility and lumefantrine selection marker.
(Publication link: https://doi.org/10.4236/ojgen.2021.114011).

2.3.10 Gender heterogeneous effects of malaria risk on agricultural productivity

This study examined the direct and indirect effects of malaria risk on agricultural productivity among smallholder farmers. We found that malaria significantly reduces crop yields and labour productivity. For instance, a 50% increase in malaria prevalence in a household can reduce the per capita land productivity by US$ 13.4/year, which is about 7.8% reduction in annual per capita income. The estimated loss in labour productivity is about US$ 1.38/person-day given a 50% rise in malaria prevalence in a household. We also observed differential productivity effects of the disease with respect to gender of the household member infected; the effect is greatest when women and children below 14 years in the household fall sick compared to men. This study highlights the need to strengthen women and children's access to malaria control and prevention services to enhance human health and agricultural productivity. Rural development projects may achieve greater health benefits by integrating malaria control interventions with the existing agricultural interventions. (Publication link: https://doi.org/10.1353/jda.2022.0011).

2.3.11 Designed a study protocol for malaria control intervention in southern Africa

House screening, a non-insecticidal method, has a long history in malaria control, but it is still not widely adopted in SSA. A study protocol for a household randomized trial was designed in Mozambique, Zambia, and Zimbabwe with the aim of adding to the evidence base for this intervention in low transmission settings by assessing the efficacy, impact, and feasibility of house screening in areas where long-lasting insecticidal nets (LLINs) are conventionally used for malaria control. This study will contribute epidemiological data on the impact of house screening on malaria transmission and assess the feasibility of its implementation on a programmatic scale.
(Publication link: http://doi.org/10.1186/s13063-021-05768-7).

2.3.12 Entomologic drivers of Yellow fever transmission

Despite the availability of an effective human vaccine, Yellow fever (YF) activity has increased in the East African region in the recent past, a trend in part attributed to poor understanding of the transmission dynamics including bionomic role of geographic populations of known vectors. The team examined bionomic features of *Aedes simpsoni* mosquitoes among important YF virus vectors, that comprise subspecies including the well-known YV virus vector *Ae. bromeliae*. The study was conducted in two contrasting arbovirus ecosystems in Kenya: peri-urban, coastal Rabai, and rural, Rift Valley Kerio Valley in Kenya. Results indicate (i) *Ae. bromeliae* as the most abundant subspecies in both areas exhibiting high survival rates, human blood-feeding, and potentially, high vectoring ability; (ii) occurrence of *Ae. lilii* contrary to previous reports; and (iii) potentially undescribed species in the group displaying human feeding tendencies. These findings highlight the utility of genotype-based analyses to generate precision surveillance data of vector populations for enhanced disease risk prediction and to guide cost-effective interventions (e.g., YF vaccinations). (Publication link: https://doi.org/10.1371/journal.pntd.0010171).

2.4 ENVIRONMENTAL HEALTH THEME

2.4.1 A global-scale expert assessment of drivers and risks associated with pollinator decline

A team of pollination experts reviewed the data and evidence for drivers of pollinator decline across six different global regions (continents). Ten different impacts of pollinator decline on human well-being were analysed. The drivers for decline in Africa are land cover and configuration, pesticide use, and climate change, although their relative importance could not be defined due to lack of data. The risks of pollinator decline for humans (pollination deficits, wild pollinator diversity, yield instability, food system resilience) are higher in the global south. (Publication link: https://www.nature.com/articles/s41559-021-01534-9).

2.4.2 MOre Young Entrepreneurs in Silk and Honey (MOYESH) programme

The programme has so far recruited, trained, and equipped unemployed young women and men in its target regions. Several trainings of trainers' workshops have been conducted staff of key partnering institutions on various technical skills to prepare them for training of programme partner youth. A capacity-building training was provided to programme staff on "Gender in Value chains" and a child-care facility provision to enhance young mothers' participation has been established in the programme areas. The team hosted a honey festival at inauguration of a queen bee rearing facility in Oromia region; a pilot E-commerce service was launched for packed table honey in partnership with Kifiya Financial Technologies; and a pilot digital payment service was successfully implemented. The team has established partnership with the Cooperative Bank of Oromia to enhance youth financial inclusion in digital finance and payment service. A loan amount of ETB 2.7 million has been provided to youth enterprises (500 youth partners in total) in the SNNP region. The programme has facilitated the opening of accounts for 2,463 youth enterprises in year two and youth enterprises have mobilized more than 22 million ETB in savings this year. Field operations in Tigray region were suspended due to safety and security concerns. The final independent evaluation of the YESH project was completed by a private consultancy firm.

In summary the achievements have been:

- Safe and smooth implementation continued in areas not affected by the conflict.
- In addition to the 27,000 jobs created in 2021, the programme reached 43% of its lifetime target jobs for youth of 100,000 over the last two years; 60% of these are young women.
- Indirect reaches added 259,000 youth in 2021, taking the total to 302,000 and 56% of these are females.
- 355 youth beekeepers' enterprises in two regions harvested 115 tons of honey, which is 82% and 18% of their annual targets for the first and second region, respectively. The third region is early in the harvest season.
- Honey harvest per hive from traditional and transitional and frame hives improved by 18%, 47% and 87% from the baseline value at commencement of the programme.
- *Financial inclusion*: About US$ 820,000 as group savings was mobilized and about US$ 220,000 of micro-loans was delivered to youth enterprises. Large loanable funds from private banks are being channelled through microfinance institutions.

2.4.3 Characterization of honey produced by six stingless bee species in western Kenya

This study established that there is an effect of bee species identity and harvesting methods on the chemical composition and antiradical activity of honey produced by six stingless bee species in western Kenya (Kakamega forest). Results showed that none of the assayed parameters significantly varied between the honey harvesting methods by "punching holes" and "squeezing" methods. By contrast, species identity drove significant differences in the assayed parameters. Positive correlations between the antiradical activity and the phytochemicals (phenols and flavonoids) were observed, and honeys from *Liotrigona* sp. exhibited the highest amounts of phenols, flavonoids, and antiradical activity. The physicochemical analyses confirmed the need to establish separate stingless bee honey standards for moisture, free acidity, invertase, electrical conductivity, and hydroxymethylfurfural, as these parameters significantly diverged from the set limits for *Apis mellifera* honey.
(Publication link: https://pubmed.ncbi.nlm.nih.gov/34314935/).

2.4.4 Antimicrobial compounds from African edible insects and their associated microbiota

The need for easily biodegradable and less toxic chemicals in drug development and pest control continues to fuel the exploration and discovery of new natural molecules. Like certain plants, some insects can also respond rapidly to microbial infections by producing a plethora of immune-induced molecules that include antibacterial and antifungal peptides/polypeptides (AMPs), among other structurally diverse small molecules. The recent recognition that new natural product-derived scaffolds are urgently needed to tackle life-threatening pathogenic infections has been prompted by the health threats posed by multidrug resistance. Although many researchers have concentrated on the discovery of AMPs, surprisingly, edible insect-produced AMPs/small molecules have received little attention. This review provided an in-depth discussion on the recent advances in the identification and bioactivity analysis of insect AMPs, with a focus on small molecules associated with the microbiota of selected African edible insects. These molecules could be used as templates for developing next-generation drugs to combat multidrug-resistant pathogens. (Publication link: https://www.mdpi.com/2079-6382/10/6/621).

2.4.5 Global overview of locusts as food, feed, and other uses

This review assesses the potential of harnessing locust swarms for beneficial uses. Among 21 known locusts, ~10 species have been traditionally consumed by humans or fed to animals for millennia in 65 countries. Their nutritional composition is comparable or superior to that of conventional meat. However, insecticide residues, microbial contaminants and allergens may compromise their safety. Some countries have developed regulations on edible insects, locusts inclusive. Safe and efficient harvest of locusts could offer nutritional and revenue opportunities in many developing countries and serve as a more sustainable management method than the widespread use of insecticides. (Publication link: https://www.sciencedirect.com/science/article/pii/S2211912421000821).

2.4.6 Microbial contaminants of edible long-horned grasshopper

This study investigated the relative abundance and identity of microbial contaminants of the edible long-horned grasshopper (*Ruspolia differens*) harvested from the wild and traded in informal markets in Uganda, to reveal high health risk points. Seven species of bacteria and seven species of fungi were recorded in *R. differens* samples. The microbial species were most diverse in samples from trapping points and least diverse in the deep-fried insects. The key pathogenic bacteria detected in marketed *R. differens* were *Staphylococcus sciuri, Acinetobacter baumannii* and *Serratia marcescens*, all of which were absent in wild-caught whole insects. Results demonstrate that *R. differens* obtained at the trapping sites and markets are contaminated with potentially harmful microbes. Therefore, they require processing through deep frying to minimise health risks associated with their consumption. Further studies are warranted to elucidate specific handling practices at distribution and trapping points which may prevent introduction of microbes into *R. differens.*
(Publication link: https://www.wageningenacademic.com/doi/10.3920/JIFF2020.0069).

2.4.7 Impact of black soldier fly larvae meal in layer chick and grower diets

The acceptance of eco-friendly black soldier fly larvae meal (BSFLM) as sustainable alternative protein ingredient in poultry feeds continues to gain momentum worldwide. This study evaluated the impact of BSFLM in layer chick and grower diets on the growth, carcass quality and economic returns. The highest final weight gain was achieved when birds were provided diet with 25.6% BSFLM. Positive cost–benefit ratio and return on investment was recorded for diet types with higher BSFLM inclusion levels (>75%). Diets with 25% and 100% BSFLM inclusion were the most suitable and cost-effective, respectively. Thus, BSFLM represents a promising alternative source of protein that could be sustainably used in the poultry industries.
(Publication link: https://www.mdpi.com/2071-1050/13/11/6074).

2.4.8 Frass fertiliser production from black soldier fly and role in circular economy

The sustainable utilisation of black soldier fly (BSF) for recycling organic waste into high-quality protein feed and organic fertiliser with a low environmental footprint is gaining momentum worldwide. Although BSF farming is becoming a rapidly growing agribusiness, studies on the BSF farming's economic aspects are limited. Using experimental data, this study analysed the economic benefits of farming BSF for animal feeds and composted frass to produce frass fertiliser (FF). Production of one megagram (Mg) of dried BSF larvae (US$ 900) would generate 10-34 Mg of FF worth US$ 3,000-10,200. Maize grown on plots treated with FF yielded 29-44% higher net income than maize harvested from plots amended with commercial organic fertiliser. Furthermore, smallholder insect farmers' direct use of FF for maize production would generate 30-232% higher net income than farmers purchasing similar FF. These results demonstrate for the first time the role of insect farming in circular economy and justifies the opportunities for future investments that would lead to enhanced sustainability for agricultural and food systems, especially for smallholder farmers in low- and middle-income countries.
(Publication link: https://www.wageningenacademic.com/doi/epdf/10.3920/JIFF2021.0013).

2.4.9 Afrotropical stingless bees as efficient alternative pollinators to honeybees

The current honeybee decline necessitates the use of alternative native pollinators to ensure global food security. We compared the pollination behaviour and efficiency of the African honeybee (*Apis mellifera*) and six African endemic stingless bees (*Meliponula bocandei, Dactylurina schmidti, Meliponula lendliana, Hypotrigona gribodoi, Meliponula ferruginea* and *Meliponula togoensis*) in a greenhouse with the non-parthenocarpic cucumber (*Cucumis sativus*) variety Super Marketer. The highest sugar content was recorded in fruits from flowers pollinated by *M. bocandei,* African honeybees*, D. schimdti* or *M. togoensis* with the same solid content as the gold standard method, i.e., hand cross-pollination. We found that *M. bocandei* was the most efficient cucumber pollinator of all species tested: because pollination by this species yielded the largest and heaviest fruits and the highest seed numbers.
(Publication link: https://doi.org/10.1080/00218839.2021.2013421).

2.4.10 Pollination of greenhouse Galia musk melon by afrotropical stingless bee species

An increasing demand for pollination services highlights the need for research on alternative pollinators for greenhouse and open field food crops. We compared the foraging behaviour and effectiveness of seven endemic African stingless bees (*Meliponula bocandei*, *Dactylurina schmidti, Plebeina hildebrandti, Meliponula lendliana*, *Hypotrigona gribodoi, Meliponula ferruginea, Meliponula togoensis*) as alternative pollinators to honeybees for greenhouse cultivated Cantaloupe melons. The highest fruit weight and fruit volume were obtained from flowers pollinated by manual pollination with *H. gribodoi*, *M. bocandei*, *M. lendliana* and *P. hildebrandti* compared to honeybees. Pollination by these stingless bees also resulted in the highest seed counts per fruit. These findings indicate that stingless bees are more efficient pollinators of sweet melon than honeybees and can be recommended for use in greenhouse crops.

(Publication link: https://doi.org/10.1080/00218839.2021.2021641).

2.4.11 Antimicrobial activity of chitosan prepared from black soldier fly pupal shell waste

Globally, the broad-spectrum antimicrobial activity of chitin and chitosan has been widely documented. However, very little research attention has focused on chitin and chitosan extracted from black soldier fly (BSF) pupal exuviae, which are abundantly present as by-products from insect-farming enterprises. This study generated the first comparative analysis of chemical and biological extraction of chitin and chitosan from BSF pupal exuviae. The antibacterial activity of chitosan was demonstrated through significant growth inhibition of bacterial species of *Escherichia coli*, *Bacillus subtilis, Pseudomonas aeruginosa, Staphylococcus aureus*, and *Candida albicans*. These findings demonstrate that chitosan from BSF pupal exuviae could be a novel therapeutic agent for drug development against resistant strains of bacteria.
(Publication link: https://doi.org/10.3390/microorganisms9122417).

2.4.12 Edible insect farming as an emerging and profitable enterprise in East Africa

In East Africa, insect farming is a rapidly growing business providing access to 'climate-smart' protein, other nutrients, and income. With the continental drive to transform existing food systems that are becoming continuously unsustainable due to scarcity of arable land and water, and high ecological imprint, insect farming for food and feed with circular economy potential has gained remarkable interest. We reviewed the recent research trends on key substrates and insect species commonly farmed, map of commercial enterprises, insect nutritional values, processing techniques, marketing, regulatory framework, and lessons learnt on insect farming. Our analysis resulted in finding some solutions to both technical and economic issues of insect farming and in providing a clear roadmap for scaling these technologies in a phased approach through effective public-private partnerships that offer opportunities for implementing a circular food economy.
(Publication link: https://doi.org/10.1016/j.cois.2021.09.007)

2.5 SPECIAL PROGRAMMES

2.5.1 BioInnovate Africa Programme

BioInnovate Africa (BA) Programme has implemented 20 regional projects in the last five years that, in one way or another, seek to improve human and animal nutrition; control plant pests, diseases and weeds; control human and animal diseases; prevent postharvest losses; convert organic waste in biofertilizers and other products; enhance bioentrepreneurs capacity; and provide support for developing sustainable bioeconomy strategies in the region. These projects are distributed in six eastern African countries, which include Burundi, Ethiopia, Kenya, Rwanda, Tanzania, and Uganda. They involve about 100 different organisations, and more than 300 scientists. Of the 20 projects, five have fully transitioned into new commercial biobased enterprises in the region. Examples of projects include Virus free sweet potato vines produced using tissues culture; Nitrogen enhanced biofertilizer (branded as Hakika™) from municipal waste; Vermicomposting of waste to produce high value biofertilizers and protein-rich feed (earthworms) supplement for fish and poultry and Aroma Honey Toffees. Some accomplishments of the BA programme are listed below.

- Collaborated to host a Webinar on 'Building back better from Covid-19 pandemic' with Invest in Africa on February 10, 2021. The webinar presented strategies to consider building back from the effects of COVID-19 pandemic situation and to hedge against future disasters or related risks especially for the business community.
- Partnered with the Thayer School of Engineering, Dartmouth College, USA to build capacity for technoeconomic analysis (TEA) of innovation projects in eastern Africa through a tailor-made online/remote course. Six students commenced the online course in January 2021 and together with counterparts in the USA, will carry out a TEA on some of the BA supported projects as part of their projects.
- Partnered with Growth Africa Foundation and provided support to fifteen projects transitioning into pilot commercial enterprises. Successful projects were commissioned as pilot enterprises by June and September 2021 in a phased manner.
- *icipe* and Sida commissioned the external review of Sida support to bioscience research and innovation in East Africa since 1999 and evaluation of BA Programme Phase II. Programme Management Office provided relevant documentation to initiate a desk review. This was followed by in-person and virtual interviews that run concurrently from January to June 2021 with selected partners in BA network, *icipe* management, Sida, policy actors, and other regional and global stakeholders. This was completed in July 2021.
- Development of a regional bioeconomy strategy for East Africa (now undergoing formal processes of approval at the East African Community).

- Eight projects successfully tested and validated their business models and whose innovative bio-based products/solutions have gained market entry.
- Eight projects that have successfully developed and tested their solutions and are awaiting investment to go to market
- Three projects that have developed prototypes and awaiting further pilot and market testing.
- Trained 34 Women Fellows from all BA participating countries in various aspects of innovation project design and bioentrepreneurs (https://bioinnovate-africa.org/category/projects/women-fellows/).
- Trained eight (8) scientists in East Africa on technoeconomic analysis in partnership with Thayer School of Engineering at Dartmouth College, USA.
- Trained 10 PhDs and 22 Masters students.
- More than 50 publications arising from various research activities within the Programme.
- Established a platform and regional bioeconomy conference series for Eastern Africa (1st and 2nd Eastern Africa Bioeconomy Conference in 2020 and 2021, respectively). https://2ndbioeconomyconference.easteco.org/

Many of the projects showed signs that they would be sustainable and could make a difference in creating jobs, improving lives, and supporting sustainable and inclusive growth in eastern Africa. To this end, the BA external evaluation proposed, and the Swedish International Development Cooperation Agency (Sida) accepted, to continue its support towards bioscience and bioeconomy in East Africa for another 5 years. The next phase commenced in April 2022. During January – March 2022, Sida granted *icipe*, US$ 500,000 for bridging BA phase II and III. The bridging phase enabled completion of vital activities, which were delayed by COVID-19, and preparation for Phase III.

Another notable achievement for the team was convening the 2nd eastern Africa Bioeconomy Conference 10th – 11th November 2021. The conference was co-organized by BA, the East African Science and Technology Commission (EASTECO), Stockholm Environment Institute (SEI) - Africa Centre, and the Biosciences east and central Africa- International Livestock Research Institute (BecA-ILRI) Hub as partners. Themed "Building a sustainable and resilient African Bioeconomy" brought together 625 regional, continental, and global participants comprising of leaders in science, private sector, and in policy, as well as the media. Key recommendations of the conference included: the need for awareness creation and policy advocacy, targeting relevant stakeholders in the bioeconomy value chain, backed by research-based evidence to address the disconnect in demand and supply of bio-based products, promoting available bioeconomy opportunities, and influencing consumer preferences and behaviour with respect to bio-based products; and the development of regulatory and institutional frameworks to facilitate various aspects of the bioeconomy.

2.5.2 Regional Scholarship and Innovation Fund (RSIF)

RSIF is a flagship program of The Partnership for Skills in Applied Sciences, Engineering and Technology (PASET) initiative by African Governments and the World Bank. A few highlights from RSIF are described below.

- The Government of Rwanda, represented by the Minister of Education is new chair of PASET with Ghana being the current vice-chair.
- RSIF now has 11 funders including African governments (Benin, Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Mozambique, Rwanda and Senegal), Government of Korea, the ACP Innovation Fund of the European Union, and the World Bank. Contribution from Nigeria is expected soon while Kenya and Rwanda are preparing their second additional contributions. US$ 51.7 million has been mobilized for RSIF from the 11 funders.
- The feasibility study for establishment of the RSIF permanent fund, including fundraising strategy and implementation plan has been finalized.
- RSIF World Bank Project mid-term review (MTR) was held from April 19 to 23, 2021 to review progress on implementation of RSIF including next steps for the establishment of the RSIF Permanent Fund.
- Four additional African Host Universities (AHUs) were competitively selected to offer PhD programmes, bringing the total to 15 AHUs, three per each PASET thematic area.
- A total of 184 RSIF PhD students (39% women) from 21 SSA nationalities have been awarded scholarships.
- 102 PhD students (40F, 62M) competitively selected for RSIF scholarships in Cohort 3.
- RSIF student publications in high quality peer reviewed outlets have now surpassed 50.
- Review process finalized for AGriDI (EUR 2.73 million to award) innovative projects (10 sub-grants awarded).
- The virtual RSIF pre-conference, 15-17 November 2021 themed, *"African-led science, technology and innovation for contributing to the Sustainable Development Goals (SDGs) and stimulating global development",* was opened by Rwanda's Minister of Education. Discussions focused on Covid-19 in Africa; Building research capacities in Africa; and

Science Funding in Africa. RSIF achievements to date were showcased and lessons shared for strengthening doctoral training, research and innovation in Africa.

- Cohort 1 students are concluding their studies; Cohort 2 are being matched for sandwich programmes internationally (40 of 82 so far); Cohort 3 are in their first year at African Hosted Universities (AHUs).
- 74 candidates (31% females; 42% faculty, 23 nationalities) have been pre-selected for scholarships in Cohort 4. An additional 20 students have been placed on the reserve list. Selection of additional candidates from Mozambique and Senegal is ongoing.
- 12 projects with a total value of US$ 945,000 were awarded in the second round of RSIF research and innovation grants. 14 ongoing projects are progressing well.
- Review process for RSIF-MozSkills subproject research and innovations grants are in progress (15 grants with total value of US$ 1.19M to be awarded).
- RSIF contributed to the book chapter "A case study of transformation in four African universities". It presents selected analytical narratives of successful institutional transformation of tertiary agricultural education (TAE) from four African universities. The discussion focuses on both 'soft changes' in organizational culture and strategies, and 'hard changes' in enrolments, staffing, programmes, departments, faculties/colleges and campuses. Outcomes of the transformation process are described, along with lessons learned. (Publication link: http://doi.org/10.1079/9781789246544.0015).
- RSIF Weekly Newsletter continues to be disseminated through MailChimp (52 editions published until the end of January 2022 with 11,688 subscribers).

2.6. PUBLICATIONS

A total of 271 peer reviewed journal articles were published during the period January – December 2021 and a total of 65 conference presentations made by *icipe* scientists. Please refer to Annex 1 & 2.

2.7. CAPACITY BUILDING AND INSTITUTIONAL DEVELOPMENT (CBID) PROGRAMME

icipe's CBID programme continues to make a substantial contribution to building the capacity of individuals and institutions through the development of MSc, PhD and postdoctoral fellows and research interns. The programme continues to conduct training and capacity building for numerous stakeholders.

2.7.1 Post-graduate (MSc and PhD), Postdoctoral and Research Internship training

Cumulatively, *icipe* had a total of 509 scholars, fellows and research interns. The gender representation in capacity building in CBID at *icipe* is shown in Figure 1.

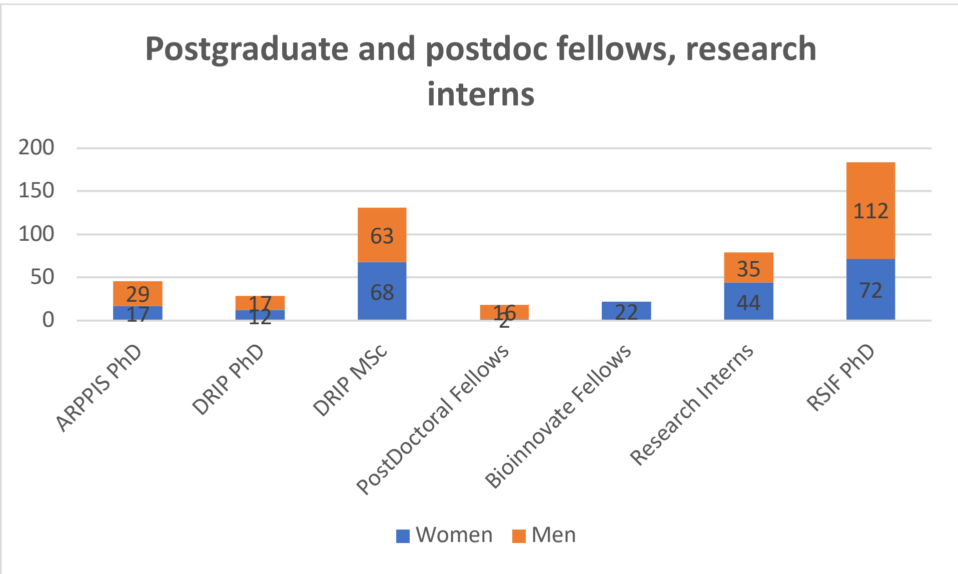

Figure 1. Gender representation in capacity building at *icipe*.

Table 1. *icipe* Graduate Students enrolment in 2021

Item	Numbers
Number of **female** PhD-students **enrolled during 2021** ***(ARPPIS, DRIP & PASET RSIF Scholars)***	**93**
Number of **male** PhD-st**udents enrolled during 2021** ***(ARPPIS, DRIP & PASET RSIF Scholars)***	**148**
Number of **female** PhD-students **graduated during 2021** ***(ARPPIS, DRIP & PASET RSIF Scholars)***	**8**
Number of **male** PhD-students **graduated during 2021** ***(ARPPIS, DRIP & PASET RSIF Scholars)***	**12**

- *Pursuing gender equity:* 47% of ARPPIS and DRIP postgraduate scholars are women. Women's representation is highest in the DRIP MSc programme (52%). Representation by women was lowest in the postdoctoral programme (11%). 39% of the RSIF scholars are women, with Cohort 3 having the highest female representation.
- *Completion:* 20 PhD scholars and 33 DRIP MSc scholars defended their thesis or graduated during 2021.
- *The icipe ARPPIS & DRIP Postgraduate, Research Internship and Postdoctoral programmes have continent-wide representation:* 20 African nationalities - from East, West, Central and southern Africa- were represented in the programmes during the reporting period: Benin (3), Burkina Faso (1), Burundi (2), Cameroon (5), DRC (2), Ethiopia (17), Ghana (2), Kenya (198), Liberia (1), Malawi (1), Mali (1), Nigeria (4), Rwanda (6), South Africa (1), Sudan (4), Tanzania (8), Togo (5), Uganda (16), Zambia (3), Zimbabwe (5).
- In addition, *icipe* managed 184 RSIF PhD scholars, 6 of whom are currently on a sandwich programme with Worcester Polytechnic Institute (WPI), USA; 5 with the Korean Institute of Science and Technology (KIST), Korea; 2 with International Livestock Research Institute (ILRI), Kenya; and 1 with Ghent University, Belgium. 19 scholars from cohort 3 whose scholarship is funded by the Nigerian government, have not taken up their scholarships since the Nigerian Government is yet to make their contribution to RSIF. More placements on-going.
- *RSIF scholars represent* 21 African nationalities: Benin (12), Burkina Faso (5), Burundi (2), Cameroon (7), Chad (3), Côte d'Ivoire (10), DRC (4), Ethiopia (10), Ghana (21), Kenya (26), Malawi (3), Niger (2), Nigeria (27), Rwanda (20), Senegal (6), South Sudan (1), Sudan (2), Tanzania (11), Togo (1), Uganda (6), Zimbabwe (5).
- *ARPPIS-DAAD 2022 Scholarships*: DAAD Call for scholarships was announced on 15 October 2021 and closed on 15 December 2021. A total of 83 applications were received. Interviews of shortlisted candidates commenced. New ARRPIS scholars are expected to start in September 2022.

2.7.2 Training Events

icipe's CBID has continued to conduct large number of trainings for students, researchers, national program partners, farmers and others in knowledge intensive areas of *icipe* technologies and products, and in research and research-related skills. CBID conducted more than 180 training events and trained 66,875 individuals (62% women) from 27 African countries (Benin, Burkina Faso, Burundi, Botswana, Cameroon, Chad, Côte d'Ivoire, DRC, Ethiopia, Eritrea, Eswatini, Ghana, Kenya, Liberia, Malawi, Mozambique, Namibia, Nigeria, Rwanda, Senegal, Seychelles, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe) and 4 other countries (Britain, Ecuador, Germany, Pakistan). Trainings were held in 13 countries in Africa (Botswana, Ethiopia, Eswatini, Kenya, Malawi, Mozambique, Namibia, Rwanda, Seychelles, Tanzania, Uganda, Zambia and Zimbabwe).

2.8. COMMUNICATIONS AND MEDIA

2.8.1 Media Coverage

icipe appeared in 700 media items, published and broadcast, locally and internationally in 275 publications and in 50 countries. The combined potential reach of these articles was 1.19 billion people, with a potential advertising value of US$ 18.2 million. The top six countries in which the Centre appeared in the news were the United States of America, Switzerland, Kenya, United Kingdom, South Africa, and China. Popular topics in this coverage included 'integrated pest management', 'fruit flies', 'food security', 'mango trees', and 'pesticides.'

The media houses/publishers with the highest number of news items mentioning *icipe* were Springer (32 articles), Multidisciplinary Digital Publishing Institute; MDPI (17 articles), AllAfrica.com (10 articles), Nature (7 articles), Standard Digital News (7 articles) and CABI (6 articles).

On social media, *icipe* had 6,626 mentions, most of them on Twitter (5,404), followed by blogs (511), YouTube (150) and Facebook (146 mentions),). These added up to a potential reach of 43.5 million. The top themes on social media included 'research', 'top-notch outputs', 'application', farmers, '50th anniversary', 'food', 'project', 'new way' and 'best agricultural research institutions.

2.8.2 *icipe* Website

Approximately 95,690 visitors and 356,750 page views were registered on the *icipe* website. The top countries (ranked in order of visitor numbers) were Kenya, United States of America, Ethiopia, Indonesia, United Kingdom, China, Germany, Nigeria, Uganda and India.

2.8.3 *icipe* Quarterly e-bulletin

Two issues of the e-bulletin were produced during this period: Volume 11 (Issue No. 1, 2021: January – June 2021) and Volume 11 (Issue No. 2, July – December 2021). One of the most popular articles in the first edition was the *Thought Leadership* column by the Director General titled 'Decolonising knowledge: *icipe* takes a stand', which was shared and commented very widely on social media. This article highlighted *icipe*'s unique position as an African yet international research institution, what needs to change in the continent's knowledge generation and access, as well as a rallying call for Africa to 'not forfeit our right and responsibility to think and to theorise from our distinctive geographic and socio-cultural perspective'.

2.8.4 *icipe* Videos

One hundred and ten (110) videos were produced from various *icipe* research for development activities.

2.9. SIGNIFICANT DEVELOPMENTS DURING THE YEAR 2021

2.9.1 *icipe* Involvement in the One CGIAR Design Initiatives

Following the reformulation of CGIAR Centres into the One CGIAR, funding ideas were requested through its Secretariat for the One CGIAR Design Initiatives. *icipe* was encouraged to seek partnerships by BMZ-GIZ, Germany. *icipe* identified and contacted project leads for 21 One CGIAR Design Initiatives and from responses provided by the leads of these initiatives, the Centre has been actively engaged in three of the 21 initiatives.

2.9.2 *icipe* Involvement in the UN Food Systems Dialogues

The UN Secretariat of the Food System Summit set up standardized Food System Dialogues in preparation for the convening of the 2021 UN Food Systems Summit (FSS) as part of the Decade of Action to achieve the sustainable development goals (SDGs) by 2030. *icipe* was invited and participated in two food systems dialogues by Swiss Agency for Cooperation and Development (SDC) and Swedish International Development Cooperation Agency (Sida). The main issue discussed was Agroecological farming with respect to biodiversity, resilience, recycling, co-creation and knowledge sharing, synergies, efficiency, human and social values, culture, enabling environment, governance, and funding. SDC, Sida and the participants in the two sessions recognized the important role that *icipe* is playing in advancing agroecological farming in Africa, especially in the management of biotic constraints (e.g., fall armyworm on maize) of food crops. It was agreed that SDC would champion to move agroecological farming to scale at the UN Summit in 2021. The policy dimension of agroecological research, data and need to bring agroecological farming to scale must be recognized by various stakeholders and strengthened.

2.9.3 *icipe*'s Role in the Newly Established Sida Regional Hub (SwECCA)

Sida is seeking to strengthen the synergies between the bilateral, regional and global work that it is supporting, including research cooperation. In this regard, a stronger integration of biodiversity, environment and climate change into all its strategic cooperation has become paramount and this has led to the creation of a **Regional Hub for Environment and Climate Change in Africa (SwECCA)** in Nairobi to ensure that these attributes are aligned to all Sida programmes. Following internal discussions with Sida colleagues in the Research Department at the Headquarters in Stockholm, it was recommended that the regional hub team visit *icipe* to acquaint themselves with *icipe* and discuss further on *icipe*'s R4D activities. The visit took place on 14th September 2021 and the Sida team appreciated exposure to *icipe* (R4D, F&A, lab and field visits) and will work closely with the Centre and various Swedish missions in Africa to ensure a clear goal on biodiversity, environment, and climate change in all Sida funded programmes. The hub will be a champion of *icipe*'s R4D work and will recommend its partners to collaborate with *icipe* and integrate biodiversity aspects into their research portfolio as well as report on the impactful work of *icipe* to its headquarters in Stockholm and to the Swedish Biodiversity Convention. Following the successful visit, *icipe* was invited by Sida to send a proposal to explore opportunities for research equipment/infrastructure upgrade.

2.9.4 Engagement with WHO/TDR

The Senior Research Adviser at Sida overseeing the Special Programme for Research and Training in Tropical Diseases (TDR) co-sponsored by Sida, UNICEF, UNDP, World Bank and WHO, expressed interest in *icipe*'s Malaria work, including work on *Microsporidia MB* and *Parthenium*, and connected *icipe* with the WHO-TDR team. The joint meeting held on 15 September 2021 agreed to explore partnerships in training and vector borne disease (VBD) research; research collaborations in leishmaniasis in East Africa (basic research and implementation – including testing of tools); shared interest in the areas of multisectoral research, One Heath, irrigation, and health; and monitoring the epidemiological outcomes after some vector borne disease (VBD) control strategies including the release of sterile male mosquitoes.

2.9.5 Joint *icipe* Stockholm Convention/IDB Anniversary

icipe and partners from the Stockholm Convention organized the Centre's first Zoom webinar on 24th May 2021 to commemorate the 20th Anniversary of the Stockholm Convention and to celebrate the International Day for Biological Diversity (IDB). The meeting presented a platform for the Centre to engage in discussions on achievements, challenges and the way forward to ensure a clean, healthy and biodiverse Africa. A total of 113 participants from 20 countries in five continents participated in the meeting.

2.9.6 Insects for Green Growth and Development

The Social Sciences and Impact Assessment (SSIA) Unit organized a symposium on "Insects for green growth and development" at the 31st International Conference of Agricultural Economists (ICAE), during August 17-31, 2021. The SSIA Unit also participated in organizing a conference on "Developing smallholder-oriented IPM strategies for fall armyworm (*Spodoptera frugiperda* Smith) management" (FAW), August 23-25, 2021.

2.9.7 Parasitoid species released in Zanzibar, in December 2021

icipe's African Fruit Fly programme continues to expand implementation of proven IPM tools and technologies across Africa. For the first time, it has introduced two exotic fruit fly parasitoid species, *Fopius arisanus* and *Diachasmimorpha longicaudata* imported from Hawaii into Zanzibar Island following regulatory approvals for the control of the Oriental fruit fly, *Bactrocera dorsalis,* a notorious pest of fruits and vegetables. These natural enemies have now been released in more than 10 African countries. Prior to the release in Ugunja Island of Zanzibar presided over by officials of the Zanzibar Agricultural Research Institute (ZARI), a workshop was conducted to train and create awareness among the extension personnel, quarantine officers and growers on mass rearing and effective conservation of the bioagents in the agroecosystem. The parasitoid in combination with other IPM strategies (i.e., orchard sanitation, use of biopesticides, protein bait spray, male annihilation techniques) should reduce fruit and vegetable infestation by fruit flies in the Island by more than 90% and protect the environment, enhance income and livelihoods of the growers.

2.9.8 Strengthening research capabilities at *icipe* through the support from Sida

Following a successful visit of Sida's Regional Hub for Environment and Climate Change in Africa (SwECCA) to *icipe* on 14th September 2021, *icipe* signed with Sida an agreement for US$ 2.6 million grant to upgrade and modernize laboratory equipment to strengthen its R&D units and new greenhouses and screenhouses on 3rd December 2021. This upgrade will ensure access to special purpose analytical equipment/instruments for conducting fundamental and applied research for tackling the challenges of the human, animal, plant, and environmental health; climate change; and biodiversity. This improved analytical capacity will enable *icipe* to achieve its Vision and Strategy 2021 – 2025. This is the second time Sida has provided support to *icipe* for the purchase of modern equipment to advance the Centre's research capabilities (US$ 1.5 million was provided in 2014).

2.9.9 Additional funding to boost research on *Microsporidia MB* for blocking transmission of malaria

The discovery by *icipe* scientists that a microbe named *Microsporidia MB* found in mosquitoes is capable of blocking transmission of malaria from mosquitoes to people continues to attract interest in malaria control space. In this regard, the Human Health Theme continues to witness an upward trend in resource mobilization through a grant by the Children's Investment Fund Foundation (CIFF), of close to US$ 1 million on 8th December 2021. This three-year project seeks to establish a foundation for *Microsporidia MB* field trials. CIFF is the third donor to fund *Microsporidia MB* research activities since the publication of the discovery in the journal, *Nature Communications***.**

2.9.10 Insect for feed standard launched in Rwanda

In November 2020, *icipe* signed an agreement to collaborate with Palladium International Limited funded by FCDO, to undertake a project to commercialize black soldier fly for animal feed in Rwanda. One of the key outcomes has been the development of standards for dried insect products for compounded animal feeds during 2021. These have been approved by the Rwanda Standard Board and launched on 3rd March 2022.

2.9.11 Extension and amendment of Regional Coordination Unit-RSIF agreement

The PASET Executive Board approved an amendment to the end date of the *icipe*-World Bank RSIF agreement to 31 December 2025 (previously 25 September 2021). The Project objective was amended to: "*To strengthen the institutional capacity for quality doctoral training, research, and innovation in transformative technologies in Sub-Saharan Africa*" and the requirement to establish and manage a sustainable permanent fund was removed. *icipe* has further requested for an amendment that would result in countries covering administrative costs (overheads) in addition to PhD student costs.

2.9.12 Hosting the Science for Africa Foundation

A collaborative hosting agreement was signed between *icipe* and the Science for Africa Foundation (SFA) on 20th December 2021. The three-year agreement stipulates provision of office; facilitating work permits for internationally recruited staff; payroll and benefits processing for all SFA staff; and provision of finance and administrative services. This agreement covers support in operating banking facilities locally, and processing of transaction that need to pass through *icipe's* finance section including taxable procurements and other direct charges.

SECTION 3: RESULTS BASED MANAGEMENT (RBM) FRAMEWORK: PROGRAMMATIC PROGRESS REPORT FOR 2021

(i) Plant Health Theme: Results Based Management (RBM) Rolling Framework Report

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
Broad objective 1: Make available IPM options for staple crops by 2025.	**Specific objective:** Long-term farming systems comparisons in Kenya and participatory on-farm research of locally adapted technologies for organic agriculture.	• Management plans are implemented according to plan. • Yield, pest and disease incidences are within range of the good performing farmers within the country. • Verified data is stored in databases. • Soil, plant and input samples are stored appropriately. • Various scientific findings are published and there are presentations during scientific conferences, seminars or workshops. • Innovations are developed and documented in leaflets/manuals. • Promotion of innovations by local stakeholders. • Capacity building of farmers, researchers, extension officers and students.	• 1st and 2nd season 2021 trials were implemented and managed well. • An internal mid-term review exercise to self- evaluate ongoing project activities was conducted. • Data summaries of trial performance in terms of yield, pest and disease dynamics were included in the annual technical report submitted to the donor in November 2021. • Soil, plant and input samples were collected at various sampling stages throughout the 2 seasons, processed, stored and analysed in various laboratories. • 10 manuscripts were initiated on various topics (free living nematodes, maize productivity, plant-based biopesticides, pesticide contamination, prokaryotic diversity in compost manure, phosphorus sorption, pest incidence in maize, microbial diversity in soil, soil fertility dynamics and weed diversity). Some of the publications were submitted for journal publications while others are still under internal review. • Annual technical report covering yearly project activities and summary findings was drafted and submitted to donor. • Conference/ workshop presentations on 'Plant-based biopesticides', 'P- use efficiency', 'Harnessing agroecological research' during Organic World Congress Conference, Biovision Symposium and PELUM Kenya Independent Food System Dialogue Workshop, respectively, were made. • Manual on management of brassica pests using plant-based biopesticides in organic farming system was drafted. • There were field visits on on-station trials by ~70 farmers and other stakeholders. • ~70 farmers were trained on soil fertility and water management, pest and disease management, crop calendar and rotation, climate smart agroforestry, animal welfare, and vertical gardening techniques for vegetable production. • 4 field technicians and enumerators were trained on push-pull techniques.	• Long-term experiments are key in addressing issues related to agricultural productivity, profitability and sustainability from diverse farming systems context in various agro-ecological zones. • Long-term experiments have the capacity to generate diverse data types that can be used to evaluate/model various scenarios of agricultural productivity and resilience. • Publications covering long-term effect topics require time in order to capture multi-year observations. • Strong partnerships among farmers, researchers, extension services and other partners are key to successful long-term experimental trial implementation and result dissemination. • Sustainable agricultural production systems are better fostered through participatory development of innovations addressing bottlenecks and improved capacities of various partners involved.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			• 4 staff members were trained on data collection, and downstream management and storage aspects. • 5 MSc studies commenced on various topics (plant-based biopesticides against legume pests, FAW, modelling of pest incidence in maize, crop water use efficiency; and soil productivity).	
	Specific objective: A knowledge hub on organic agriculture (OA) established.	• 1 compendium in each of the 4 countries. • 100 flyers/factsheets in English and 2 local languages. • 40 videos in 4 local languages (by Access Agriculture). • 40 radio or TV ads in 3 Languages (English and 2 local languages) • 3 mobile apps in 1 language (English). • 3 positive tests by participating country partners in East Africa.	• Information of organic agriculture from 4 countries and produced several dissemination materials which are available in many vernaculars. • Project made significant progress with strong communication strategy and partnerships in East Africa.	• We learned there are several organic agriculture practices in the region that need our attention.
	Specific objective: Contribute to improve livelihoods and resilience of smallholder farmers in Eastern Africa maize production systems through enhanced preparedness, integrated and eco-friendly management of the invasive fall armyworm (FAW) *Spodoptera frugiperda* for food and nutritional security by 2022.	• At least 100 extension officers per target country have access to monitoring surveillance tools by 2022. • At least 100,000 maize growers have access to monitoring surveillance tools by 2022. • By 2020, 1 additional effective FAW IPM option registered and available for commercialization. • At least 3 best-bet cultural practices identified and promoted by 2019. • At least 3 effective and sustainable IPM strategies to counter FAW developed for different agro-ecologies and countries by 2022. • Development of a dynamic simulation model of the interactions between FAW and a community of lepidopteran maize stemborers with their associated parasitoids by 2021. • At least 3 publications highlighting FAW bioecology completed by 2021. • At least 1 effective natural enemy released in 3 target countries by 2020.	• 1,703 CFPs, extension officers, district officers trained. • 5 FAW pheromone lures and 3 different traps assessed for efficacy in Kenya. • On-farm validation of the optimized climate-resilient PPT for FAW in Kenya (30 farm in 12 regions). • Field demonstration plots of effective biopesticides (Kenya: 10, Tanzania: 5). • 10,485 households reached through field demonstrations and ToTs • 4 best-bet cultural practices already promoted. • 9 publications on FAW bioecology published. • 5 natural enemies for FAW identified. • 2 egg parasitoids and 1 larval parasitoid mass-released in 5 districts of Kenya. • >150,000 parasitoids released for FAW management in Kenya. • A press release on efficacy of FAW natural enemies undertaken. • 1 publication on FAW natural enemies completed. • Label extension for use of Mazao Achieve (ICIPE 78) completed in Kenya. • New oil-based biopesticide formulations being developed for FAW management.	• 4 best-bet FAW IPM practices are already promoted. Effective partnerships with private and public sector scaling partners are critical in scaling these technologies. • Extensive knowledge on FAW biology, ecology and effectiveness of IPM strategies established. • Regional context-specific integration of these knowledge and techniques is critical to achieve effective management of FAW in Africa. • Extensive outreach of FAW IPM technologies have been achieved. This is largely due to a combination of dissemination pathways involving mass-media tools, ToTs and on-farm demonstrations. • Significant capacity among various extension agencies and maize growers has been created on FAW management. There is need to follow on how this is cascaded to the larger cereal grower communities.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		• At least 100,000 parasitoids released per country by 2022. • At least 2 biocontrol technologies developed by 2020. • At least 25,000 growers in 3 target countries directly benefitting from biocontrol technologies by 2022. • 25,000 maize growers using push-pull for FAW control by 2022. • At least 1 FAW resistant cultivar (or hybrid) availed and disseminated in partnering countries. • At least 290,000 maize growers reached with sustainable FAW-IPM technologies by 2021. • At least 40% of the maize production area affected by FAW in the target project areas covered by at least 1 effective FAW IPM options by 2022. • At least 3 technologies demonstrations in each country in each year. • At least 1 TV program/Youtube video, 1 radio program and 1 news article per year developed and translated. • At least 5,000 booklets/posters/brochures on FAW developed, printed and distributed each year. • At least 1 FAW microsite developed and maintained. • At least 750 stakeholders trained through ToT events by 2022. • At least 3,000 lead maize growers in each project country participate in technology dissemination activities. • At least 1 Postdoc, and 3 PhD and 5 MSc students trained on FAW research by 2022. • at least 1 open day for policy makers and NARS partners in each year.	• Registration dossiers for ICIPE 41 with Kenya Biologics submitted. • Training facility for small-scale production of biopesticides established in *icipe* and with the private sector partner Horttiserve. • Safety of FAW biopesticides to other natural enemies assessed. • 4 publications on FAW biopesticides completed. • 5,101 farmers were trained on use of PPT for FAW control in 2021. • Various studies on understanding the mechanism of resistance to FAW in push-pull completed. • Resistance to FAW among locally adapted cultivars and landraces screened. • Cultivar 'SC Duma 43' indicated low levels of antibiosis. • Indirect defense response of the different maize cultivars to FAW egg and larval infestation is being elucidated. • Through various outreach channels, >1,122,678 million people reached with FAW IPM technologies. • ToTs on FAW IPM technologies have covered most maize production hotspots in the target countries. • On-farm experimental and demonstration trial established in KALRO-Embu farm. • Joint evaluation and demonstration of FAW biopesticide undertaken with partners NARO in Uganda. • Through 12 ToT events, over 543 extension officers were trained in the target countries. • Multi-location trials conducted in Western Kenya on third-generation push-pull. • 6 Youtube video's on FAW IPM, 2 radio program and 2 newsletters on FAW IPM developed and shared with policy makers. • A webpage on FAW IPM technologies developed with the Technology Transfer Unit microsite. • 1,703 CFPs, extension officers, district officers trained on FAW IPM. • Through 12 ToT events, over 543 extension officers were trained. • 10,485 maize grower households reached through field demonstrations and ToTs.	• Extensive research capacity on FAW IPM has been created. Further long-term assessment on how this contributes to new IPM technology generation in Africa is critical. • Beyond its impact on maize production, FAW impacts on food security, health and nutrition, especially of weaker sections of the communities, (children and women). • FAW IPM technologies promoted such as push-pull have the potential for women empowerment.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		• At least 150 high-level stakeholders reached per country with FAW evidence data by 2022. • At least 50% of the maize growers to be included in the survey in the target areas aware of the socio-economic benefits of sustainable FAW IPM options.	• 3 postdoc, 9 PhD and 7 MSc and 4 interns trained on FAW research through direct and complimentary funding from EU FAW IPM. • 2 open day for policy makers and NARES on FAW IPM conducted. • A paper on FAW impact on maize production, food security, and health in Ethiopia is published in PLOS ONE journal. • The impact of FAW on the nutrition and food security of children and mothers in Uganda was documented. • Knowledge, attitudes and practices (KAP) and the enabling policy environment related to FAW management and gender adoption gaps assessed in Ethiopia. • PPT impact on women's empowerment, mitigating FAW and milk production assessed. • Maize growers' willingness to adopt FAW IPM technologies such as biopesticides assessed.	
	Specific objective: Developing, commercializing and upscaling of biopesticides for integrated FAW management to improve the livelihoods of smallholder farmers.	• 3 awareness campaigns. • Policy paper on harmonization of biopesticides registration and use. • Report on socio-economic benefits of biopesticides in different cropping systems. • Report on policy and regulation for FAW biopesticides registration. • 1 conference presentation. • Label for one the FAW biopesticides extended in Kenya. • Validation of newly formulated product. • Registration permits. • Eco- and mammalian toxicity test reports. • Field efficacy reports. • Reports of registration trials. • Interactions between natural enemies. • Novel formulations. • Registration dossiers. • Field efficacy permits. • Reports/ peer-reviewed publications. • Patents. • ToT reports.	• Awareness campaigns among farmers and extension officers were conducted on the use of biopesticides to control FAW in Kenya, Tanzania and Uganda. • Policy paper on harmonization of biopesticide registration and use revised. • Stakeholder engagement at the regional level with regulatory authorities and East African Council has resulted in harmonization of biopesticide trial protocols. • A survey conducted on policies on biopesticides in Ghana and South Africa to strengthen the review paper on regulatory procedures and compared to the harmonized biopesticides registration guidelines of the East African Community (EAC). • Socio-economic benefits of biopesticides in different cropping systems (monoculture, intercropping and push-pull) were demonstrated in Uganda. • Field demonstrations were conducted and coupled with field days on the use of biopesticides for FAW management. • To further create awareness and visibility of the new biopesticide products, the oral presentation 'Development of biopesticides for sustainable management of FAW in East Africa' was made at the International Congress on	• Domestication of EAC biopesticide registration guidelines in target countries contributed to fast registration of FAW biopesticides. • With high collaboration and awareness creation among regulatory authorities and policy makers, registration of biopesticides becomes a participatory action involving developers (R&D institutions), the private sector and regulatory authorities/policy makers. • Public-private partnerships (PPPs) are a key to effectively strengthen the biopesticide value chain. • It is paramount to involve regulatory authorities and policy makers from the conception of the project to facilitate the fast-track registration or label extension of biopesticides. • Regional guidelines for biopesticide registration enable biocontrol product introduction, registration, commercialization and upscaling.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		• Project reports. • MSc theses. • Research data. • Training materials. • Field demonstrations. • Field days. • ToT participant list.	Invertebrate Pathology and Microbial Control & 53rd Annual Meeting of the Society for Invertebrate Pathology. • An award received as top-cited publication for the paper 'Ovicidal effects of entomopathogenic fungal isolates on the invasive fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae)' published in the Journal of Applied Entomology. • Through a public and private partnership between *icipe* and Hottiserve, a pilot biopesticide mass production unit has been established at Isinya, Kenya. • Multilocational registration trials for *Metarhizium anisopliae* ICIPE 78 (Mazao Achieve) and *M. anisopliae* ICIPE 7 (Mazao Detain) are completed and reports submitted in Kenya, Tanzania and Uganda, waiting for final approval for label extension and registration permits for sustainable FAW management. • In collaboration with Biobest, the label of Mazao Achieve has been extended and permit obtained for FAW control in Kenya in October 2021. • We demonstrated that the combination of both FAW biopesticides (*M. anisopliae* ICIPE 78, ICIPE 7 and ICIPE 41) and the associated key FAW indigenous parasitoids (*Telenomus remus* and *Trichogramma chilonis*) provide better management of FAW. • Registration permit for ICIPE 78 for FAW management in Kenya obtained. • Second season of socio-economic field trials of Mazao Detain and Mazao Achieve to assess their efficacy under different cropping systems (PPT, monocropping and farmer field practices), and impacts of using these biopesticides are currently ongoing in Uganda. • Field efficacy trials with *M. anisopliae* ICIPE 41 were conducted by Kenya Biologics in collaboration with *icipe*, and a dossier was submitted to KEPHIS for registration of ICIPE 41 against FAW, which has also been approved and transferred to PCPB for last registration trials. • Using 'three-in-one' approach and filling the gaps of non-susceptibility of potent isolates on FWA larvae, significantly higher FAW larval mortality rates (59-75%) were obtained with lower LT_{50} values ranging between 4.24 - 5.78 days when combining *M. anisopliae* ICIPE 7, 78 and 41 than the single isolates.	• Private partners find PPPs for FAW management economically viable to invest in the opportunity. • Bioprospecting is key to increase the portfolio of biopesticides, especially in the case of invasive pests such as FAW. • Private sector partners are key to upscale newly developed biopesticides. • Strengthening capacity through various training activities at different levels is very important for knowledge sharing and involvement of all stakeholders. • Effective linkages with universities, private sector and other stakeholders are key for adequate capacity building on biopesticide value chains.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			• Dose responses study of the various combinations of 'three-in-one' has been conducted, and molecular characterization of the different combinations are ongoing, as well as their mass production on various substrates to assess their yield, and their growth rates under different temperature regimes. • Continuous bioprospecting was conducted and two isolated *Beauveria bassiana* stains were found to cause >85% second instar larval mortality 7 days post-treatment. In addition, dose responses of these two potent isolates were conducted to determine their lethal concentration (1 x 10^6 to 1 x 10^9 conidia/ml). • Three manuscripts have been developed on non-target effects of *M. anisopliae* ICIPE 78, ICIPE 7 and ICIPE 41 on *Cotesia icipe*, *Telenomus remus* and *Trichogramma chilonis* (key indigenous parasitoids of FAW); we demonstrated that combination of entomopathogenic fungi with parasitoids provides better management of FAW through indirect infections. • New oil-based formulations (corn oil, olive oil, canola oil) of ICIPE 41 were developed and corn oil-*M. anisopliae* ICIPE 41 based formulation was found effective against FAW larvae with no negative effects on the major FAW parasitoids under laboratory and field conditions. • Endophytic fungi *Hypocrea lixii* F3ST1- and *Beauveria bassiana* G1LU3-induced metabolites were identified to negatively affect pea leafminer and FAW, which could effectively be used in next generation biopesticide development. We have established the mechanism of action of these endophytes against FAW and the data were published in the journal, Molecules. • *Beauveria*, *Fusarium*, *Hypocrea* and *Trichoderma* were screened for their endophytic property through seeds and foliar inoculations. *T. atroviride* F5S21, *T. asperellum* M2RT4, *T. harzianum* F2R41, *T. harzianum* F2L41, *H. lixii* F3ST1 and *F. proliferatum* F2S51 colonized roots, stems and leaves of the plants through both inoculation methods. The effects of these endophytes on FAW *in planta* (oviposition, larval mortality, pupation, and adult emergence) and plant growth promotion are currently being assessed. • 22 progressive farmers and entrepreneurs belonging to farmer groups have been trained in small-scale	

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			biopesticide production at *icipe* between 15-17 July, and 27-30 July 2021. • 6 MSc students have been recruited in Kenya and Uganda; 1 has already graduated, 1 defended her thesis and awaits graduation, 1 completed and the rest are finalising their write up. • In partnerships with Biobest and Hotiserve, 3,662 ToTs were trained in Kenya and Tanzania. • 20 demonstration plots (5 in Tanzania and 15 in Kenya) were established on biopesticide use for FAW and other pests, and several stakeholders were trained and sensitised.	
	Specific objective: Enhanced food security, resilience and livelihoods of smallholder maize and tomato farmers through scaling of climate-smart integrated pest management (CSPM) practices and technologies to counter the effects of climate change on pest management by 2022.	• Capacity of at least 2,100 model female and male farmers built to train other farmers by 2022. • At least 100 farmer-based organizations participate in capacity development for ToT by 2022. • At least 500 female and male agricultural extension agents participate in training on CSPM technologies and their use to train farmers by 2022. • Capacity of at least 20 private sector and civil societies built through training by 2022. • 200 experts from NARES and institutions working on climate change trained on CSPM technologies and mass-rearing of parasitoids to support extension officers by 2022. • 100 policy makers engaged.	• The project made significant progress in 2021 by scaling several climate smart technologies for tomato and maize to several smallholder farmers in Uganda and Ethiopia while training several stakeholders. • Socioeconomic impact assessment and materials for trainings have been developed. • Technologies such as push-pull, natural enemies for pests of maize and tomato and biopesticides have been introduced and scaled. • A mass rearing facility for natural enemies has been established at NARL and Hawassa and parasitoid releases have taken place.	• The project made significant strides. However, there were few challenges related to the COVID-19 pandemic, particularly travel restrictions and bans.
	Specific objective: Joint action to develop biocontrol methods against the invasive FAW in Africa.	• Join SLU-*icipe* proposal developed and submitted to funding body (The Swedish Research Council) • Collaborative research ongoing on FAW chemical ecology and biocontrol. • A PhD student from *icipe* is currently on a research visit to SLU for experience sharing	• No outputs yet.	• No lessons learnt yet.
	Specific objective: Reinforcing and expanding the community-based FAW	• Number of people trained in FAW IPM. • Number and percentage of hectares protected against FAW.	• CBFAMFEW II has made significant progress in all target countries. While Ethiopia, Uganda and Rwanda are scaling FAW IPM technologies while reinforcing community based	• The progress made in this project provides a better understanding of the FAW. Data science can significantly

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
	monitoring, forecasting for early warning and timely management to protect food security and improve livelihoods of vulnerable communities.	• Number and percentage of people practicing appropriate FAW management practices. • Percent of maize postharvest loss reduced. • Percentage of people trained who retain skills and knowledge after 2 months. • Percentage of attendees at joint planning meetings who are from the local community,	FAW, Zambia and Malawi are involved in introducing the concept of CBFAMFEW. • Agreements with NARS partners have been signed. • Demonstration sites have been established. • Students have been recruited and several publications have been produced.	contribute to a better understanding of the pest and will help to develop advisory information.
	Specific objective: Develop an integrated digital tool for Integrated Pest Management through the program Malawi Digital Plant Health Service (MaDiPHS).	• Number of pest/disease/weed prediction systems used by farmers.	• Not yet funded.	• No lessons learnt yet.
	Specific objective: Use of *Cotesia typhae* in the biocontrol of the Mediterranean corn borer in France.	• Reproductive success of *C. typhae* and the molecular mechanisms of virulence onto the Mediterranean corn borer. • Environmental risk of introducing *C. typhae* in France. • Parasitism potential of *C. typhae* against the Mediterranean corn borer on corn plantations. • Feasibility of parasitoid mass rearing with a perspective of industrial production and commercialization.	• The reproductive success of *C. typhae* and the molecular mechanisms of virulence analyzed. • Ongoing activities linked to assess the environmental risk of introducing *C. typhae* in France. • Ongoing activities linked to evaluate the parasitism potential of *C. typhae* against the Mediterranean corn borer on corn plantations. • No outputs yet for the activities linked to mass rearing with a perspective of industrial production and commercialization as they will start in 2022.	• A specific population of *Cotesia typhae* in Kenya is more virulent to the Mediterranean corn borer and developed well into this host. It is then a good candidate to control this pest on corn plantations in France. • No lessons learnt yet for the ongoing and starting activities.
Broad objective 2: Make available IPM options for horticultural crops.	**Specific objective:** Scale out integrated pre- and postharvest pest management approaches for thrips and tospoviruses infesting vegetables and grain legume crops in East Africa in collaboration with international and national partners by 2023.	• At least 1,000 French bean, tomato, onion and grain legume farmers and stakeholders reached with thrips and tospovirus IPM strategies by 2021. • At least 3 field demonstration of thrips IPM strategies based on intercropping, use of biopesticides and semio-chemicals undertaken in Kenya by 2021. • At least 2 popular articles on thrips and tospovirus IPM published by 2021. • At least 2 publications on thrips and tospovirus IPM by 2022.	• Publication on remote sensing for monitoring severity of MLN published. • 1 publication on seed transmission of MLN viruses published. • 1 publication on mating behaviour of bean flower thrips published. • 1 publication on field efficacy of bean flower thrips pheromones and its interaction with thrips biopesticides published.	• Area-wide monitoring tools such as remote sensing could be useful in monitoring MLN. • Monitoring MLN incidence in seed farms is critical in its management. • The field efficacy of bean flower thrips pheromones is highly variable. It is critical to understand the factors responsible for the variability.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
	Specific objective: To explore the potentially synergistic relationship between MAT and SIT when applied simultaneously to improve the efficacy of *Bactrocera dorsalis* fruit fly management.	• Potential alternative semio-chemicals for sexual enhancement of sterilized *B. dorsalis* screened by 2021. • Potential alternative semio-chemicals for sexual enhancement of sterilized *B. dorsalis* field validated by 2022.	• Laboratory feeding and wind tunnel assays using *Mondia whitei* showed 8-fold reduction of responsiveness of *B. dorsalis* to methyl eugenol when compared to the control in a dose-dependent manner. • Irradiated flies preferred feeding on 1% methyl eugenol followed by 20% vanilly-acetone and 20% trans-cinnamic acid. Following the ingestion of the substances, mortality was significantly lower in flies that ingested the various substances, being lowest in those that ingested vanilly-acetone (5%). The results were presented at the 2nd RCM 'Assessment of simultaneous application of SIT and MAT to enhance *B. dorsalis* flies'.	• Significance of the growers' indigenous knowledge in advancing scientific knowledge.
	Specific objective: Diversity of endosymbionts and entomopathogens of Dipteran pests and their impacts on dipteran mass-rearing for SIT applications.	• Document diversity of endosymbionts in mass-reared colonies of *B. latifrons*, *B. dorsalis* and *Glossina* sp. • Identify alternative fungi isolates that are less virulent to tsetse fly for compatibility with SIT programs.	• Further screening of 5 previously selected isolates has been undertaken with 2 isolates identified as having potential to be integrated with SIT. Further work is ongoing. • Currently, we are also undertaking 16S metabarcoding of insects exposed to the selected EPFs.	• None
	Specific objective: Upscaling and institutionalizing fruit fly IPM technology among smallholder fruit growers in East Africa.	• Quantification of damage, composition of fruit flies, host range of fruit flies and catalogue of natural enemies. • Numbers of IPM sites and model farmers. • Number of demonstration sessions on the available fruit fly IPM technologies to growers with NARS. • Number of impact assessments undertaken by NARS. • Condition of *icipe* cultures of the two parasitoid species and number of mass releases carried out. • Number of NARS and community extension service providers (CESPs) trained, and growers reached. • Number of awareness campaigns and training materials distributed. • Number of stakeholder meetings taken place and committees formed. • Number of databases of mango growers reached, accessibility of database and	• Trap catches are still very high though the numbers are in a downward trend over time as IPM interventions are implemented • 12 host plants were found to be highly susceptible to attack by fruit fly species. • 5 farmer sensitization campaigns were undertaken, 2 in Kenya (Makueni County) and 3 in Tanzania (one in Dar es Salam and two in Zanzibar). • Colonies of the two parasitoid species are being maintained in good numbers for field releases. • 3 mass releases (one in Makueni, Kenya and two in Zanzibar (at Kizimbani and in Uzi Island)) of the parasitoid species have been undertaken. • We have trained 36 NARS and CESPs (17 males and 19 females), and sensitised 309 growers (205 males and 104 females) in Kenya and Tanzania. • 5 awareness campaigns were conducted (2 in Makueni, Kenya; 1 in Mukuranga, Dar Es Salam; and 2 in Kitope and Kizimbani, Zanzibar). • 1,920 English and 1,350 Kiswahili flyers; and 35 fruit fly manuals were distributed to growers and extension officers.	• Excellent collaborative efforts foster excellent achievements. During this reporting year *icipe* obtained import permits for the 2 key exotic fruit fly parasitoids species and with this collaboration we also managed to introduce and do field releases of the parasitoids for the first time in Zanzibar. • Training the NARS and CESPs as ToTs is an asset for the project as these trainees play a big role in sensitization of growers on conservation of the parasitoids and use of IPM in their areas of jurisdiction. • A committee of growers was formed in Zanzibar, and they are in the process of finalising the constitution for a mango growers association. This will provide a link between the growers and the Ministry of Agriculture officials.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		available interactive platforms for communication and feedback. • Awareness of private sector and number of private sector partners supplying the technologies to the growers.	• 2 stakeholders meetings were undertaken in Zanzibar and 1 fruit growers committee was established. • 1 database with 536 growers in Kenya is available. • Using the already established SMS platform, 14 advisory messages were sent to the growers on various aspects of fruit fly management. • 1 radio programme was broadcasted on a national broadcaster (Radio Maisha) and 2 in Kenya on various aspects of fruit fly IPM.	
	Specific objective: Integrating pest and pollinators management (IPPM) to enhance productivity of avocado and cucurbits among smallholder growers in East Africa.	• Landscape dynamics for cucurbit-avocado production systems in 3 diverse agro-ecology characterized. • Insect pests and pollinators and their abundance in 3 production systems assessed. • Pollination deficit in the target crops assessed. • Interactions between pollinators and IPM practices on pest, pollinators and yield documented. • Sustainable pollination and best-bet IPM options for cucurbits and avocado promoted. • Knowledge, attitude and practices (KAP) towards IPPM documented. • Ex-ante adoption of IPM pollination services documented. • PhD and MSc students trained on bee symbionts, integration of IPM with pollination services and GIS/earth observation tools.	• Earth observation (EO) data (Sentinel 2 data and NDVI indices) was used to guide the implementation of IPPM interventions in an avocado production system in Murang'a (Kenya). The study was published in Remote Sensing Applications: Society and Environment. • We demonstrated the strength of guided regularized random forest (GRRF) algorithms to accurately map cropping patterns in small-scale • farming-dominated landscapes. This study was published in Agriculture. • We tested 8 nonlinear models to describe thermal biology of entomopathogenic fungi currently used for biological control. This study was published in Biocontrol Science and Technology. • We tested 5 *M. anisopliae* and 1 *B. bassiana* strain for their nontarget effects against the honey bee *Apis mellifera* and the stingless bee *Meliponula ferruginea* in the laboratory. This study was published in Economic Entomology. • We found a very high reliance of avocado on insect pollinators. This study was published in Basic and Applied Ecology.	• We showed the utility of integrating EO and socio-economic data in selecting sites for implementing agro-technologies at a landscape scale. • We found optimal temperatures for growth and conidial germination of entomopathogenic fungi were below temperatures of central bee brood areas. • The tested isolates are nontoxic to bees. • Most entomopathogenic strains are non-toxic according to the International Organization of Biological Control (IOBC) classification, but some strains need further testing the field. • Because of high reliance on insect pollination, pollination deficits in smallholder farms stand at >20%, which can be remedied by beehive supplementation.
	Specific objective: Combating arthropod pest for better health, food and resilience to climate change (CAP-Africa).	• Historical data on key pollinators, pests and natural enemies collected and pollinator diversities of the target crops catalogued by 2022. • Number of growers trained on the IPM of key invasive pests of the target crops by 2021. • Ecological models simulated and pest risk assessment (PRA) for at least 3	• 27 species of pollinators, belonging to 8 families in the order Hymenoptera and Diptera, were identified in the target crops. • The potential distribution and global risk of invasion by *Bactrocera zonata* using MaxEnt predicted suitable areas in West, East and Central Africa under current climatic conditions. • Under future climate scenarios, model prediction showed a significant potential range expansion of *B. zonata* in Western Sahara, and Southern, Central, East and West Africa (Zingore et al 2021).	• None.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		invasive pests threatening Africa developed.	• The PRA for *B. zonata* in East Africa is currently being undertaken as part of a student MSc.	
	Specific objective: Assessment of innovative pest biocontrol technologies for sustainable intensification of fruit production systems.	• At least 3 peer-reviewed manuscripts. • At least 2 reports. • Field experiemental data. • Endline household survey dataset.	• 1 manuscript published: (Wangithi et al (2021). Adoption and dis-adoption of sustainable agriculture: a case of farmers' innovations and integrated fruit fly management in Kenya. Agriculture). • A second paper with data from Senegal prepared in 2021. • Field experiment conducted during the 2020/2021 and 2021/2022 mango seasons. • The results of the 2020/2021 season presented at an international seminar and at a conference (Muriithi et al. (2021). Effect of integrating autodissemination technique with male annihilation technique on fruit fly infestation rate and magnitude of mango losses. Conférence Intensification Durable 2021, Dakar, 23-26 November 2021). • Msc student recruited to conduct endline household survey and assess the impact of the additional IPM practice (i.e. auto dissemination technique (ADT)).	• Dis-adoption of IPM technologies evident from the survey sites in Kenya and attributed to various reasons, key among them technology-related constraints including limited access to IPM products, limited returns from investing in IPM, and lack of premium for IPM produced mangoes. • The Senegal study revealed the role of farming systems in pest management, with farms targeting export markets being more input-intensive including using wide range of pest management practices in comparison to input-extensive and gathering farming systems. • We found significant reduction of fly infestation for male annihilation technique (MAT) treatment for both Tommy and Kent mango varieties after the intervention, however the two mango varieties were contrasting when MAT and ADT were used in combination, where Tommy displayed significant reduction while for Kent, infestation increased. Across groups, integrating MAT and ADT reduced the infestation rate by more than 48% than when using MAT alone for Tommy variety, hence mango losses due to the pest decreases significantly. • The experiment further revealed increased infestation of the indigenous fruit flies when the IPM practices reduces the population of *B. dorsalis*.
	Specific objective: Combating the invasive tomato leafminer *T. absoluta* through the Implementation of an eco-friendly IPM approach on tomato in East Africa.	• The laboratory performance of the parasitoid against *T. absoluta* determined by 2020, and field release undertaken, and establishment assessed by 2021. Awareness on the burden of *T. absoluta* created among the stakeholder, farmers' perceptions of	• The nature and outcome of the interaction between the parasitoid *Dolichogenidea gelechiidivoris* and the mirid predator *Nesidiocoris tenuis* in the control of a co-shared host/prey, *Tuta absoluta*, was assessed under laboratory conditions. The findings revealed that the presence of *N. tenuis* did not affect the oviposition performance and the progeny of the parasitoid.	• Close collaboration with NARS and the regulatory body in fast-tracking the importing and release of natural enemies is important. • We confirmed that *Tuta absoluta* is the major tomato-infesting pest, with chemical pesticides being used by most farmers to

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		management of *T. absoluta* documented and potential demand for the same determined and shared with stakeholders by 2021. • At least 2,000 farmers and other tomato value chain actors are aware of the knowledge, attitudes and practices (KAP) of farmers in regard to tomato production and IPM technologies assessed. • Baseline survey datasets.	• When both natural enemies were combined, the efficacy in reducing *T. absoluta* populations was significantly higher than that of either natural enemy used alone (Aigbedion-Atalor et al (2021) Insects). • In addition to Kenya, we have expanded our parasitoid releases to Uganda for classical biological control of *T. absoluta*. • Assessment of the parasitoid colonization in Kenya showed that the parasitoid is already established in the major tomato growing area of Kirinyaga County. • 1 manuscript published (Chepchirchir et al (2021)) on farmer perception and knowledge, and ex-ante demand for IPM technologies for management *of Tuta absoluta*. • A paper assessing the knowledge, perception and willingness to stock the biopesticide ICIPE 20 was published (Ogutu et al. (2022)).	control it. Majority of the study respondents were however willing to pay for IPM. Training and IPM awareness creation are recommended for sustainable adoption of the innovations. • A higher proportion of agro-dealers were willing to pay for ICIPE 20 at a higher price than Coragen, the most popular insecticide for management of *T. absoluta*. Further, the results showed that age, education, access to social networks and credit facilities, and information access relate to agro-dealer's knowledge, perception and willingness to stock the biopesticide. The study recommends training of agro-dealers to promote greater uptake of the biopesticides.
	Specific objective: Promote sustainable management of *T. absoluta*, an invasive pest of solanaceous vegetables, for food and nutritional security in East Africa.	• Validate the most promising EPFs. • Standardise parameters for an attract-and-kill product based on EPFs with lure strategies. • Explore induction of system resistance by endophytic fungi. • Validate, implement and disseminate IPM package for *T. absoluta*. • Identify, characterize and evaluate blends for *T. absoluta* repellency from wild tomato for *T. absoluta* suppression. • Baseline survey datasets. • Train NARS from each project country on the developed IPM package. • Sensitise growers through FFS and awareness campaigns. • Train PhD and MSc students on IPM technologies for *T. absoluta* suppression.	• Spatial prediction for the already identified *T. absoluta* candidate biopesticides ICIPE 18 and ICIPE 20 revealed that the 2 isolates are suitable and could be considered for management based on temperature and location (Agbessenou et al. (2021) Scientific Reports). • On-farm demonstrations were conducted in 35 tomato fields in Uganda (Masaka, Mbale and Kapchorwa Districts) for farmers, adult and youth that were trained on site. • Chemical analysis of the headspace volatiles of the host and non-host plants of *T. absoluta* revealed 9 compounds to be the most important volatiles relative to the host plants, while another 9 compounds are important to the non-host plants. Work on this aspect is still ongoing. • Study assessing the awareness, attitude and control practices of farmers on *T. absoluta* and examine the potential adoption of a proposed IPM strategy for the management of the pest using a randomly selected sample of 316 and 345 tomato growing households in Kenya and Uganda, respectively, was published (Chepchirchir et al (2021)). • 3 ToT workshops (one in each project country), where 67 extension and quarantine officers and model farmers were trained. • 285 farmers were sensitised and trained in Kenya and Uganda by *icipe* and partners. Further trainings were	• It is important to increase the number of available technologies. This will give growers a wide range of technologies that are suitable and convenient for use to all range of growers. • Significant proportion of the survey respondents were willing to adopt the IPM strategy, with probability of adopting the strategy being positively related to a farmer being male, residing near a source of inputs, accessing training, and possessing good knowledge, attitude and practices towards the use of non-pesticides strategies. Thus, training, promotion and awareness creation of *T. absoluta* IPM are recommended for the sustainable management of the pest in tomato production. • To enhance uptake and adoption of IPM technologies, capacity building is of paramount importance.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			undertaken by the Ugandan partners across all the project sites, training of 283 additional farmers. • 3 PhD students and 7 MSc students are working on various aspects of the project.	
	Specific objective: Alien invasive fruit flies in Southern Africa: implementation of a sustainable IPM program to combat their menaces.	• Increase in mango yield by 25% and reduction in chemical insecticide use by 50% by 2022. • 40 demonstration and learning sites for scaling up proven IPM. technologies established in the target countries by 2021. • At least 1 working paper on landscape land use and land cover characterization to guide IPM implementation and maps elucidating suitable areas for parasitoid establishment by 2021. • Obtain and renew import permits, introduce and mass reared of the parasitoids (*F. arisanus* and *D. longicaudata*) in the target countries by 2021 • Large-scale augmentative releases and establishment, colonization and dispersal of released parasitoids undertaken by 2022. • At least 1 ex-ante by 2021 and ex-post socio-economic study by 2022 undertaken. • Awareness on economic, social, environmental and human health impacts of interventions, created among various stakeholders by 2022. • 1 million resource-poor farmers are aware of fruit fly IPM • 3 postgraduate students will graduate by 2022.	• Mango orchards in Zimbabwe were mapped using satellite data and machine learning models, manuscripts on the same have been submitted to Journal of Photogrammetry and Remote Sensing. • 23,500 each of *F. arisanus* and *D. longicaudata* parasitized puparia were shipped to the target countries for parasitoid field releases and boosting the laboratories colonies. • As a measure to cope with COVID-19 pandemic, we have capacitated 26 women and 5 men on mango drying using solar energy. • Qualitative data using focus group discussions were also collected in Mozambique, while in Zambia ProWEAI data were collected from 500 individual mango farmers. • Using the contingent valuation approach, the study elicited the willingness to pay (WTP) for fruit fly IPM practices among the sampled households.	• Empowering women, increasing their access to extension services, and providing livelihood alternatives would increase uptake of pest management technologies such as IPM. • Our preliminary findings from the Pro-WEAI analysis showed women are less empowered than men in dual households, with the largest gaps observed in the adequacy of work balance, autonomy in income and respect among household members.
	Specific objective: An integrated approach to mango production to improve smallholders' food	• Number of IPM tools scaled. • Number of smallholder growers trained. • Number of nursery and orchard management tools, postharvest handling tools.	• 1,342 mango farmers were trained, provided with technological inputs and technical supports, and are demonstrating and practicing integrated mango management.	• Topwork (grafting, pruning, thinning) is a highly demanding technology by the farmers, which requires timely facilitation of equipment, arrangement of scions and

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
	security and incomes in Ethiopia.	• A classical biocontrol program against the white mango scale implemented.	• Beneficiary farmers were identified and number of farmers with increased yield will be measured annually in 2022 and 2023. • Number of farmers with increased income will be measured annually; presently data are being collected in January 2022.	skilled technicians, and identification of specific varieties needed by the farmers. • Topwork could be a solution to control white scale through removing infected branches and twigs in addition to its primary objective of improving yield. • Farmers need better planting materials and seek information on planting seasons and pest management
	Specific objective: Establishing the status of the alien invasive *Drosophila suzukii* in Kenya and develop measure for its containment and management.	• The status of the pest in Kenya is established and the extend of spread documented by 2021. • The spread of the pest to other areas curtailed by 2022.	• The outcome of the delimiting survey, which was undertaken in the major berries producing area, showed that the pest is confined to the county of the initial detection. However, with the movement of the fruit the likelihood of pest spreading is quite high. • At the detection site the use of different lures continued for pest suppression.	• None.
	Specific objective: Intensified agroecological-based cropping systems to enhance food security, environmental safety and income of smallholder producers traditional African vegetables in East Africa – AGROVEG.	• Number of households who adopt biological and agroecological-based approaches to control pests. • Number of biological control and agroecological-based approaches tested and ready to be implemented with farmers. • Number of certified TAV varieties tested with farmers, promoted and disseminated. • Number of value chain actors participating on project adapted existing market and information platforms. • Number of functional agroecological-based vegetable existing platforms adapted. • Number of farmers and other value chain actors correctly applied recommended agroecological farming approaches. • Number of farmers and other value chain actors trained in good agroecological-based practices.	• No outputs as the project started in 2022.	• No lessons learnt as the project started in 2022.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
Broad objective 3: Make available IPM options for industrial crops.	**Specific objective:** Generate sustainable wealth creation for improved livelihood and poverty alleviation in rural areas, through a green circular economy and sustainable coffee production (SCP) promotion in Africa.	• Training publications. • A practical handbook on the triple certification scheme. • GI book of requirements. • Project database. • Contracts with farmers for GI, FT and ECO certification. • GI, FT and ECO certification criteria compendium. • Various site maps created. • Social and legal prospective study developed. • Compendium on coffee pest and disease control measures in compliance with ECO certification. • IPM and climate change adaptation strategy guidebook. • Pamphlets, factsheets. • SWITCH regional conference compendium. • Policy recommendations. • Platform implementation.	• The web-based IT platform has been developed and has been deployed on the net (https://rwenzorimountaincoffee.org/). • Due to the COVID-19 impact on the project, all field activities have been abandoned (microclimate, and pest and disease monitoring). • A 6 month project extension has been granted (until July 2022) to finalise the GI certification process.	• GI coffee certification is attracting increasing interest in Uganda (from producers to national institutions), with high potential for regional upscaling. • Coffee cooperatives' needs in organization management and governance are better understood and taken care of.
	Specific objective: Support the sustainable development strategy of Uganda's green economy by improving the performance of coffee agroforestry production systems to mitigate climate change impact on the national agriculture and forestry sectors.	• Number of farmers adopting improved P&D management tools. • Acreage and regions where improved systems are implemented. • Fruit production statistics. • Number of farmers adopting/increasing fruit production. • Number of farmers trained for agroforestry practices. • Number of Lead Farmers trained. • Number of technicians trained. • Number of coffee producers with access to web-based knowledge platform. • Number of mobile device applications created. • Number of applications installed. • Number of consultations of the platform.	• No outputs yet as the project started in 2022.	• No lessons learnt yet as the project started in 2022.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		• Compendium generated about coffee and fruit production. • Number of Robusta coffee producing cooperative adopting the platform as a management tool.		
Broad objective 4: Develop push-pull systems.	**Specific objective:** Improve ecological and economic performance of push-pull technology (PPT) through comprehensive management of striga, stemborers and FAW infestation in collaboration with international and national partners by 2025.	• Food sufficiency and household incomes of 350,000 push-pull farmers increased by at least 50% by 2025 through higher and sustained crop, fodder and milk yields. • Novel scientific knowledge on early herbivory and plant signalling generated and applied in crop protection by scientists, extension agents and policy makers by 2023. • Staple grain yield increased by 30% for >20,000 farmers in sub-Saharan Africa by 2025 through early herbivory alert. • Scientific knowledge generated on tri-trophic interactions and innate plant defences, push-pull control mechanisms and suitable companion plants by 2023. • Scientific knowledge included in integrated management of FAW in Africa by scientists, extension agents and policy makers by 2025.	• Stemborers, striga and FAW infestations were effectively managed by 284,423 (125,576 female, 158,847 male) farmers on >170,650 ha, among whom 186,287 farmers (89,266 females and 97,021 males) have adopted the climate-smart PPT, gaining between 3.5-6.2 t/ha, and providing food sufficiency to >1,700,000 people. • 150,000 farmers have improved dairy animals utilizing fodder for push-pull with milk yields >460 litres/cow/year. • Stemborer management approach was further developed by exploiting early herbivory traits and plant signaling. The potential of stemborer egg induced 'call-for-help' defense trait in improving stemborer control efficiency by push-pull in maize was further evaluated using the parasitic wasp *Cotesia sesamiae*. • A FAW management approach was developed by understanding the mechanisms by which push-pull controls the pest and incorporating more versatile intercrop and trap plants. • The potential roles of selected forage grasses (trap plants) in management of FAW through companion cropping was evaluated (Cheruiyot et al 2021). • 6 African maize cultivars were also evaluated for different aspects of resistance to FAW (Chririboga, et al 2021). • An integrated management approach was developed and implemented for *Striga* sp. control in cereals. Push-pull plots recorded significantly lower means for *Striga* sp. counts, FAW and stemborer damage; and higher grain yield than in plots that followed farmers' own practices. • >35 partnerships maintained for adaptation, validation and scaling up of climate-smart push-pull in 18 sub-Saharan countries. • Large scale dissemination of climate-smart push-pull reached 76,300 new farmers (42,981 males and 33,319 females) directly and through partnerships in 2021. Secondary reach through partners, social media and mass media created awareness of 5.5 million people.	• The three variants of push-pull (conventional, climate-smart and third generation) have maintained suitable chemistry and effectively controlled stemborers, *Striga* sp., weed and FAW; with proficiency in improving soil fertility, moisture retention and organic matter and high-quality fodder production. • FAW could have competitive advantages over stemborers on maize plants. A recent study (Hailu, et al 2021) indicates a possible displacement of stemborer from maize onto sorghum. IPM packages should consider managing FAW and stemborer together in both maize and other cereal hosts. • Although *Brachiaria* and Napier grass cultivars were strongly preferred to maize for oviposition, results indicate plants attractive to FAW adults and larvae that could be utilized in a multiple trap crop approach to target various stages of the pest. • Complete resistance to FAW feeding was not found in the evaluated maize cultivars, but differences in acceptance and preference when FAW larvae were detected in choice tests between certain cultivars. 'SC Duma 43' maize hybrid had an antibiosis effect on FAW larvae.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
	Specific objective: Intensify push-pull technology (PPT) to improve food security, nutrition and incomes.	• A push-pull system developed for vegetables. • Proven and validated push-pull vegetable agronomic designs adopted by 3,000 farmers by 2025. • At least 3,000 farmers in Western Kenya reached by 2025 with new knowledge on integration of vegetables in push-pull. • Vegetable production and consumption in 3,000 households adopting the technology increased by at least 20% by 2025. • At least 3,000 famers (including women and youth) increase farm incomes by 30% from vegetable sales by 2025. • At least 1 study conducted on impact of integrated system on vegetable pests and natural enemies. • At least 2 active semio-chemicals, produced by companion plants, evaluated on the behaviour of vegetable pests and their natural enemies by 2022.	• Integrated push-pull vegetable agronomic management designs were tested on farmer-preferred vegetables both on station and on-farm, involving 575 farm households in western Kenya. • Major pests of farmer preferred vegetables were identified, and their current management options studied. The response of parasitoids of key vegetable pests such as diamondback moth (*Plutella xylostella*), the tomato leafminer (*Tuta absoluta*) and aphids was tested to volatiles of both greenleaf and silverleaf *Desmodium*. • The impact of cereal push-pull system on vegetable pests and their natural enemies was evaluated; and the chemical ecology of vegetable pest-plant-natural enemy interactions elucidated within the context of integrated push-pull system. • An economic study analyzed the profitability of vegetable agronomic options planted by smallholder farmers under different push-pull vegetable agronomic arrangements. Three different agronomic options were compared by means of gross margins cost-benefit analysis, and net present value.	• Comparative on- farm results show the pests were highest in sole vegetable plots, followed by full push-pull-vegetable intercrops, and least in vegetable-*Desmodium* intercrops. On-station results show those treatments with maize + *Desmodium* + vegetable performed best in controlling pests and diseases. In the first season, aphids, a pest that can cause up to 100% yield losses on kales, was lowest in *Desmodium* plots. At the 4th week of the first experiment, kales + maize had 62% aphid damage while in *Desmodium* treatment only 10% of the plants were damaged. These results were similarly noted in the second season. • Vegetable intercropped in full push-pull system was the most profitable option for farmers in all vegetable studied with a positive net present value of KSh 1,165/ha just within two seasons taking kales as a sample and a cost-benefit ratio of 1.74. • These results suggest economic viability of integrating vegetables into push-pull. Gross margins were relatively higher for full push-pull-vegetables than in other agronomic options.
	Specific objective: Combat arthropod pests to achieve better health, food and resilience to climate change (CAP-Africa).	• Climate-smart push-pull extended to 1 additional agro-ecology and 1 additional farming system by 2024. • Climate-smart push-pull adopted by about 100,000 farmers by 2025. • At least 2 policy guidelines developed on PPT transfer by 2024. • 2 impact studies conducted covering Eastern Africa by 2025.	• To improve further resilience and agro-ecological range of the push-pull system under current and predicted impacts of climate change, more adapted and suitable companion plants, *Brachiaria brizantha* cv. *Xaraes* and *Desmodium incanum* were identified and integrated into a new version of push-pull, termed 'third generation PPT'. The adapted version retained the basic principles of the technology: suitable chemistry to control stemborers; striga weed and FAW, with proficiency in improving soil fertility, moisture retention and organic matter; and added value, for example in provision of high-quality fodder. • Field performance and farmer opinions of this new version were evaluated in comparison with the earlier version,	• Both climate-smart and third generation PPT plots recorded significantly lower means for stemborer damage and *Striga* counts and higher means for grain yield than in control plots. Both PPT plots did not significantly differ in *Striga* counts but the climate smart PPT exhibited higher stemborer damage than third generation PPT. Generally, in on-farm trials, both PPT plots recorded significantly lower means for *Striga* counts, FAW and stemborer damage; and higher grain yield than in plots that followed farmers' own practices.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			climate-smart PPT, and farmers' own practices of growing maize in controlling stemborers, FAW and *Striga* weeds. • The climate-smart push-pull was disseminated to 76,300 new farmers (42,981 males and 33,319 females) through strategic partnerships.	• Farmers preferred the third generation PPT for important traits possessed by the companion plants used in this technology, in which their counterparts in climate-smart PPT are deficient. The cultivar *Xaraes* was rated as 'very good' for resistance to spider mites, biomass yield and drought tolerance while *D. incanum*, was rated 'very good' for seed production and drought tolerance. The third generation PPT, therefore, presents a better option to in developing new crop pest management strategies and meet different needs of farmers especially in arid and semi-arid conditions.
	Specific objective: Promote biocontrol of FAW in smallholder cropping systems by enhancing crop diversity and ecosystem services.	• At least 4 farmer-preferred cereal varieties assessed by 2022. • A novel FAW-resilient push-pull system, which will include control of stemborers and *Striga* weed, developed and adopted by 30,000 farmers by 2023. • FAW-resistant companion crops, which repel the pest and attract pest's natural enemies (egg and larval parasitoids), evaluated and incorporated in a resilient push-pull system by 2024. • FAW natural enemies identified in sample field locations by 2022. • Tri-trophic interactions between FAW natural enemies and host crops assessed by 2023. • Biologically active compounds mediating FAW-host plant-natural enemy interactions determined by 2024.	• Laboratory bioassays were conducted to understand the interaction of maize genotypes with FAW and its natural enemies. The arrestment and feeding of FAW neonate larvae on locally adapted maize cultivars, hybrids and landraces was also assessed in no-choice and choice experiments. The development of larvae-pupae, food assimilation under laboratory conditions and plant damage were also assessed in a field experiment. • The impact of different legumes in combating FAW was assessed within the PPT. On-station trials included treatments, replicated four times, of greenleaf *Desmodium*, common bean, green grams, groundnuts, crotalaria, cowpea and maize monocrop as a control. • An oviposition bioassay conducted on *Desmodium* sp. intercrop and *Brachiaria* sp. border plants' attraction/repellency of FAW female moths in the push-pull system in 6 different treatments were tested: (i) green leaf *Desmodium* sp. (GL); (ii) silver leaf *Desmodium* sp. (SL); (iii) *Brachiaria Mulato* II; (iv) maize hybrid Duma as a control treatment; (v) Duma + GL; (vi) Duma + SL. • Field surveys and on-farm field assessments were conducted and the impact of PPT on suppression of FAW validated. Better adapted and effective companion plants (*Brachiaria* cv. Xaraes, *Brachiaria* cv. Piata, *Desmodium incanum* and *Desmodium ramosissimum*) were consistently more effective against FAW.	• The number of FAW eggs laid indicate repellency effects of greenleaf *Desmodium* sp., silver leaf *Desmodium* sp. and *Brachiaria* cv. Mulato II plants against FAW female moths. • There was no complete resistance to FAW feeding in the evaluated maize cultivars, but differences were detected in acceptance and preference when FAW larvae were given a choice between certain cultivars. The smallest pupal weight and the lowest growth index were found on 'SC Duma 43' leaves, which suggests an effect of antibiosis of this maize hybrid against FAW larvae. In contrast, the highest growth index was recorded on 'Rachar' and the greatest pupal weight was found on 'Nyamula' and 'Rachar'. The density of trichomes on the leaves of these maize cultivars was not directly related to the preference of neonates for feeding. • Greenleaf *Desmodium* had the least infection suggesting it as the most effective control of FAW. Greenleaf *Desmodium* also posted the highest yields compared to other legumes.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			• *Desmodium incanum* and *Brachiara* cv. *xaraes* were also intercropped with sorghum and the system was also tested against FAW infestation. • The behavioural responses of *Telenomus remus* to volatiles from silverleaf *Desmodium* was assessed in laboratory bioassays to understand the interaction of maize genotypes with FAW and its natural enemies. • The volatiles of silverleaf *Desmodium* were more attractive to the parasitoids compared to an organic solvent, DCM. This suggests *Desmodium* has potential capacity to recruit *T. remus* within push-pull. Further behavioural assays are currently underway using greenleaf *Desmodium*. • The climate-smart push-pull option was validated for the combined control of stemborers, *Striga* sp. and FAW on 858 farmers' fields in different agro-climatic conditions in 9 counties in Western Kenya and Northern Tanzania for FAW management.	Monocropped maize had the lowest yield. Whilst the search for the perfect trap plant for FAW continues, *B. brizantha* cv. Xaraes and *P. purpureum* cv. *South Africa* were more attractive to FAW than maize when planted early. • Both the climate-smart and third generation PPT reduced FAW larvae (89.7% and 85.5%, respectively) and FAW damage (71% and 60%, respectively) and increased maize yield (by 95.2% and 88.2%, respectively) as compared with farmers' own practices. • The yields from the two treatments; climate adapted technology (2.4 t/ha) and 3rd generation push-pull (2.3 t/ha) were higher than that from the control (1 t/ha). • FAW infestation in the different legumes ranged from 19.7% in greenleaf *Desmodium* sp. intercrop to 62.5% in the maize monocrop. Maize intercropped with greenleaf *Desmodium* sp. had the least infestation, which was significantly different than the other treatments, and posted higher yields (4.7t/ha). • The FAW natural enemy *Cotesia icipe* was attracted to maize volatiles induced by larvae feeding. The main induced maize volatiles include aromatic indole, and mono- and sesquiterpenes.
	Specific objective: Scale up biocontrol innovations in Africa.	• Study conducted to identify how biocontrol interventions have been successfully adopted and understand the bottlenecks to further adoption by 2022. • Study conducted to evaluate how farmer-farmer networking can be facilitated using a prototype mobile phone-based information sharing system by 2023.	• A systematic review and meta-analysis of biocontrol technologies was conducted in cooperation with Leeds University. A quantitative synthesis of existing literature was done to assess the effectiveness of different biological control interventions in Africa, to better understand the key factors driving the success or failure of biocontrol interventions, focusing on four measures of outcome that are commonly used to quantify the effectives of pest management practices: pest abundance, pest damage, yield and natural enemy abundance.	• The meta-analysis indicates that biocontrol interventions can effectively reduce pest abundance and crop damage by over 50%, while increasing crop yield by more than 60%. Biocontrol technologies performed as well as synthetic chemical pesticides and increased natural enemy populations. The implication is that biological control could make a big difference in increasing yields on smallholder farms.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			• The manuscript 'Effectiveness of biological control innovations/interventions in sub-Saharan Africa: a meta-analysis' was drafted and submitted for publication. • A mobile phone app was developed in cooperation with a private developer, Agape communications to transmit push-pull biocontrol technology information via mobile phone GSM networks in Africa. The app was tested in Kenya and Uganda and made available via Google Play.	• Farmers rated the mobile phone app as self-explanatory and easy-to-use. and did not need a trainer to explain the concepts. The most sought after information was about the benefits of push-pull, how to plant and manage push-pull.
	Specific objective: UPSCALE – Upscaling the benefits of push-pull technology (PPT) for sustainable agricultural intensification in East Africa.	• The understanding and spatial applicability of push-pull scaled up in at least 4 countries to at least 25,000 farm households in East Africa by 2024. • Diversified, optimized push-pull options scaled out as widely as possible in 5 countries by 2024. • PPT expanded from cereal to at least 4 other crops and cultivation systems by 2024. • The factors influencing push-pull success across scales determined by 2023.	• The UPSCALE project was launched in Kenya, Rwanda, Tanzania and Ethiopia with 19 partners and several thematic areas: expansion of push-pull adoption to as many farmers as possible; expansion of push-pull effectively using optimal conditions for success; integration of push-pull in long-term sustainability and climate resilience strategies; further improvement of the existing technology to increase its flexibility and added-value; mainstream women and youth in technology dissemination and adoption; and wider engagement of all value chain actors to extend the benefits of PPT, its sustainable intensification for food security and environmental sustainability. • Socioeconomic baselines of the target communities in study region and indicators for monitoring project effectiveness and impact were established. • Target locations were mapped, and 150 fields selected for joint study design. • Work started on the determinants of pest control and other ecosystem functions in current maize push-pull and monocrop systems. • Work started on mapping food-webs across push-pull and monocrop fields to determine key natural enemies and pest control resilience. • In adapting PPT across scales and crops, standardized protocols were developed for push-pull and non-push-pull fields. • To diversify, optimize and scale out push-pull options as widely as possible, socioeconomic household surveys (1,556 households) were conducted in 5 countries, agroecological field sampling was done across gradients in landscape-scale habitats; socio-ecochemical mapping was conducted, farmers' needs were assessed for multi-crop integration; remote sensing of land cover/land use, and climate	• To achieve the goals of improved food security, livelihoods and climate change resilience, while reducing the environmental impact of agricultural practices, interventions need to substantially improve understanding of the drivers of cereal push-pull effectiveness and climate resilience at different levels using large-scale gradients in land use, climatic and soil conditions, and identify suitable regions and landscapes for targeted expansion of push-pull beyond its current spread. • Interventions need to develop user-friendly tools in collaboration with local, national, and transnational partners to identify and target appropriate regions and methods for push-pull expansion. • Interventions need to identify barriers to implementation and opportunities for improvement of PPT dissemination and adoption. • Interventions need to evaluate 'spill-over effects' of PPT outside the fields and farms where it is implemented, • Interventions need to establish a knowledge exchange hub and communities of practice for optimal flow of information between stakeholders at all levels for active communication, coordination, dissemination and facilitation of sustainable intensification methods including push-pull in different systems and regions of East Africa.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			modelling were initiated; and participative socio-ecological modelling done with 5 multi-actor communities of practice. • To sustain adoption and lasting impacts of the upscaling: multi-actor communities of practice (MAC) were established for transdisciplinary integration and knowledge building; socioeconomic survey was conducted for understanding of barriers to adoption; product value chains were mapped for market integration of push-pull products; push-pull was widely communicated and disseminated to >6.5 million people, and at least 1,832 farmers (857 males, 975 females) and 156 extension staff (110 males, 46 females) directly trained by *icipe* field staff and partners; and digital tools including apps and a Knowledge Exchange Hub developed.	
	Specific objective: Elucidation of the science and effectiveness of local innovations for managing fall armyworm (FAW) (LIMFA).	• Staff and laboratory/insectary space available to conduct the laboratory observation. • No negative effects of COVID-19 on implementation of the project.	• Under laboratory conditions. detergent was most effective causing 100% mortality of FAW larvae.	• Detergent was most effective under laboratory condition followed by neem leaf extracts
	Specific objective: Enhance cropping system resilience under climate change towards sustainable maize production in East Africa.	• Number of analyses on pests and yield analysis done across different farms in different cropping seasons and landscapes. • Number of predator diversity and community composition, parasitism rates and biocontrol effectiveness identified in different cropping systems and landscape structure. • Number of quantitative foodwebs built using a novel approach of estimated densities of predators and predator-prey body size ratios. • A Bayesian state-space model combining yearly time-series data developed for sites with and without push-pull cropping system.	• 1,931 data points from 483 unique farmers and 24 cropping seasons analysed on push-pull cropping system effect on pest abundance (insects and parasitic weeds) and yield. • Arthropod community data from 16 pairs of push-pull and non-push-pull farms in different landscapes identified for two seasons. • Arthropod community data from 16 pairs of push-pull and non-push-pull farms for season 3 ongoing. • A first draft model on landscape-scale predictions of push-pull effectiveness under future climate was developed.	• Benefits of push-pull cropping systems improve slightly over time and even have positive effects on adjacent non-push-pull maize fields. • Push-pull and non-push-pull farms harbour diverse arthropod communities across different agroecologies.
	Specific objective: Develop a push-pull system exclusively for vegetables.	• Number and quality of companion plants evaluated for push and pull functionality in vegetable push-pull cropping system.	• Developed a proposal to acquire resources and the proposal was funded by Biovision Foundation to carry out the work starting in 2022.	• No lessons learnt yet.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		• Number of partners or research stations engaged in developing crucifers push-pull cropping systems. • Number of smallholder farmers and farmer organizations/groups engaged in on-farm trials aimed at validating cruciferous push-pull cropping systems. • Number of functional agroecological-based vegetable existing platforms adapted. • Number of smallholder farmers and other value chain actors correctly applying recommended agroecological-based farming approaches.		
	Specific objective: A4a: evidence for the feasibility of scaling up agroecology.	• At least 80% interviewed beneficiary farmers use *Desmodium* and *Brachiaria* seeds successfully in the push-pull system. • Rapid assessment of main barriers and success factors of PPT determined. • At least 150 push pull seed production demonstration plots established.	• By December 2021, 87% beneficiary farmers use *Desmodium* and *Brachiaria* seed successfully in their push-pull system. • Rapid survey on main barriers and success factors for the adoption of PPT conducted in November 2020. • The project demonstrated PPT demos with a total of 167 beneficiary farmers including 93 farmers in 2020 and 74 farmers in 2021.	• Need for continuous engagement with the farmers was one of the lessons that we learnt from the beneficiary group in terms of instilling the project benefits to grassroots. • Regular follow-up is required, as most of the farmers are busy with their different farm activities, which gives them less attention for the PPT plots. • Farmers are suspicious about new technologies or new projects; we observed that training is an important approach to make the beneficiary farmers more aware of the technology.
Broad objective 5: Make available IPM options for invasive and migrant pests.	**Specific objective:** Established a decision-oriented tool to predicting insect damage on crops under climate change by 2021.	• At least 1 high impact paper published.	• Damage and crop loss functions for FAW have been established at 5 levels of temperature and CO_2. • Damage and crop loss functions have been linked to insect pest models. • A paper is being drafted for publication in Nature.	• Not only the effect of temperature, but also that of CO_2 is having major impacts on the insect damage, crop loss and ultimately yield of the crop.
	Specific objective: A proactive development of biopesticide for sustainable management of the desert locust *Schistocerca gregaria* in Africa.	• Number of isolates tested. • Number of isolates commercialized. • At least on application technique developed.	• This project started in 2022 and there are no outputs yet.	• No lessons learnt yet.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
Broad objective 6: Make available IPM options for soil pests and enhance soil health.	**Specific objective:** Microbial uptakes for sustainable management of major banana pests and diseases.	• At least 20 EBCAs screened against banana nematodes and the banana weevil. • At least 6 EBCAs selected and active against banana nematodes and the banana weevil. • Antagonistic effect of EBCAs combinations tested against banana nematodes and the banana weevil. • EBCAs for field trials selected and active against banana nematodes and the banana weevil.	• EBCAs (endophytes and biocontrol agents) have been screened against the burrowing nematode (*Radopholus*), the lesion nematode (*Pratylenchus*) and the banana weevil (*Cosmopolitis sordidus*). Three *Beauveria bassiana* isolates (ICIPE 648, ICIPE 660 & ICIPE 273) were found to be highly effective against the adult banana weevil. • Controlled field trials demonstrated that inoculation of the East African highland banana cultivar Mbwazirume and the dessert banana cultivar Grande Naine with the non-pathogenic endophytic fungus *F. oxysporum* isolate V5w2 suppresses banana nematode (*Radopholus*) infection and increases banana productivity.	• Compatibility and performance of the candidate isolates with already existing environmentally friendly management strategies will help develop a strong IPM strategy against the banana weevil. Further on-farm trials are needed. • We need to elucidate the mechanisms underpinning nematode suppression and increased banana yield observed after treatment with *F. oxysporum* isolate V5w2. The influence of single or combined application of the assessed endophytes on soil microbiome and soil health should also be assessed to better understand other benefits that could be derived from this potential biopesticide. • How can we improve adoption of the research products (results) by farmers? Increased farmer field trials to verify research may help.
	Specific objective: Diagnostic tool for the identification and quantification of the potato cyst nematode (PCN).	• Contribute to better agronomic practices by detecting key pests early. • Contribute to reduced pesticide use. • Improved potato yields.	• Together with partners UK Agri-Tech Centre Crop Health and Protection (CHAP) and PES Technologies, *icipe* has developed a proof-of-concept for a diagnostic tool to identify and quantify potato cyst nematodes. We are developing this solution to provide more soil health indicators from a single soil sample than any other tool so far.	• PES Technologies are now conducting further analysis of sensor data and developing it further, with the aim of eventually providing farmers with a quick, easy and cost-effective soil health tool and PCN assessment method.
	Specific objective: Capacity building in nematology.	• A soil health (nematology) platform established in the region, comprising researchers, students, research institutes/universities, extension workers, farmers organisations and private sector. • Soil health and nematology expertise established at *icipe* contributing to improved food security by identifying key below ground pests and associated diseases in crops and providing options for their management. • Increased awareness and understanding of nematodes as pests among all farmers (small holder and commercial) leading to short- and long-term solutions.	• A soil health (nematode) platform at *icipe* as a hub is expanding and collaboration with (national and international) universities is strengthened (mainly through hosting and training of students). • We also started the Nematology Education in Sub-Saharan Africa project (NEMEDUSSA), a joint effort by a consortium of universities from Sub-Saharan Africa and Europe, in which PANEMA (A new pan-African nematology network) is a main initiative. • The NemAfrica lab runs an active journal club where students (internal and external) gain experience giving presentations of either their own work or other publications for discussion and critical review, enhancing their presentation skills.	• Communication with partners is essential for sustaining the soil health nematology platform. • Enhanced funding required and actions to obtain them. • Enhanced activities and follow up with all stakeholders (students, researchers, farmers etc.) will ensure awareness creation in soil health (nematology). • Low awareness among stakeholders is observed in general.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			• Support is also given for scholarship opportunities. The international MSc in Nematology Program at Ghent University Belgium, has since 2017 awarded 7 scholarships to students from the *icipe* NemAfrica lab. Regular activities on internships, undergraduate and postgraduate training are continued. • Alongside, we coordinated the annual Kenya Track which enables International MSc in Agro-and Environmental Nematology (IMANEMA), Ghent University, Belgium to undertake industrial training in Kenya in 2021. 6 students from Ethiopia, Cambodia, Kenya and Tanzania participated as part of their Kenya Track. • We hosted the annual Basic Crash Course Nematology (BCCN), with 15 participants from Burundi, Ethiopia, Kenya, Nigeria, Uganda. • Participated in a number of key fora on nematology, organised awareness events for practitioners and farmers, in partnership with industry actors. • 4 peer review publications.	

(ii) Animal Health Theme: Results Based Management (RBM) Rolling Framework Report

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
Broad objective 1: Develop a sustainable integrated biorational strategy for controlling vectors of animal trypanosomiasis by 2025	**Specific objective1**: To develop and evaluate effective, low-cost baits and repellent blends for vectors of camel trypanosomosis (surra) by 2025	• Number of technologies and strategies developed • Numbers of smallholder farmers impacted • Percent reduction in the prevalence of AT in intervened sites • Percent increment in animal production and productivity	• Three potential attractants identified and formulated for biting flies. • Three repellents formulation developed for biting flies • One repellent evaluated at a small-scale in a field setting.	Extended drought and nomadic lifestyle of the pastoralists made its application and follow-up challenging. Enhanced engagement of NARES and trained pastoralists will be critical for evaluating, scaling, and sustaining the technologies
	Specific objective 2: To improve traps and targets for tsetse and biting flies by enhancing the visual attractivity of these by 2025	• Number of traps and targets developed and evaluated for tsetse and biting flies	• Two potentially effective targets for controlling tsetse and stable flies developed. • We have screened 16 different fabrics to identify visually attractive colours to tsetse and stable flies. • One fabric (red colour) has been identified as a potential fabric for making traps for stable flies.	By modelling insect vision, we can circumvent long and costly bioassays for identifying attractive fabrics. Such an approach is easily replicable and can be scaled to other vectors of one health significance.
	Specific objective 3: To upscale the integrated use of novel tsetse and biting fly traps, attractants, and repellents in partnership with the private sector 2025	• Number of complementary technologies identified with potential for integration for a push-pull strategy • Push-pull strategy optimized and evaluated • Number of agreements signed with private partners • Number of private partners actively producing and distributing technologies • Number of advocacy events • Number of meetings with multilateral agricultural bodies	• • Two complementary technologies identified for integration against tsetse flies (Ebhodaghe et al 2021); tsetse repellent blend and Ngu traps. • One randomized trial was implemented to evaluate different repellent combinations and Ngu traps and identified optimal combinations. • One agreement signed with the private sector to produce tsetse control fly screens. • At least ten meetings held with public and private agricultural bodies and	Approaches of using physical meetings to sensitize and engage with partners for upscaling of technologies are vulnerable to travel restrictions. Due to the COVID19 pandemic and consequent travel advisories, the number of meetings achieved was much lower than targeted. By building systems that allow for engagement without the need for physical meetings, we managed to interact with the private and public sectors adequately and ensured upscaling.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		• Meetings with local governments and national agricultural research and extension systems • Number of policy documents for vector control with biorational technologies	extension systems. This does not include several meetings held online due to restrictions resulting from the COVID19 pandemic.	
	Specific objective 4: To update tsetse and trypanosomiasis risk maps for Kenya and East Africa	• Number of practical algorithms developed and evaluated • Number of maps for tsetse distribution in different counties of Kenya	• One algorithm developed that uses satellite-based modelling to identify breeding and foraging sites for tsetse flies (Gachoki et al 2021). • One map of tsetse distribution in different counties of Kenya drafted.	We learned that satellite-based modeling could be an effective alternative for identifying high-risk tsetse areas. For Shimba Hills, we were able to show that 63% of the potential tsetse breeding area was within the Shimba Hills National Reserve (SHNR) park. Additionally, we identified pockets of potential breeding areas outside of SHNR. Such models can be critical for sustainably targeting biorational technologies against tsetse flies.
	Specific objective 5: To optimize a strategy for reducing the transmission of trypanosomiasis with enhanced trapping of trypanosome-infected tsetse flies by 2025	• Chemical profiles for livestock infected with trypanosomiasis • Number of novel semiochemicals identified • Dataset for the responses of tsetse and biting flies to trypanosome-induced semiochemicals • Number of attractive trypanosomes induced semiochemicals identified • Numbers of biomarkers identified • Availability of prototype toolkit for diagnosis • Number of private partner agreements for the development of diagnostic kits	• Chemical profile for Trypanosoma-infected livestock determined. • One novel semiochemicals identified. • One urine-based diagnostic toolkit for trypanosomosis developed. • One novel blend that increased the attraction of infected and blood-fed *G. pallidipes* formulated together with its dispenser	Semiochemicals identified from urine tested singly or in the blend are less efficient compared to the whole urine odor. Further studies are required to optimize blends.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		• Number of baits for infected tsetse and biting flies • Number of dispensers developed and evaluated		
	Specific objective 6: Explore the potential use of the tsetse endosymbiont bacteria species, *Sodalis glossinidius*, in controlling African trypanosomiasis	• Number of datasets for the prevalence of *Sodalis glossinidius* in wild *Glossina pallidipes* • Densities estimates *for Sodalis glossinidius* in wild *Glossina pallidipes* • Number of *Sodalis glossinidius* isolates cryopreserved • Effect of Sodalis soup on trypanosome establishment and development in tsetse flies documented • Number of research collaborations established • Number of research associates/students trained	• This specific objective has not been started. Several proposals have been submitted to secure funds for the same. • One research collaboration established with the Liverpool school of tropical medicine. • One research associate trained in biology of *Sodalis glossinidius*.	
Broad objective 2: Novel tools and strategies for biorational ticks management developed, evaluated and implemented by 2025.	**Specific objective 1**: Novel bioacaricide for topical application developed, evaluated, registered and upscaled to at least 50,000 smallholder farmers by 2025	• Number of research collaborations established • Number of research associates/students trained • Number of market surveys completed • Number of strategies for area-wide application of bioacaricide	• Two collaborations established with the local government of Kwale and Kilifi counties and the private sector company Real IPM. • Three research associates and students trained in various aspects of tick management using biopesticides. • One market survey for willingness to pay for tick biopesticide implemented in Kwale, Kenya • One strategy for area-wide application of tick biopesticide is currently under evaluation in Kilifi County in Kenya. Laboratory experiments ongoing to	Biopesticide formulations are sensitive to environmental factors and storage conditions during transport and distribution. To deploy in remote areas characterized by high tick infestation, there is a need to improve formulation for better shelf life. The complex tick biology and ecology complicates the evaluation of biopesticide in the field. For effectiveness, biopesticide formulations should be broad-spectrum against tick species population.

Outputs	Outcomes	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			identify attractants in the botanical *Calpurnia aurea*, for application in novel attract-kill strategies.	
Broad objective 3: Sensitize and enhance the capacity of smallholder farmers and national agricultural research and extension systems (NARES) to implement area-wide tsetse flies, biting flies, and tick control with biorational technologies by 2025	**Specific objective 1**: Impart skills and capacity for sustainable scaling-up of integrated control strategies for tsetse flies and ticks	• Number of training held • Number of awareness workshops implemented	• At least twelve training on area-wide tsetse, biting flies, and tick control in Ethiopia and Kenya. • Thirty-two awareness meetings have been implemented in Kenya and Ethiopia. Four were structured workshops with NARES and smallholder farmers sensitized on the use of biorational technologies with a hands-on approach. • A total of 706 persons (33% female) directly benefited from this action.	We have, over the years, invested in training smallholder farmers and NARES officers. The target community has the knowledge and skills to do and continue project activities, including setting and monitoring tsetse fly traps and transmission of data electronically. These trained persons have continued scaling out biorational technologies uninterrupted in spite of COVID19 restrictions. The T.o.T approach is cost-effective for sustained upscaling of effective technologies in hard-to-reach target areas.
Broad objective 4: Increase the training and capacity building for the biology, ecology and management of livestock and zoonotic diseases vectors by 2025		• Number of postgraduate students trained • Number of interns trained	• 6 Ph.D. and 10 MSc graduate students trained • Two intern students trained	There is a high demand for postgraduate training justifying the investment and need for scaling training in biology, ecology, and management of livestock and zoonotic diseases.

(iii) Human Health Theme: Results Based Management (RBM) Rolling Framework Report

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieveing Outcomes	2021 Lessons Learnt
Objective 1: Contribute towards malaria elimination through the development of effective vector control strategies and public health initiatives by 2025	**Specific objective 1.1** To support countries to implement integrated vector management (IVM) approaches for malaria control and elimination; through demonstration of the effectiveness of diversified, environmentally safe innovative vector control methods, capacity building and policy advocacy by 2022	• Number of articles on malaria IVM theme published in peer reviewed journals. • At least 3 policy briefs for guidance on implementation of IVM in project countries. • Levels of malaria prevalence and mosquito relative density in study areas with and without IVM interventions. • Change in socio-economic status of households in areas involved in IVM	IVM evaluations in the field: • The effectiveness of adding house screening to the usage of long-lasting insecticide treated nets (LLINs) to reduce malaria and malaria vectors beyond the levels observed when only LLINs are used was further evaluated in Ethiopia, Mozambique and Zambia through entomological, parasitological and socio-economic assessments. • *Bacillus thuringiensis israelensis* (Bti) was successfully procured from a factory in Tanzania and used in the evaluation of dry season (winter) larviciding in Botswana, Eswatini and Namibia. • Data from all project countries continued to be collated and analysed at icipe, leading to the publication of five journal papers listed below. Publications: • Asale A, Abro Z, Enchalew B, Teshager A, Belay A, Kassie M, Mutero CM (2021). Community knowledge, perceptions, and practices regarding malaria and its control in Jabi Tehnan district, Amhara Region, Northwest Ethiopia. Malar J, 20: 459 • Sangoro PO, Fillinger F, Saili K, Nkya TE, Marubu R, Masaninga F, Trigo SC, Tarumbwa C, Hamainza B, Baltazar C, Mberikunashe J, Chisanga B, Kassie M, Chanda E, Mutero CM (2021). Evaluating the efficacy, impact and feasibility of community-based house screening as a	*icipe*'s publication of outputs with research evidence on effectiveness of house screening and bio-larviciding was timely and will likely inform decision-making by the national programmes regarding the two practical interventions for malaria vector control in Kenya and Ethiopia. A business continuity plan for IVM work in the context of COVID-19 was important in ensuring that implementation of malaria research activities continued with minimum interruptions.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieveing Outcomes	2021 Lessons Learnt
			complementary malaria control intervention in southern Africa: A study protocol for a household randomized trial. Trials 22: 883. • Ng'ang'a PN, Aduogo P, Oliech G, Mutero CM (2021). Long lasting insecticidal net ownership, use and coverage in a high malaria transmission area near Lake Victoria, Western Kenya. BMC Public Health 21:1046. • Nkya TE, Fillinger U, Dlamini M, Sangoro PS, Marubu R, Zulu Z, Chanda E, Mutero CM, Dlamini Q (2021). Malaria in Eswatini, 2012-2019: a case study of the elimination effort. Malar J. 20:159. • Ng'ang'a PN, Aduogo P, Mutero CM (2021). Strengthening community and stakeholder participation in the implementation of integrated vector management for malaria control in western Kenya: A case study. Malar J. 20:155.	
		• *icipe*'s ongoing role as a co-executing partner and lead research organization for evaluation of new innovative IVM interventions in the context of AFRO-II project Global Environment Facility (GEF)/UNEP- through the main Executing Agency is WHO-AFRO • Number of MSc and PhD students trained in IVM approaches, including in development of vector surveillance tools. • At least 200 national program staff of eastern and southern Africa countries trained in IVM for malaria control by 2025. • Number of IVM workshops held for policy makers and other key stakeholders.	Capacity building: • Two MSc students registered at the Higher Institute of Public Health and Technology in Mozambique. • Conducting a refresher course on morphological identification of adult mosquitoes for field assistants mandated with implementing this activity. • Conducting a refresher course on blood sample collection during the active case detection in the study cohort and the parasitological cross-sectional survey.	

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieveing Outcomes	2021 Lessons Learnt
		• Number of community members (male and female) trained in IVM for malaria control and elimination in at least seven African countries. • Number of regional IVM training courses for malaria control held at icipe. • Number of countries (ministries of health) which have adopted IVM policy for malaria control since 2020.		
	Specific objective 1.2 Development of non-insecticidal monitoring and control tools based on the odour-orientation behaviour of vectors by 2025	• Host plant influence on vector biology and underlying mechanisms elucidated • Interaction of vectors and other resources and underlying semiochemicals characterised • Behavioural impact of mediating semiochemicals in lab and field settings evaluated • Student training and thesis • Peer-reviewed publications	• Demonstration that plant metabolites exuded through the roots into water breeding sites influences egg-laying behavior of gravid malaria vectors, development of juveniles (larvae and pupae) and survival of emerged adults • 1 PhD student graduated • 1 high level publication	Unrecognized effect of host plant allelochemicals on malaria vector bionomics could impact effective malaria control
	Specific objective 1.3 Transmission blocking approaches developed and deployed by 2023	• Mosquito-associated endosymbionts that have characteristics suited to development into a malaria transmission-blocking strategy identified. • Methods of maintaining and augmenting natural prevalence of transmission blocking endosymbionts established. • Geospatial and environmental variables' effects on transmission-blocking endosymbiont prevalence in nature established. • Peer-reviewed publications.	• Microsporidia MB identified as a suitable endosymbiont for blocking the transmission of malaria parasites by Anopheles mosquitoes. Two Microsporidia MB transmission routes (mother to offspring and sexual) identified as potential dissemination mechanisms. Two high level publications on Microsporidia MB published.	A significant diversity of understudied transmission blocking endosymbionts are present in Anopheles populations in Kenya. The predominant challenge in implementing endosymbiont-based transmission blocking is effective dissemination of the endosymbiont. Using natural dissemination routes in conjunction with a better understanding of how environmental variables affect transmission is likely to be key.
	Specific objective 1.4 Cattle-targeted interventions for integrated control of human and animal disease vectors by 2024	• Novel concepts conceived and products developed under laboratory and field conditions. • PhD student training and thesis. • Strong stakeholder and community relations established for participatory co-production of intervention. • Randomized controlled trial completed and analysed. • Peer-reviewed publications.	• 2 novel products developed for integrated control of biting arthropods of veterinary and medical importance. • Community-based vector monitoring system established and baseline data collected. • Intervention for RCT co-produced with stakeholders and guidelines developed.	Co-production of research (in conception of problem, design of intervention, collection of data etc) increased community and stakeholder support and ownership. Such co-production however, requires significant more time and resources, but is likely leading to longer-lasting impact. One Health interventions targeting vectors for humans and livestock are well perceived by community.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieveing Outcomes	2021 Lessons Learnt
	Specific objective 1.5: Bionomic and ecologic determinants of residual malaria transmission in selected ecologies of Eastern Africa done by 2025	• Resistance in malaria vectors and associated mechanisms investigated at phenotypic and genomic levels • Role of secondary vectors as drivers of residual malaria transmission established • Relationship between environment, vectorial traits, malaria transmission in relation to control interventions established • Vector survival patterns in relation to local environment elucidated • Student training and thesis • Peer-reviewed publications	• *An. longipalpis* C identified as an emerging vector of importance in outdoor malaria transmission in selected dryland ecosystems of Kenya as well as uncovering of multiple cryptic malaria vectors • First detection of mutations in the GSTe2 gene conferring resistance to pyrethroid/DDT in An. longipalpis C • 1 article published (Kinya et al. 2022. Sci Reps (In press) • 1 MSc thesis submitted	Hotspots of malaria exist in areas of seasonal transmission risk and driven by diverse vectors including lesser-known or previously described species
	Specific objective 1.6 Risk factors that increase and decrease vector production and malaria transmission based on irrigation and land use assessed by 2022	• Risk factors that increase and decrease vector production based on irrigation and land use identified. • Association between irrigation and malaria vector abundance, seasonality and biting patterns and sporozoite infection established over a 3-year period. • Geospatial variables for malaria propagation on farm and landscape identified. • Peer-reviewed publications.	• All field work of a 4-year longitudinal study completed and all mosquito and malaria parasite data analyzed using molecular tools. • Databases cleaned and prepared for analyses, exploratory analyses completed. • Spatial data analysis ongoing. • 1 manuscript prepared for publication.	Land use, specifically irrigation significantly increases exposure to vector bites. In the western Kenya study site, majority of rural households benefit little from the ongoing irrigation activities in terms of increased income but carry the highest burden in terms of exposure to infectious bites.
Objective 2: Determination of ecology and epidemiology of arboviral diseases in eastern Africa by 2025	**Specific objective 2.1**. To determine entomologic risk of arbovirus transmission and /or outbreaks in selected regions of East Africa by 2024	• Distribution and bionomics of adult target mosquito vectors in relation to climatic variables determined • Vector competence studies based on lab experiments investigated • Vector diversity, genetics, dispersal patterns, and geographic and habitat influence characterized • Peer-reviewed publications • Student training and thesis	• Lab experiments and cross-sectional field studies undertaken • Adaptation of Ae. bromeliae (YFV vector) in urban landscapes exhibiting high vectorial abilities • Findings of Ae. aegypti as an inefficient vector of yellow fever virus (YFV) in urban landscapes in Kenya, however, high potential for Ae. bromeliae in sustaining an urban transmission • Second project phase funding secured • 2 PhD thesis drafted • 2 MSc students graduated • 2 publications: Kamau et al 2022: PLoS Negl Trop Dis. 16(1):e0010171; Agha et	Need for combining lab experiments, field and genotype-based analytics, and climatic data for precision surveillance to enhance arbovirus disease risk prediction and control

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieveing Outcomes	2021 Lessons Learnt
			al 2022: Emerging Microbes and Infection (In Press)	
	Specific objective 2.2. To determine the distribution and exposure risk of arboviruses to humans and associated domestic and peridomestic vertebrate hosts	• Seroprevalence of selected arboviruses in humans and other hosts selected areas determined • Risk factors for arbovirus exposure in humans determined • Biobank of samples and associated metadata established • Peer-reviewed publications • Student training and thesis	• Field survey of serum and serological analysis of i) non-human primates for exposure to flaviviruses completed, ii) humans underway	Circulation of viruses in non-human primates (reservoirs) indicates ongoing sylvatic transmission with potential for spillover to humans
	Specific objective 2.3. In depth virus surveillance, characterisation, and discovery done by 2023	• Pathogen discovery and epidemiologic impact investigated Virus biology, • Molecular detection tools designed for further epidemic investigation • Peer-reviewed publications • Student training and thesis	• Extensive field surveys and then lab screening and characterization, have uncovered known and novel viruses in diverse blood feeding insects as well as data on clinical relevance • Several manuscripts in preparation • 2 PhD theses drafted	Diverse potential arboviral pathogens circulating, yet with undetermined impact on public health
	Specific Objective 2.4: Design predictive models for arboviral disease transmission by 2023	• Framework for modelling transmission dynamics of different arboviruses developed • Improved early warning system for disease occurrence • Prediction of impact of outbreaks	• Extensive data based on lab experiments and ground truthing available for modelling	
	Specific objective. 2.5: To develop trapping tools for conducting vector surveillance to improve surveillance of YF and dengue.	• Attractiveness of host-derived cues on field vector populations evaluated in in sylvatic and domestic settings • Semiochemical basis for habitat site selection by vectors elucidated • Odor-baited tools specific for males for use in SIT application investigated	• Lab and field evaluations of promising host derived cues on catches of Aedes vectors conducted at the coast and Kerio Valley • 1 manuscript drafted	
Objective. 3. Understanding freshwater pollution and the links to the distribution of Schistosoma host snails in Western Kenya	**Specific objective 3.1.** Association between abundance of host snails for human pathogenic trematodes and abundance of macroinvertebrates with pesticide pollution, assessed by 2022	• Completion of field work. • Completion of microcosm and laboratory bioassays. • Peer-reviewed publications. • PhD training and thesis.	• Pesticides bioindicator index developed for the effect of pesticide pollution on macroinvertebrates to tropical freshwater habitats. • Impact of pesticide pollution on snail distribution established. • Results published. • PhD thesis drafted.	Strong association between agricultural and pharmaceutical pollution and macroinvertebrate species composition in freshwater streams in western Kenya. Water pollution decreases competitors and predators of schistosomiasis host snails whilst not directly affecting them, hence indirectly lead to increased snail numbers.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieveing Outcomes	2021 Lessons Learnt
			• Second project phase funding attained.	
	Specific objective 3.2 Spatial and longitudinal risk factors for Schistosomiasis transmission in river systems in western Kenya assessed in association with agricultural and industrial pollution by 2024	• Longitudinal field surveys completed in 4 river systems. • Ecotoxicological bioassays completed in laboratory. • Publications.	• Field sites established in 4 river systems and half of scheduled surveys completed. • Protocols for laboratory tests completed.	n/a
Objective. 4. Investigating the disease ecology of tungiasis (sand flea disease) for the development of treatment and prevention strategies	**Specific objective 4.1.** Developing tungiasis prevention tools by 2025	• Formative research completed to assess contextual factors for tungiasis transmission. • Intersectoral collaboration established, and novel low-cost flooring solution designed. • Bioassays completed to establish impact of insect synthetic and natural growth regulators on sand flea development. • RCTs completed to test (1) impact of flooring on tungiasis; and (2) IGRs on tungiasis. • Publication. • PhD training and thesis.	• Formative assessment completed and novel flooring solution tested in a pilot RCT. Sealing household floors led to a 50% reduction in tungiasis prevalence in the pilot trial. A manuscript has been drafted. • Bioassays have been initiated for testing IGRs on flea development and field trial protocol developed and approved by KEMRI for field work.	Behaviour change interventions are critical to be implemented alongside floor improvements or insecticide applications to maximize impact. This will be applied in a second phase of the project with a larger trial size starting end of 2022.
	Specific objective 4.2: Identify the factors driving intense transmission & responsible for a high tungiasis disease burden	• School and household risk factors surveys completed. • Publication.	• School and household risk factor surveys implemented in Siaya and Kwale counties, Kenya. • Data collection completed and databases prepared for analysis.	Highly heterogeneous distribution of tungiasis in field sites with school prevalence rates of 8-14 year-old between 0-23%. Whilst the primary health care system is usually aware of the disease in affected location, there is lack of knowledge and lack of support and treatment options. There is an urgent need for capacity building and more operational research.
	Specific objective 4.3 Understand pathogenesis & identify determinants of severe morbidity in tungiasis by 2023	• Schools and household surveys. • Cognitive and psychological assessments. • Publication.	• Pathogenesis investigated in schools and household surveys. • Cognitive and psychological assessments with children and guardians completed. • Databases compiled and data analyses implemented. • 2 manuscript drafts prepared.	Preliminary results suggest a strong association between disease and child cognitive development outcomes. Determinants of severe disease associated with home environment and caregiver attitude. There is need to intensify research in the context of this NTD and mental health.
	Specific objective 4.4 Determine the ecology of off-host stages of T. penetrans by 2024	• Soil surveys. • Investigation of development cycle of sand flea. • Development of molecular tool for identification of sand flea species.	• Over 1000 soil samples investigated and sand fleas extracted. • 2 novel molecular procedures developed to identify larvae. • Morphological tool for larvae ID compiled. • Life cycle of flea established in laboratory.	The indoor environment is a hotspot for the development the off-host stages of the sand fleas; specifically around sleeping areas of affected patients.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieveing Outcomes	2021 Lessons Learnt
Objective 5: Understanding leishmaniasis transmission dynamics in Kenya and development of control strategies by 2025	**Specific objective 5.1:** Risk mapping and bioecological studies of leishmaniasis disease vectors	• Plant feeding behavior of wild sand flies characterised • Habitat influence of sand fly structuring and associated drivers determined • Chemical communication in sand flies investigated to develop surveillance and control tools • Students trained and thesis	• Sand fly plant-feeding preference, nutrient benefit and volatile correlates described • Attractiveness of sand flies to plant-derived compounds in lab assays documented • The linkage between sand fly composition in selected habitats and volatile organic compounds established • Enantiomeric specificity of sandfly species to the compound 1-octen-3-ol investigated • 3 publications • 1 PhD student graduated	Plants constitute an integral resource for wild sand flies
	Specific objective 5.2: To develop an odour-baited sandfly attraction trapping device - the “SanTrap” for the control of leishmaniasis	• Experiments undertaken using a commercially available solar-powered trap, Lumin-8 in comparison with CDC light traps.	• Practicality of using a solar-powered device for sand trap sampling underscored.	Efficiency of the Lumin-8 trap is lower, compared to the CDC light trap. Modifications will be explored to take advantage of solar charging and enhance efficiency.
	Specific objective 5.3: Epidemiological factors associated with cutaneous leishmaniasis transmission in Gilgil, Nakuru County, Kenya.	• Sampling extended to a new focus of Visceral and Cutaneous Leishmaniasis in Kajiado County. • Sampling also undertaken in Isiolo County in northern Kenya	• Contribution to establishing two VL treatment sites in Kajiado County, in collaboration with the county government, and the national leishmaniasis program. • CL parasite *L. tropica* was detected in patient samples. • We identified *Leishmania donovani* (VL parasite) and *L. major* (CL parasite) in Isiolo. • One conference paper generated from Kajiado study. • One peer reviewed publication output from the Isiolo study.	Collaboration with national and local government have engendered a good working environment in Kenya, with good prospects for new programs.
	Specific objective 5.4: Identifying sand-fly endosymbionts and their potential effect on Leishmania transmission	• Diverse symbionts identified, most commonly *Wolbachia*, *Rickettsia*, and *Spiroplasma* spp.	• Baseline data obtained on symbionts associated with sandfly vector species	Endosymbionts hold promise to be exploited to block Leishmania transmission.

(iv) Environmental Health Theme: Results Based Management (RBM) Rolling Framework Report

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
Broad objective 1: Strengthen knowledge on arthropod biodiversity and impacts of ecological factors by 2025.	**Specific objective:** Survey, inventory, and description of new species of East African insects published and data made internet-accessible by 2025.	• Number of taxonomists agreeing to participate and study East African insects • No. of manuscripts published • No. of visits to GBIF datasets of *icipe* • No. of new species described	• Six peer-reviewed publications published. • GBIF datasets of icipe cited 56 times in 2021 • New record of Smicromorpha parasitoid of weaver ant in Kenya in 2021	Online databases and networks of taxonomists and naturalists are great to transmit biodiversity information
	Specific objective: Information on important pollinating Diptera (true flies) collected and made available on the internet by 2025.	• Data on important Dipteran pollinators made available and number of visits to GBIF, including number of downloads of data. • Information on wild-bee, non-Apis pollinators is increased, underscoring importance of non-Apis bees in providing pollination services and database of wild-bee pollinators increases	• A 35% increase in insect database records to ca. 55,000 specimens, with ca. 30% of the total being of Hymenoptera. • Contributed to a global review on mining bees belonging to Andrenidae in 2021. Bossert et al. (2021) Phylogeny, biogeography and diversification of the mining bee family Andrenidae. Systematic Entomology, 1 – 20.	Curated insect database records in icipe and links with databases offers opportunity for further big data analysis on factors influencing arthropod diversity and dynamics in Africa
	Specific objective: Taxonomic information on African insects including major African pests and vectors used by scientists, students and public by 2025.	• Number of students and staff members trained • Number of projects funded that incorporate taxonomic data. • Number of publications in arthropod taxonomy in collaboration with projects	• 3 projects incorporated taxonomic data from biosystematics unit. • Number of projects funded that incorporate taxonomic data. • 4 Publications in arthropod taxonomy in collaboration with projects. One publication on Camel specific keds with Animal Health, 2 Publications on Edible Saturnids and Palm weevils with INSEFF program and one publication on parasitoids of weaver ants.	Increasing use of biosystematics unit support in other theme projects is encouraging.
Broad objective 2: At least 6 new eco-friendly nature-based products for pest,vector control and baiting bee swarms (honeybees, stingless bees) adopted for improvement of livelihoods of rural and wider community members in East Africa by the year 2025.	**Specific objective:** At least 2 new potential products for mosquito control identified, developed and formulated	• Number of products produced and used. • Number of reports and publications. • Number of students trained.	• Insect oil-based formulation of Mosquito repellent developed and tested. • One publication on mosquito larvicide, Ochola, J. B., Mutero, C. M., Marubu, R. M., Haller, B. F., Hassanali, A., & Lwande, W. (2022). Mosquitoes Larvicidal Activity of *Ocimum kilimandscharicum* Oil Formulation under Laboratory and Field-Simulated Conditions. Insects, 13(2), 203. • 1 PhD student graduated	Plant based larvicides can be useful tools in mosquito management
	Specific objective: Community-based production and use of plant-derived products for mosquito control initiated in at least one project site.	• Number of processing facility established • No. of community members utilizing plant derived production for mosquitoes	• Propagation protocol for Catnip plant (*Nepeta cataria*) developed, shared with community farmers to produce and supply to community enterprises in Burundi	*Nepeta cataria* is a valuable indigenous plant for product development.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
Broad objective 3: Threats to Honeybee and Stingless bee health and factors contributing to resistance response of bees assessed by year 2025	**Specific objective:** Evaluation of the contribution of the gut microbiota to honeybees and stingless bees physiologies, nutrition, and resistance against natural pathogens and agro-chemicals.	• List of bacterial species inhabiting the honeybee/stingless bee gut in Kenya. • Establishment of a gut microbiota laboratory. • Scientific publications • Establishment of international collaborations. • Number of graduated students trained.	• The bee gut microbiota (Apis mellifera) from different regions in Kenya, as well as the gut microbiota of eight stingless bee species • 2 publications on Bee (Honeybee and Stingless bee) gut microbiota (Tola et al., 2020, Microorganisms 8 (11), 1721; and Tola et al., 2021, Microorganisms 9 (12), 2420. • 2 more publications on gut microbiota of BSF and Anopheles mosquito completed. • Collaboration with University of Lausanne established • 1 PhD study completed.	Gut microbiota in stingless bees is species specific Quality of forage contributes to gut microbiota specifications
Broad objective 3: Increasing honey and silk production by 20% in selected African farming communities by 2025.	**Specific objective:** Increase food security and income-generation opportunities for smallholder farmers in the four Indian Ocean island nations and Zanzibar through improved bee-keeping technologies and pollination services by 2022.	• No. of farmers trained and adopting on improved beekeeping technologies • No. of enterprises registered • No. of private sectors working with farmer groups • No. of marketplaces (honey and silk processing) established • No. of stakeholders trained on internal control systems for honey quality	• 1014 smallholder farmers trained on best beekeeping management practices and an additional 360 hives procured. • Socio economic impact carried out in Mauritius and Zanzibar indicating higher honey productivity among trained beekeepers using modern hives than untrained farmers using modern and traditional technologies • 3 operational honey marketplaces (Ugunja and Pemba in Zanzibar and Morondova in Madagascar). • Internal Control Systems (ICS) and organic beekeeping standards developed for Seychelles, Zanzibar and Madagascar. Pre-external certification audit done in Zanzibar with 87% compliance to the internal standards. • 7 technicians from Zanzibar and Seychelles Bureau of Standards trained at *icipe* on honey quality control based on the *Codex Alimentarius*. • Laboratory equipment for analysis of key honey quality control parameters procured for Zanzibar Bureau of Standards and Seychelles Bureau of Standards. • USD 23,440 and USD 1,319 earned by 67 beekeepers in Zanzibar and Madagascar and 3 stingless bees' farmers in Zanzibar respectively. • 7 species of stingless bees identified in Madagascar and 6 species in Zanzibar from ground survey. Only 2	Hive productivity and number of honey harvest is depending on colony strength, health, and quality abundance of adequate forage plants Proper management of colonies in adequate environment strongly contribute to hive productivity

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			species from Zanzibar are potential for honey production under domestication. • Impact of landscape vegetation structure on Physicochemical and bioactive properties of honey of 2 stingless bee species of economic importance completed in Zanzibar. • 20 Training of Trainers (ToTs) and 100 farmers trained on meliponiculture in Zanzibar. • 17 rearing sites of stingless bees established and 425 stingless bees hives distributed in Zanzibar. • Okwaro, L. A., Muli, E., Runo, S. M., & Lattorff, H. M. G. (2021). Coexistence of honeybees with distinct mitochondrial haplotypes and hybridised nuclear genomes on the Comoros Islands. The Science of Nature, 108(3), 1-7. • Dogantzis, K. A., Tiwari, T., Conflitti, I. M., Dey, A., Patch, H. M., Muli, E. M., ... & Zayed, A. (2021). Thrice out of Asia and the adaptive radiation of the western honey bee. Science advances, 7(49), eabj2151.	
	Specific objective: Participatory beekeeping for ecological protection of Mangrove forests in Zanzibar (ZanBee) done by 2022	• Increase to 25% of beekeepers engaged in other environmental activities • Increase in planting of multipurpose trees in area to 100 pieces (per beekeeping group) by project end • 1-2 different products derived from beneficial trees • Increase of honey production by 500 kg per year (by 2022 compared to 2021) • At least 20% of farmers increase price of their products during project period by 20% • At least 20% of participating farmers engage in hive product diversification	• Post delays in project implementation due to COVID, project agreement between icipe and local partner (Department of Forestry and Non-Renewable Resources (DFNNR) signed and first instalment of funds transferred, and procurements initiated. • ToTs to conduct training on best beekeeping management practices identified, • 140 smallholder farmers (50% women) selected within 10 beekeeping associations for participatory training on best beekeeping management practices • 100 Kenyan top bar hives purchased for 10 beekeeping associations • 10 sites in mangrove areas assessed and selected for apiaries establishment • 10 sites in mangrove areas assessed and selected for tree nursery establishment • Nursery inputs purchased and distributed to10 mangrove beekeeping associations • Stakeholder to conduct training on tree nursery and management practices identified	Beekeeping and related ecological protection need to be effectively pursued.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
	Specific Objective: To develop and verify best management practices including scientifically proven evidence for suitability of certain beekeeping inputs like hive type and apiary environment to improve beekeeping in Arid and Semi-Arid Lands (ASALs)	• Best Management Practices (BMP) for improved beekeeping identified, documented and used to train beekeepers. • Participatory on-farm research established for analysis of hive type suitability in different agroecological zones of the ASAL incl. establishment of a floral calendar. • Determination of optimal time point of honey harvest for increased yields.	• Relevant literature on beekeeping in Africa was reviewed • Basic training tutorial from icipe updated with new and relevant facts • Funds for set-up of the venue and catering of training participants disbursed to local partner (KAMAKI Coop.) • All 24 hives of each type (Langstroth (modern) hive, Kenya Top Bar Hive (KTBH), traditional log-hive, Kapkuikui Super log-hive) constructed by local carpenters chosen by KAMAKI Coop. using locally available materials • Muturi, M. N., Papach, A., Lattorff, H. M. G., & Neumann, P. (2021). A scientific note on in-hive positioning determines small hive beetle trap efficacy. Journal of Apicultural Research, 1-2.	Positive leads from BMP implementation for beekeeping in Kitui needs to be translated to other regions.
Broad objective 4: Effectively harness pollination services and conserve pollinator-plant interactions for enhanced crop productivity by 2025	**Specific Objective:** Integrative Pollinator-Plant Interaction Assessment of Ecosystem Service Diversity in Sub-Saharan Africa (JRS Biodiversity Foundation Project) by the year 2021	• Web-based platform (database) for Plant-Pollinator Interactions in use • Number of data records deployed in database (10,000 interaction records). • Assess risks for common pollinator species and establish species distribution modelling. • 300 molecular barcodes of bees provided. • Capacity building for biodiversity bioinformatics for *icipe* staff.	• Web-based platform (database) for Plant-Pollinator Interactions The beta version was improved and is available via Google Play store. . • 16,932 interaction records involving 183 plant species. • Assessed risks for common pollinator species and establish species distribution modelling. • Identified bee 190 morpho-species with a higher abundance and diversity for the Taita Hills compared to Murang'a. • Trapping technology for bees optimized, with bees effectively caught in sweep nets, while Halticids effectively trapped in water pan trap. • One peer reviewed publication: Dzekashu et al. (2022). Floral turnover and climate drive seasonal bee diversity along a tropical elevation gradient. Ecosphere, 13(3), e3964.	Web-based platform (database) for plant-polinator interactions need to be strengthened and linked to other online biodiversity database available.
	Specific Objective: Evaluate the pollination efficiency of different stingless bee species in enhancing fruit quality of horticulture crops	• Assess pollination efficiency of seven stingless bee species and African honeybees on some horticulture crops. • Assess susceptibility of stingless bees to some horticulture entomopathogenic fungi and synthetic pesticide.	• Pollination efficiency conducted on greenhouse cucumber, sweet melon, blue berry and eggplant. • 3 peer reviewed articles published on stingless bee pollination efficiency:	Both stingless bee and honey have unique niche crops and pollination capabilities that needs to be effectively harnessed.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		• Capacity building on Meliponiculture undertaken to stakeholders. • Demonstration rearing sites established. • Scientific publications • No. of MSc and PhD students trained	• a) Kiatoko et al. (2021). Effective pollination of greenhouse Galia musk melon *(Cucumis melo* L. var. reticulatus ser.) by afrotropical stingless bee species. Journal of Apicultural Research, 1-11. • b) Kiatoko et al. (2021). African endemic stingless bees as an efficient alternative pollinator to honey bees in greenhouse cucumber (*Cucumis sativus* L). Journal of Apicultural Research, 1-13. • c) Omuse, et al. (2022). A fungal–based pesticide does not harm pollination service provided by the African stingless bee *Meliponula ferruginea* on cucumber (*Cucumis sativus*). Apidologie, in press. • 2 Msc students trained • Susceptibility of stingless bees assessed on 1 entomopathogenic fungi and 7 synthetic pesticides a) Omuse et al. (2022). Susceptibility of the Western honeybee *Apis mellifera* and the African stingless bee *Meliponula ferruginea* (Hymenoptera: apidae) to the entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria bassiana*. Journal of Economic Entomology, 115(1), 46-55. • 1 Msc study completed. • Over 210 ToTs trained in 12 African countries • Stingless bee rearing site established in 8 African countries.	
	Specific Objective: Pollinators of cash crops in Kenya	• Assess the pollinator diversity of avocado crop in Kenya. • Assess the pollinator diversity of Macadamia crop in Kenya. • Depository of specimens • Scientific publications • No. of MSc and PhD students trained	• Repository of avocado and Macadamia pollinators specimens established at *icipe*. • 5 peer review articles published: • Okello et al. (2021). Abundance and community composition of flower visiting insects of avocado (*Persea americana* Mill) in the East African region. International Journal of Tropical Insect Science, 41(4), 2821-2827. • Sagwe et al. (2021). Pollinator supplementation mitigates pollination deficits in smallholder avocado (*Persea americana* Mill.) production systems in Kenya. Basic and Applied Ecology, 56, 392-400. • Ochungo et al. (2021). Pollen diversity and protein content in differentially degraded semi-arid	Supplemental commercial pollination for cash crops needs to be pursued

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			landscapes in Kenya. Journal of Apicultural Research, 60(5), 828-841. • Dicks et al. (2021). A global-scale expert assessment of drivers and risks associated with pollinator decline. Nature Ecology & Evolution, 5(10), 1453-1461. • Adan et al. (2021). Use of earth observation satellite data to guide the implementation of integrated pest and pollinator management (IPPM) technologies in an avocado production system. Remote Sensing Applications: Society and Environment, 23, 100566. • 3 PhD students completed.	
	Specific Objective: Contribute in discriminating the African stingless bee species using molecular tools by 2025	• Assess species diversity of African stingless bees using DNA barcoding • Depository of specimens • Species characterization based on wing geometric morphometric • No. of MSc students trained • Scientific publications	• Depository of African stingless bee species specimens established at *icipe.* • DNA sequences generated and deposited in bold database for 28 species. • Wing geometric morphometric data established for 25 species. • Preliminary list of species diversity established. • 1 MSc student trained and completed.	Integrative taxonomy tools involving morphological, ecological, biological and molecular tools are critical for deciphering the diversity of stingless bee.
	Specific Objective: Local knowledge, ecology and evolution of sub-Saharan African stingless bees by 2025	• Determine host plants for pollen and nectar across stingless bee species and Agroecological zones, • Diversity, distribution and habitats of stingless bee in 1 sites of Kenya and one site in Ethiopia (Yabelo) established and communicated by May 2024 • Anti-bacterial properties of propolis from stingless bee species • Model the ecological niches of stingless bee species and their host plants under climate change scenario • Scientific publications • No. of MSc and PhD students trained	• 211 honey samples collected from Indian oceans, east, central and west Africa. • Physicochemical and metabolites composition of honey analyzed using Nuclear Magnetic Resonance (NMR). • 1 peer review article published: a) Makori et al. (2022) The use of multisource spatial data for determining the proliferation of stingless bees in Kenya, GIScience & Remote Sensing, 59:1, 648-669. • 1 MSc student completed.	Understanding traditional knowledge related to stingless bee and characterization of stingless bee honey for unique value proposition is critical
	Specific Objective: (Norad-CAP Africa): Increasing health and livelihood of target communities in Kenya by	• Assess pollination efficiency of seven stingless bee species and African honeybees on some horticulture crops	• Pollination efficiency conducted on greenhouse bell pepper and watermelon.	Harnessing stingless bee pollination is unique niche crops and honey

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
	improving the knowledge on the use of social bees as key pollinators for crops and hive product production	• Compare physico- chemical and bifunctional properties of sympatric stingless bee and honeybee Apis mellifera honey • Quality of stingless bee honey produced from diverse agroecological zones of Kenya established and communicated by 2025 • Scientific publications • No. of MSc students trained	• Physico- chemical and bifunctional properties of honey analyzed for sympatric stingless bees. • Agroecological zones impact on physico- chemical and bifunctional properties of stingless bees. honey analyzed. • 1 peer review article published: Mokaya et al. (2022). Characterization of honeys produced by sympatric species of Afrotropical stingless bees (Hymenoptera, Meliponini). Food chemistry, 366, 130597. • 1 MSc student trained.	characterization for value propositions is critical
Broad objective: Generate 100,000 dignified and fulfilling employment opportunities for unemployed young women and men in honey and silk value chains and complementary income generating activities by 2024 (MOYESH program)	**Specific Objective:** Establish partnerships and identify and develop resources for scaling up beekeeping and silk farming enterprises to increase employment and learning opportunities for youths (PARTNERSHIP AND RESOURCES MOBILIZATION)	• Amount of honey, hive products, silkworm cocoons and silk yarn produced by the youth enterprises	• 325.8 tonnes of honey, 32.5 tonnes of beeswax and 222 kg of silk cocoon and yarn produced by the youth enterprises.	Complementary businesses can boost income and thus help reduce dropout.
	Specific Objective: Link young men and women with financial service providers through digital financial services and business-to-business (B2B) linkages (FINANCIAL INCLUSION)	• Number of youths that received credit services from financial service providers (MFIs and Banks) • Number of youth enterprises that accessed working capital through B2B agreements with private actors • Number of youths that used youth friendly financial products and services (saving, credit appraisal, mobile and agent banking services) • Amount of loans and savings mobilized through VSLA	• In the pilot, Sigmo Woreda, 10 youth enterprises have been identified and are now processing loans totalling ETB1,000,000 (ETB100,000 for each enterprise). • 67 enterprises in SNNP and Oromia regions received ETB 10 million loan	Uncollateralized loans organized jointly by Financial Institutions, partnering private banks and the Mastercard Foundation offer hope that small loans can be made available to youth partners at least in some site.
	Specific Objective: Develop market linkages and youth-owned profitable beekeeping, sericulture and complementary enterprises (MARKET LINKAGES AND ENTERPRISES ESTABLISHMENT)	• Number of youth enterprises that started generating income from silk, honey and related value chains • Amount of income received by youth from complementary side businesses • Amount of honey and hive products tested for export	• 26,325 youths (63% females) started their businesses in 2021 • Total programme direct reach is 42,469 (62% females) • The programme created indirect jobs for 259,000 people • The income earned by the youth enterprises reached ETB96.7 million (~USD2.4 million).	Local colony multiplication by youth can serve as a major strategy to reduce the threat of colony availability on time and absconding.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			• Buildings secured for renovation and use as marketplaces in Gimbo, Shishonde and Gesha Woredas. • Site plan and construction license secured for Dabo Hana, Setema, Yayu and Sigmo Woredas of Oromia region and Wonago and Yirgachefe Woredas in SNNP region.	
	Specific Objective: Develop skills and capacity of youth and partners to undertake and manage successful and sustainable beekeeping and silk enterprises as well as complementary activities (SKILLS CAPACITY DEVELOPMENT)	• Percent of stakeholders reported improved capacity in providing technical support and training to youth to establish successful and sustainable enterprises. • Percent of youth reported improved technical skills and knowledge in beekeeping and silk farming activities • Percent of youth reported improved entrepreneurship, business and soft skills (soft skills score)	• Legal trade registration of 1,557 youth enterprises supported in the three regions. • In total 273 enterprises in Amhara region, 962 in SNNP region and 322 enterprises in Oromia region have finalized their trade licenses. In addition, 1,927 enterprises (1,332 in SNNP, 322 in Oromia and 273 in Amhara regions) have developed and used business plans and record books.	Peer to peer exchange visits, practical trainings on value addition prove very effective.
	Specific Objective: Develop and implement gender sensitive monitoring, evaluation and learning (MEL) system to guide decision making and facilitate learning (MEL)	• MOYESH MEL framework in place • Baseline survey report and completed M&E Matrix • Functional web based (MIS) monitoring system in place • Number of monitoring reports produced and shared • Number of case studies, success stories, technical studies and best practices produced and shared • Mid-term and final evaluations conducted, and reports made available	• Training was also given for 26 technical assistants on how to collect and upload data using Kobo toolbox. The platform will create real time monthly data from each enterprise in specific programme Woreda. • The Year 2 progress monitoring survey successfully completed; data analysis and report writing underway.	Despite technological challenges, smart phones and tablets can be used as effective tools to collect and capture data.
	Specific Objective: Establish effective project coordination, partnerships and communication strategies for successful management and implementation of the program (COORDINATION AND IMPLEMENTATION SUPPORT)	• Number of program launching workshops • Number of annual program review and planning meetings conducted • Number of regional and national steering committee meetings conducted • Program communication plan in place and under implementation • Number of communication outputs prepared and disseminated (leaflets, banners, etc.) • MOYESH Program website developed and functional	• Regional programme steering committees for Oromia, SNNP and Amhara were successfully hosted twice; these meetings discussed progress made in programme implementation and endorsed the Year 3 indicative targets. • Two programme newsletters produced. • Several publicity articles and case stories produced and published in media. • The programme website is operational. • Two MoUs and three MoAs developed and finalised.	Community mobilization is an effective way of harnessing the potential of local communities in identifying the right unemployed youth and resource mobilization such as land and honeybee colonies.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		• MOYESH digital information exchange platform developed and used to share information with youth and stakeholders • Number of training manuals published and translated to regional languages • Number of NGOs and private sectors that signed MoUs to support implementation of MOYESH Program • Number of Technical and Financial Reports produced and shared with the Foundation • Number of quarterly and monthly reports produced and shared with the MCF and Program Management Committee	• Four quarterly progress narrative and financial reports prepared in the i=given format and submitted. • Several progress review and planning virtual meetings held with the Mastercard Foundation. • Three quarterly progress updates prepared and submitted ahead of teleconferences with colleagues at the Mastercard Foundation. • Experience sharing exchange visits organized for youth partners and local extension staff.	
Broad objective: Insect feed for poultry, pigs and fish production in Sub-Saharan Africa.	**Specific Objective:** Cost-effectiveness and potential livelihood effects of insect-based feed technologies assessed through a gender lens along the value chain.	• At least 2 scientific papers on efficient insect mass-rearing techniques as affected by different agro-ecological zones. • 1 training guide on insect mass-rearing for feed with reference to production scales and gender developed. • 3 scientific publications on cost-effective organic fertilizer production through insect mass-rearing. • Stories of change focusing on experience and success from youth, men and women and other actors involved in the use of insect as feed documented. • At least 300 insect mass-rearing enterprises owned by women, men and youth established. • At least 10 feed producers integrating insect in their feed.	A total of 5 articles were published on the cost-effectiveness on insect farming and insect-based feeds • Beesigamukama et al. (2021) Economic and ecological values of frass fertiliser from black soldier fly agro-industrial waste processing. Journal of Insects as Food and Feed, 0 (0)- Pages: 1 – 10. https://doi.org/10.3920/JIFF2021.0013. • Okello et al. (2021) Farmers' Perceptions of Commercial Insect-based feed for sustainable livestock production in Kenya. *Sustainability*, *13*, 5359. https://doi.org/10.3390/su13105359. • Khaemba et al. (2021) Consumers' perception towards eggs from laying hens fed commercial black soldier fly (*Hermetia illucens*) larvae meal-based feeds. Poultry Science, doi:https://doi.org/10.1016/j.psj.2021.101645. • Sumbule et al. (2021) Cost-effectiveness of black soldier fly larvae meal as substitute of fishmeal in diets for layer chicks and growers. Sustainability, 13, 6074. https://doi.org/10.3390/su13116074. • Wachira et al. (2021) Efficiency and improved profitability of insect-based aquafeeds for farming Nile Tilapia fish (*Oreochromis niloticus* L.). Animals, 11, 2599.	Insect farming is a regular cash flow for poultry, fish and pig farmers; thus, it is an important strategy for increasing employment and reducing poverty.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			https://doi.org/10.3390/ani11092599. One article on the circular economy of black soldier fly farming in East Africa published. • Tanga et al. (2021) Edible insect farming as an emerging and profitable enterprise in East Africa. Current Opinion in Insect Science 2021, 48:64–71. https://doi.org/10.1016/j.cois.2021.09.007. Six (6) drafted or submitted manuscripts on the economic viability of insect-based feeds. • Mwangi et al. (2021) Benefits of incorporating black soldier fly larvae meal into laying hen diet on the nutritional quality of eggs. Frontiers in Nutrition (Submitted). • Sumbule et al. (2021) Black soldier fly larvae-based diet boost laying hen egg production and profit: Overcoming major protein source dependence in Africa. Animal Feed Science and Technology (submitted) • Okello et al. (2021) Farmers' willingness to pay for commercial insect-based chicken feed. Food policy (Submitted) • Okello et al. (2021) Economic performance of insect-based feeds for broiler chicken production under smallholder farmers production systems in Kenya (under review) • Khaemba et al. (2021) Economic viability of eggs production from hen fed insect-based feeds under smallholder farming systems (under review) • Makatiani et al. (2021) Smallholder pig and poultry farmers' awareness of black soldier fly (*Hermetia illucens*) farming in, Kenya (under review). Five training videos on all aspects related to black soldier fly farming produced and placed online with over 17,000 views recorded. Two smallholder farmers manuals developed to guide insect farming as feed for livestock and fish.	

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			One report on lessons learnt on black soldier fly farming under on-farm conditions in Kenya developed. 14 feed millers trained to incorporate insect-based feed in poultry, fish and pig feed. 87 insect mass production facilities owned by women, men and youth were established. Three draft policy briefs have been developed for publication on activities related to the insect farming	
	Specific Objective: Finetune and deploy rearing techniques under small- and medium-scale on-farm conditions to improve capacity planning to meet customer demand for insect-based protein and fertilizer.	• Report produced on existing supply chain models for key commodities in Kenya; and on the role of youth, women and men in feed supply chains. • Publication on the gender differential economic benefits of insect farming and insect-based feed for poultry, fish and pig production systems along the value chain in Kenya. • Publication on the long-term potential impact of insect-based feed technologies on food and nutrition security in Kenya. • Report on economic viability of insect-based feed supply chain models in Kenya. • 2 MSc and 1 PhD student trained.	2 articles published on the safety and diversity of black soldier fly published. • Tanga et al. (2021) Organic waste substrates induce important shifts in gut microbiota of black soldier fly (*Hermetia illucens* L.): Coexistence of conserved, variable, and potential pathogenic microbes. Front. Microbiol. 12:635881. doi: 10.3389/fmicb.2021.635881. One article on the global genetic structure of BSF raised on various waste has been established. • Kaya et al. (2021) Global population genetic structure and demographic trajectories of the black soldier fly, *Hermetia illucens*. BMC Biology, 19:94. https://doi.org/10.1186/s12915-021-01029-w. 1 PhD and 5 MSc students graduated One draft report on the effect of waste on the quality of BSF larvae fed on 12 different substrates in Uganda developed.	Farmer exchange visits, hands-on practical trainings on value addition in insect farming prove to be very effective to increase adoption. Decentralization of insect farming to community level is an effective way to harness the potential of local farmers through trainings at these learning or demonstration sites.
	Specific Objective: Develop and test gender-inclusive insect feed supply models and build capacity along the value chain.	• Training manual developed. • At least 3,000 fliers produced and distributed. • At least 300 posters produced and distributed. • At least 6 training reports produced.	Mawai et al. (2021) Gender specific preference and willingness to pay for meat derived from chicken fed insect-based feeds. Over 3562 certificates of participation were developed, printed and distributed to farmers who successfully	Training of trainers (ToT) is crucial in expanding or upscaling BSF farming.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		• A curriculum on insect uses in animal feed developed. • At least 3,000 youth, men and women trained. • At least 10 entrepreneurs with successfully financed business models. • Report on existing supply chains in other commodities and their applicability to insect-based feed produced.	completed the training of trainer (ToT) course on "Organic waste recipes, BSF production, processing, and animal feed formulation". A total of 2,745 farmers trained (42% females) on all aspects related to black soldier fly farming, processing, and packaging. 75 SMEs own black soldier fly rearing facilities that is operational, producing live larvae for their poultry production Five different business models were evaluated, with outgrower model showing great potential. However, smallholder farmer model was widely practiced by over 90% of the farmers.	
Broad objective: Testing business models for scaling insect-based protein feed for use in poultry farming and aquaculture in Kenya	**Specific Objective:** Markets and marketing channels for insect-based protein feed using different business models developed.	• Cost-effective and suitable commercial models identified and adapted for use of insects as feed. • Supply chains model for commercial production of insects documented. • Out-grower models utilizing insect for feed by farmers and private sectors established. • Private sector feed millers subcontract entrepreneurs and contribute to the training and awareness campaigns of BSF production. • Pre-financing for different needs in the production system documented. • SMEs develop outgrower models for sourcing insects from farmers/ cooperatives and established market linkages with feed processors.	One draft report on determinants of investor's preference for business models in insect-based feed value chains in Kenya. A draft report on the impact of COVID 19 on male and female BSF entrepreneurs in Kenya. One (1) model on profitability of black soldier fly farming enterprise published. • Mutuku et al. (2021) Determinants of profitability of black soldier fly farming enterprise in Kenya. Journal of Insects as Food and Feed, 0 (0)- Pages: 1 – 8. https://doi.org/10.3920/JIFF2021.0066. One cost estimate report on black soldier fly was developed for smallholder insect farmers. Eleven (11) SMEs applied the outgrower model with each supporting at least 25 farmers Private feed miller (Treasure Feed Limited) trained 46 youths on-site on broiler and layer chicken feed formulation.	Insect farming as a complementary business can significantly boost income generation among the smallholder farmers and thus contributing to reducing poverty.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			One draft manuscript on business model has been developed. Bulinda et al. (2021) Gender inclusive investor's preference for business models in insect-based feed value chains in Kenya. One of the entrepreneurs (InsectiPro Ltd) in the project secure substantial financial grant from Dutch Sustainable Trade Initiative (IDH) (US$ 200,000) and Bill & Melinda Gates Foundation (BMGF) (US$ 2.1 million). The BMGF project is implemented in partnership with *icipe*. Six insect-based enterprises within the project (Zihanga Ltd, The Insectary Ltd, NutriEnto Ltd, The Bug Picture Ltd, Biobuu Ltd and Bug Life Ltd) got financial support of US$ 10,000 from Rockefeller Foundation and Dalberg to scale BSF production. Sanergy Ltd (insect farming company) and *icipe* won a £100,000 grant from the Foreign, Commonwealth & Development Office (*FCDO*) to undertake further research to improve production. The project is titled: "Validation of low-cost sensors for optimal insect protein production" to help scale up BSF larvae production as sustainable protein to boost livestock and fish farming. The County governments of Busia and Nyandarua supported youth groups involved in BSF farming in the respective Counties with 1 million Kenyan shillings (US$ 10,000)	
	Specific Objective: Transfer and promote insect-based protein feed technologies among the various actors along the value chain.	• Simple and cheap mass production technology with high potential for scale at the farm and SME levels established. • The most effective technologies for different commercial models documented. • The constraints/challenges of BSF production and options/challenges documented. • At least 200 entrepreneurs and start-ups have access to proven low-cost technologies.	In Kiambu County, 150 youths and women (40% females) were trained on insect mass production technology. Four (4) new BSF production facilities were developed. A total of 25 SMEs were trained on procedures to develop and submit documents to acquire certification for insect for food and feed products.	Increasing number of BSF farmers in various communities close to the farming community of farmers can serve as a major strategy for sustainability when the project phases out.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
		• At least 200 farmers adopt the technology of mass production of BSF for feed on-farm.	All 25 SMEs got certifications for their insect-based product, which allow them to use KEBS Standardization Mark and market their product internationally.	
	Specific Objective: Evidence-based data to support scaling and adoption of insect-based protein feed enterprises generated	• Develop a business case for production of insect for feeds via the different models and make recommendations on the most viable business models. • Develop and distribute an easy-to-use manual for setting up of successful insect farms with details on costing. • At least 2,500 metric ton of insect-based protein produced and utilized for on-farm trails. • At least 3 optimal facilities for effectively scaling out on-farm production of BSF established. • Nutritional and safety qualities of BSF reared on various substrates under different production models compared to laboratory reared BSF. • At least 200 farmers recruited to participate in on-farm assessment and performance of insect-based protein feed on poultry and fish in target locations. • Nutrient quality established of formulated feeds produced by private feed millers to meet the nutritional demand of poultry and fish for optimal on-farm productivity. • Establish the socio-economic benefits of insect-based protein farming and feed formulation in poultry and aquaculture production. Establish the viability of insect-based protein enterprises for job creation among youths and women.	An on-line mobile interactive platform (DuduTalk) for BSF farmers and feed processors has been developed. Three (3) manuscripts drafted on insect-based feeds • Wamai et al. (2021) Growth performance and economic analysis of substituting soybean and sunflower cake with black soldier fly larval meal in chicks and grower chicken diets. Animal Feed Science and Technology (submitted) • Wamai et al. (2021) Laying performance and cost effectiveness of laying hen fed diet containing black soldier fly larval meal. Animal Nutrition (submitted) • Wamai et al. (2021) Laying hen fed diet with black soldier fly larvae meal produced improved quality eggs: Implications in human nutrition and health. Food Quality and Preference. (submitted) Estimated production of dried BSF larvae in Kenya in 2021 was above 7,000 metric tons. A report on the nutritional profile of black soldier fly larvae grown on 26 waste streams in Kenya was developed. Two (2) step-by-step manuals on black soldier fly production was developed, Two (2) value-addition manuscripts developed: • Makokha et al. (2021) Full-fat black soldier fly larvae meal inclusion in laying hen diet enhances its meat quality for food. Journal of Functional Foods (submitted) • Mwangi et al. (2021) Nutritional quality of eggs from hen fed diet with full-fat black soldier fly larvae meal. Food Science and Nutrition (submitted)	Web-based platform (database) for black soldier fly farming need to be strengthened, automated, and linked to other online database stems. Insect-based farming can easily be taken up as supplemental commercial business venture for income generation.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
Broad objective: Systematic review of the state of research, product development and utilization of the long-horned grasshopper *Ruspolia differens* in Africa.	**Specific Objective:** Expert review and documentation of past and current research and development initiatives related to *R. differens.* Organize a stakeholder validation workshop in Kampala, Uganda.	• Draft scientific publication on the state-of-art of *R. differens* research and product development in Africa. • 1 workshop organized in Uganda with stakeholders drawn from 5 different countries.	A state-of-the-art systematic review on the nutritional composition, bioactive compounds (sterols and flavonoids), oils, product shelf life, safety of marketed products, consumer acceptability, willingness to pay, and regulations governing primary production and consumption of *R. differens* was developed. Kababu et al. (2021) Are long-horned grasshoppers, *Ruspolia differens* (Serville) (Orthoptera: Tettigoniidae) a nutritious and healthy food choice? A critical review.	Expert review workshops are crucial to consolidate research efforts from previous studies and establish new gaps for future investigations.
Broad objective: INSect-based agriBIZiness for sustainable grasshopper and cricket production and processing for food in Kenya and Uganda (INSBIZ)	**Specific Objective**: Market potential and market performance of insect-based food products assessed.	• At least two private sector players invest in insect-producing agro-businesses in Kenya and Uganda. • Market potential for grasshopper and cricket products in Kenya and Uganda • Market performance (penetration and cost-benefit performance) for grasshopper and cricket products in Kenya and Uganda	Five (5) cricket products including: dry cricket flour, cookies, sweet and salty extruded snacks (Krickies) and an instant composite flour for porridge were developed and their certification by KEBS completed while that of UNBS is on-going. One manuscript on market performance of grasshopper has been developed in Uganda One (1) manuscript on cricket production, market supply and consumption of cricket submitted. • Musungu et al. (2021) Production, consumption and market supply of edible crickets: Insights from East Africa. Agricultural and Food Economics (submitted)	Development of marketing access and linkage help in new product uptake.
	Specific Objective: Mass rearing protocols for crickets and grasshoppers adapted, piloted and up scaled	• At least two SMEs mass rearing crickets and grasshoppers in Kenya and Uganda.	Three (3) private sector partners: Agrarian Systems Ltd. (Uganda), Nutreal Ltd (U) Ltd., and InsectiPro Ltd (Kenya) have invested in the development and commercialization of insect-based food products. Two articles published on mass trapping protocols • Sengendo et al. (2021) Cost–benefit analysis of improved light trap for harvesting the edible grasshopper, *Ruspolia differens* (Orthoptera: Tettigoniidae): Evidence from Uganda. International Journal of Tropical Insect Science https://doi.org/10.1007/s42690-021-00505-8. • Sengendo et al. (2021) Efficient harvesting of safe edible grasshoppers: Evaluation of modified drums and light-emitting diode bulbs for harvesting *Ruspolia differens* (Orthoptera: Tettigoniidae) in Uganda.	Step-by-step protocol or manuals are important to help guide insect farmers

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			Journal of Economic Entomology, 114(2), 2021, 676–683. doi: 10.1093/jee/toab025. One (1) on mass rearing technologies of cricket developed in Uganda. ✓ Ssepuuya et al. (2021) Effect of alternative rearing substrates and temperature on growth and development of the cricket *Modicogryllus conspersus* (Schaum). Journal of Insects as Food and Feed, 2021; 7(2): 163-172. One manuscript on natural enemies of *Ruspolia differens* accepted. • Alfonce et al. (2021) Identification and virulence screening of fungal and bacterial entomophathogens of edible long-horned grasshopper *Ruspolia differens* (Orthoptera: Tettigoniidae) from Uganda. African Entomology (accepted) Two (2) manuscripts on host-plant and agricultural by-product based diets for *Ruspolia differens* developed. • Alfonce et al. (2021) Host plant-based artificial diets enhance development, survival and fecundity of the edible long-horned grasshopper *Ruspolia differens* (Orthoptera: Tettigoniidae). Journal of Insect Science (submitted). • Kababu et al. (2021) Innovative feedstocks for optimal mass production of the edible grasshopper (*Ruspolia differens).* Frontiers in Physiology (under review)	
	Specific Objective: Ready-to-eat whole insects, insect flours for use as ingredients in food preparation developed and characterized, and insect-enriched porridge flours and cookies processed	• At least two food-based SMEs produce and commercialize insect-based food. • At least two safely packaged insect products available on the market Effect of various rearing and processing conditions on nutritional characteristics of crickets and grasshoppers documented.	Three (3) insect-based products, namely cookies, instant flour for porridge and ready-to-eat grasshoppers have been improved, branded and market tested in outlets in Kampala, Uganda. 63% of the respondents in Uganda were willing to taste the cookies and 82% of the people who tasted the cookies liked them due to their good taste.	There is emerging interest in youth and women uptake of new technologies such as insect farming in Kenya and Uganda

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			Four (4) cricket-based roasted products are being sold online (https://greenspoon.coy.ke/?s=crickets) by InsectiPro Ltd, Kenya. Two (2) manuscripts on cricket and grasshopper products submitted. Ochieng et al. (2021) Dynamics in nutrients, sterols and total flavonoid content during processing of edible grasshopper for food. Food chemistry (submitted) Fombong et al. (2021) Affordable processing of edible Orthopterans provides a highly nutritive source of food ingredients. Foods 2021, 10, 144. https://doi.org/10.3390/foods10010144 Labu et al. (2021) Microbial contaminants in wild harvested and traded edible long-horned grasshopper, *Ruspolia differens* (Orthoptera: Tettigoniidae) in Uganda. Journal of Insects as Food and Feed. DOI 10.3920/JIFF2020.0069 Three (3) manuscripts on ready-to-eat porridge, cookies and consumer acceptability developed. • Maiyo et al. (2021) Nutritional quality of four novel porridge products blended with edible cricket (*Scapsipedus* icipe) meal for food. Foods (submitted) • Ochieng et al. (2021) Assuring quality, safety and consumer acceptability of cookies fortified with *Ruspolia differens* meal to combat malnutrition. *Food Quality and Preference (under review)* • Ochieng et al. (2021) In vitro protein digestibility, aroma characterization and consumer acceptability of wheat-cookies enriched with processed *Ruspolia differens*. Journal of Food Science and Technology (under review)	
	Specific Objective: Favourable enabling environment for insect-based food through policy,	• Policy briefs, advocacy and awareness creation materials established.	Eight (8) insect-based food products were exhibited in Uganda and information on market penetration and	Value-addition using insect-based meal increases acceptability

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
	advocacy and awareness creation established	• Insect based food standards developed and approved in both countries. • At least 2 exhibitions of insect-based food products done.	consumer willingness to eat and pay for products established.	
Broad objective: Promotion of insect meal Commercial Production in Rwanda.	**Specific Objective:** Orientation and stakeholder workshop.	• 2-3 stakeholder meeting organized by end of March 2021. • 1 MSc student and 1 technical staff recruited by March 2021. • Organize 3-4 days virtual training and field visit to insect rearing facilities of selected companies in Rwanda by March 2021.	6 stakeholder meetings were organized with over 82 participants (42 females) 2 MSc students recruited to work on organic waste recipes for optimal production of BSF larvae 12 persons (2 from each private company) provided hands-on training for 5-days on insect-based farming technologies	Knowledge sharing is a good platform to incentivize community uptake of technologies
	Specific Objective: Work with selected BSF companies to develop substrate rearing and formulation.	• At least 3 companies selected, with finalized workplan and rearing parameters for mother colonies by June 2021. • Establish the nutritional profile of BSF reared on various substrates by August 2021. • Work with GoR to get permit by June 2021.	Out of the 6 private companies, three were selected and provided financial support to established commercial BSF farms in Rwanda. Nutritional profile of BSF larvae grown in the various farms was established. Government of Rwanda provided support and provided permit to establish BSF farms in Rwanda.	Private companies' willingness to adopt and scale BSF technologies is important for the success and market orientation of product development.
	Specific Objective: Provide support to relevant public sector agencies on insect feed related policy and regulations instruments.	• A draft standard on the use of insects in animal feed by September 2021. Information of risk and safety assessment by October 2021.	Three new standards: Code of practice, Edible insects' products, and Products containing edible insects were developed and launched in Rwanda alongside 3 commercial insect farms.	Government willingness to facilitate standard development is crucial.

(v) Social Science and Impact Assessment Unit: Results Based Management (RBM) Rolling Framework Report

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
Broad Objective 1: Evaluate the livelihoods, environmental, and health impacts of pests and Integrated Pest and Vector Management Strategies (IPVMS)	**Specific objective 1**: Socioeconomic, environmental, nutrition, and human health impacts of IPVMS and pesticide use at micro-level established	• Manuscripts on socioeconomic environmental, nutrition, and human health impacts of IPVMS and pesticide use	• Impact of collaring Trypanosomiasis was published in collaboration with the African Union Pan African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC) coordinators. (https://doi.org/10.1371/journal.pone.0254558).	Adoption and scaling of the collar technology developed by icipe can help generate an economic gain of US$78-869 million per annum for 18 African countries, with a cost-benefit ratio of 9:1. Sensitizing governments and other stakeholders along the value chain with the help of PATTEC platform and designing a context-specific technology scale strategy can mitigate the enormous economic losses caused by this insect.
			• A working paper titled One size does not fit all: Heterogeneous impact of mango fruit fly IPMs was produced.	Most IPMs are profitable for small-scale and medium-sized farmers. However, most practices were not profitable for large-scale farmers. More research is needed to understand how to improve the returns to investment for large-scale farmers, to spur demand and wide adoption of the IPM technologies.
			• The Socioeconomic Impacts of House Screening (HS) against Malaria Transmission using Experimental Evidence in Eastern Zambia presented at the International Conference of Agricultural Economists (ICAE), August 2021.	We learned HS as a supplement to existing malaria control reduces malaria prevalence, the number of sick days due to malaria, and the number of malaria episodes. Impacts on adults are more pronounced than on children. House screening increases labour supply and income and the labour effect is larger for women household members. A cost-benefit analysis suggests that the private benefits of house screening exceed the costs.
	Specific Objective 2 Adoption and demand for IPVMS and awareness and knowledge of pests and diseases and control measures	• Papers on demand for IPVMS and Knowledge, Attitude, and Practices of pests and diseases	• Individuals Willing to Pay for Community-Based Eco-Friendly Malaria Vector Control Strategies studied. • https://doi.org/10.3390/su12208552	Mean WTP values were higher among male participants than female participants. Urban residents were willing to pay a slightly higher price than rural residents. Household per capita income and building capacity of households through training significantly increased WTP. The high adoption potential of the technology and the need to devise inclusive policy tools, especially those that enhance collective action, resource mobilization, and capacity building to empower both men and women and stimulate investment in eco-friendly technologies for malaria prevention.
			• A manuscript on adoption and dis-adoption of innovations and Integrated Fruit Fly Management in Kenya was published. https://doi.org/10.3390/agriculture11040338.	Dis-adoption of IPM technologies was evident from the survey sites in Kenya and attributed to various reasons key, among them technology-related constraints including limited access to IPM products, limited returns from investing in IPM, and lack of a premium for IPM produced mangoes.
			• Livestock farmers' knowledge, beliefs, and management (KBM) of arboviral diseases (ADs) in Kenya were evaluated. (https://doi.org/10.1371/journal.pntd.0009786).	Only a quarter of the farmers knew about ADs (Rift Valley fever, Chikungunya fever, and Dengue fever), while over four-fifths could not manage any diseases. Access to information (experience and awareness), income, education, religion, and distance to a health facility considerably influenced the intensity of farmers' KBM of ADs in Kenya. Initiatives toward improving access to information through awareness campaigns are necessary to mitigate behavioural barriers in ADs management among rural communities.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
			• A study on assessing farmers' perceptions and willingness to pay for the tsetse repellent collar was published (https://doi.org/10.1371/journal.pntd.0009663).	63% of livestock keepers were willing to pay for the tsetse repellent collar technology (TRC) at the same cost they spent treating an animal for AAT. On Average, farmers were willing to pay KES 3,352 ($33) per animal per year for the TRC. Uptake of TRC can be enhanced through training, especially among women farmers.
			• Knowledge, Attitude, and Practices on Tomato Leaf Miner, Tuta absoluta on Tomato, and Potential Demand for Integrated Pest Management among Smallholder Farmers in Kenya and Uganda were studied. (https://doi.org/10.3390/agriculture11121242)	*Tuta absoluta* is the major Tomato infesting pest, with chemical pesticides being used by most farmers to control it. Most respondents were, however, willing to pay for the IPM. Training and IPM awareness creation were recommended for sustainable adoption of the innovations.
Broad Objective 2: Socioeconomics and environmental implications of edible insects	**Specific Objective 1**: Evaluate environmental, economic, food security, employment, and climate change mitigation benefits of edible insects farming for feed and food	• Papers and policy brief on socioeconomic-environmental-health-climate mitigation benefits of insect farming and insect-based feed	• The ex-ante potential economic impact of adopting insect-based feed in Uganda produced	Insect farming is becoming a growing and lucrative business in Kenya and Uganda. Scaling insect-based feed innovation has huge socioeconomic and environmental benefits.
			• Draft working paper on environmental impact assessment of black soldier fly farming in Kenya generated	
			• A symposium on the potential of insects for green growth and development was organized at the International Conference of Agricultural Economists (ICAE), August 2021.	Important to use such a forum to enhance awareness of the benefits of insects among regional and international communities.
	Specific Objective 2: Understand consumers and producers' intention to farm and consume edible insects	• Published paper on farmers' perceptions of insect-based feed and livestock production	• A paper was published on farmers' perceptions of commercial IBF products and factors influencing adoption. (https://doi.org/10.3390/su13105359)	Over 90% of the farmers were ready and willing to use IBF. Feed performance, social acceptability of insects in feed formulation, feed versatility, and marketability of livestock products reared on IBF are the key attributes that would inform farmers' purchase decisions. Awareness of IBF attributes, group membership, off-farm income, wealth status, and education significantly influenced farmers' perceptions of IBF. Interventions such as experimental demonstrations that increase farmers' technical knowledge on the productivity of livestock fed on IBF are crucial to reducing farmers' uncertainties about the acceptability of IBF.
		• Paper on understanding consumers' perception of the use of eggs produced using an insect-based feed.	• An article was published on empirical evidence on understanding consumers' perception towards eggs from laying hens fed commercial black soldier fly larvae meal-based feeds. (https://doi.org/10.1016/j.psj.2021.101645)	Awareness creation and evidence-based demonstration of the benefits of BSFL-based feed in poultry production would improve consumer perception and foster uptake of this rapidly growing and emerging technology.
		• Paper on factors affecting human consumption behaviour of insects as food	• Paper on Entomophagy in western Kenya: The role of psychological and cultural factors accepted for presentation at the Insects to Feed the World 2022 conference, Quebec, Canada.	Psychological factors, such as perceived barriers, social norms, environmental concerns, and cultural factors play significant roles in households' insect-eating behaviour. Further objective knowledge about the nutrient value of insects is important in households preferring insects to beef.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learnt
Broad Objective 3: Role of digital agricultural technology in scaling up technologies and livelihoods and M&E systems	**Specific objective 1**: Understand gender roles, barriers, and enablers to decision-making and other household dynamics influencing Digital Agricultural services (DAS) adoption	• Working paper	• A working paper on gendered access, ownership, and use of smartphones in Northern and Eastern Uganda was produced and shared with different stakeholders.	More men compared to women own smartphones. We also learned that phone ownership is skewed, with almost all households who do not own phones being widowed or divorced women. To achieve equity through digital technologies, a group approach may be preferred to cater to those without phones.
Broad Objective 4: Gender and youth mainstreaming and research analysis	**Specific objective 1**: Women's empowerment index and technology adoption	• Working paper on the relationship between women empowerment and adoption	• A paper was produced on the association between women's empowerment and willingness to pay for integrated fruit fly management (IPM) practices.	Women empowerment significantly increased the likelihood to pay a higher price for the fruit fly IPM, suggesting empowering women would increase the uptake of pest management technologies.
Broad Objective 5: Ecosystem services and commercial insects' roles in food systems	**Specific Objective 1:** Role of pollination services and disrupting cropping patterns in closing nutrition gaps in sub-Saharan Africa	• A paper on the role of reallocating land from pollinator independent crops to pollinator-dependent crops in closing the nutrients consumption gap	• A paper on Closing household nutrition deficiencies through animal pollinator-dependent (PD) crops in sub-Saharan Africa was presented at the International Conference of Agricultural Economists (ICAE), August 2021. (https://ageconsearch.umn.edu/record/315241/references)	Increasing the proportion of PD crops cultivated area relative to pollinator-independent crops reduces the likelihood of nutrient deficiencies and increases household income. It is essential to inform policymakers and development partners to consider adjusting existing cropping systems and investing in nutrient-dense crop production as a pathway to close the micronutrient deficiency gap.
Broad objective 7: Capacity building impact assessments	**Specific objective 1**: Evaluate *icipe's* and its partners' capacity-building investment	• Report on the impact of icipe's capacity building activity	• A survey was launched to trace former participants of the capacity-building initiatives at *icipe*.	NA
	Specific objective 2: Mentor Ph.D. and MSc students	• Students graduated	• 3 MSc students graduated	The equal commitment of University supervisors is important for the timely completion of studies by students.

(vi) Capacity Building and Institutional Development Programme: Results Based Management (RBM) Rolling Framework Report

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieveing Outcomes	2021 Lessons Learnt
Objective: Increase the number and quality of researchers and middle level practitioners required to respond to arthropod-related research and ASET development challenges in Africa by 2025.				
1. Between 2021 and 2025, (a) 150 PhD and 150 MSc postgraduate students (at least 40% women) representing at least 18 sub-Saharan Africa nationalities in all sub-regions, at various stages of their postgraduate programme, conducting all or part of their research at icipe in arthropod and related sciences; (b) 200 PhD students in the Regional Scholarship and Innovation Fund project (at least 40% women), representing at least 18 sub-Saharan Africa nationalities in all sub-regions of SSA, at various stages of their PhD program at RSIF African Host Universities, conducting research in various ASET fields.	• At least 95% of students complete postgraduate training. • At least 75% of PhD students who complete their training each year during 2021–2025 contribute to research, development and higher education in Africa, dealing with reducing poverty, improving food and nutritional security, improving human, animal and environmental health; and work in Universities, National Research Systems, sub-Regional Organisations (SROs), International Research Centres (IRCs), and the private sector in Africa. • At least 50% of MSc graduates trained at *icipe* continue a career in R&D or higher education.	• Number of PhD and MSc students in the *icipe* postgraduate programmes at various stages of training, and number completing training with *icipe*, each year during the period 2021-2025. • Number of women in the programme each year. • Number of African countries represented in the postgraduate programmes each year. • Number of scientists trained at *icipe* and RSIF African Host Universities engaged in research, development and higher education in Africa. • Number scientists trained at *icipe* and RSIF African Host Universities leading research and development projects or playing a leading role in higher education in Africa. • Number of research activities/projects implemented in African institutions by scientists trained at *icipe* and RSIF African Host Universities during 2021-2025. • Number of graduates with positions of leadership in public & private organisations/enterprises in Africa.	• During 2021, there were 59 PhD fellows and 101 MSc fellows at various stages of their postgraduate training programme at icipe. In addition, icipe managed 173 Regional Scholarship and Innovation Fund (RSIF) PhD scholars at 15 African universities. • In 2021, women represented 43% of all postgraduate fellows at *icipe*, and 37% of RSIF PhD fellows. • In 2021, 19 African nationalities, from all sub-regions of SSA were represented by postgraduate students at icipe (Benin, Burkina Faso, Cameroon, DR Congo, Ethiopia, Ghana, Kenya, Liberia, Malawi, Mali, Nigeria, Rwanda, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe). RSIF scholars represented 23 African nationalities (Benin; Burkina Faso; Burundi; Cameroon; Chad; DR Congo; Côte d'Ivoire; Ethiopia; Ghana; Kenya; Malawi; Mali; Nigeria; Niger; Rwanda; Republic of the Congo; Senegal; South Sudan; Sudan; Tanzania; Togo; Uganda; Zimbabwe). • In 2021, 18 PhD and 32 MSc students completed postgraduate training with *icipe*. Of these, 18 PhD students 12 (67%) are currently engaged in research, development or higher education in Africa; 2 (11%) are engaged in research outside Africa and 4 (22%) are currently seeking employment. Of the 32 MSc students, 16 (50%) are pursuing a career in R&D or higher education in Africa, 2 (6.25%) are engaged in research outside Africa, 5 (16%) are undertaking a PhD and 2 (6.25%) are seeking PhD opportunities. No data are available for the remaining 7 (21.5%) MSc students who completed their studies with *icipe*. • 118 PhD and 161 MSc students completed training at icipe in 2014-2021. • 85 PhD students (72%) and 86 MSc students (55%) who completed training at *icipe* in 2014-2021 are engaged in research, development and higher education in Africa. • 27 *icipe* postgraduate students who completed training at icipe since 2014 are in senior positions or leadership roles in Africa.	Capturing details of MSc and PhD students after completion of studies at *icipe* remains a challenge, particularly MSc students and students that pursue careers outside of R&D and higher education. Much information is gleaned from internet searches because many alumni do not respond readily to email surveys. Data on the number of research activities/projects implemented in African institutions has also been very difficult to obtain.
2. Dissemination of research results by icipe postgraduate students through 400 scientific	Research results disseminated in relevant formats at scientific community and policy maker levels	• Number of publications that result from research conducted by students at *icipe* (theses,	• In 2021, of the 271 peer-reviewed papers published by *icipe*, 126 (46%) were authored by postgraduate students, 106(39%) as lead authors.	

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieveing Outcomes	2021 Lessons Learnt
publications (including theses, book chapters, peer-reviewed scientific papers, conference abstracts and proceedings, training brochures and manuals, policy documents, in print and online media) in the period 2021-2025		book chapters, peer-reviewed papers, conference abstracts and proceedings, training brochures and manuals, print and online media). • Number of students contributing to policy documents. • Quality and relevance of icipe led-research results shared with scientific community determined by the number of citations in peer-reviewed publications. • Number of students participating in scientific meetings/conferences	• Citation metrics: Peer-reviewed publications by students in 2021 had an average 3.44 citations (range 0-17) and 496 downloads (range 0 to 8270) per publication. • 18 PhD and 32 MSc theses were completed and successfully defended in 2021. • In 2021, 19 postgraduate students participated in 29 international/ regional scientific meetings & conferences. • In total, 576 peer-reviewed scientific papers were published by *icipe* Postgraduate students in 2014-2021. • 125 PhD and 171 MSc theses were completed by *icipe* postgraduate students in 2014-2021.	
3. Career development opportunities for at least 20 early career postdoctoral fellows implemented during the period 2021-2025	• At least 75% of postdoctoral fellows and visiting scientists on completion at icipe proceed to contribute to research, development and higher education in Universities, NARS, SROs, IRCs, and the private sector in Africa each year during the period 2021-2025. • At least 50% of postdoctoral fellows attract competitive research grants during their tenure at icipe. • At least 50 scientific publications in peer-reviewed journals are published by postdoctoral fellows and visiting scientists during the period 2021-2025. • At least 50% of postdoctoral fellows at *icipe* supervise PhD and MSC students as primary or secondary supervisors.	• Number of postdoctoral fellows. • Number of grants applied for and received by icipe postdoctoral fellows each year. • Number of postdoctoral fellows trained at icipe contributing to research, development and higher education in Africa. • Number of research publications in peer-reviewed journals. • Numbers of postdoctoral fellows supervising postgraduate students as primary or secondary supervisors.	• 26 postdoctoral fellows were engaged in research at *icipe* in 2021. • 28 peer-reviewed articles were published by postdoctoral fellows (16 as lead author), representing 10% of all *icipe* peer-reviewed publications in 2021. • In 2021, *icipe* postdoctoral fellows participated in 38 grant applications; 9 were awarded and signed; 1 approved - awaiting contract; 5 under review with various funders; and 23 were unsuccessful (i.e., at least 24% success rate). • Of the 47 postdoctoral fellows recruited since 2014, 21 are currently postdocs at *icipe*, 7 are now scientists with *icipe*, 12 are working with national R&D systems, 6 are research consultants and 1 is deceased.	
4. 200 Research Interns (at least 40% women) trained during the period 2021-2025.	• At least 50% of trained research interns progressing to higher education, research and	• Number of interns trained. • Number of women in the programme each year.	• 65 research interns were trained in 2021 (37 [57%] women). Average duration of an internship was 6 months. • In total 240 interns (145 [60%] women) were trained at *icipe* in 2014-2021.	Tracking of interns is challenging – many do not respond to requests for information.

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieveing Outcomes	2021 Lessons Learnt
	development careers each year during the period 2021-2025.	• Number of research interns progressing to higher education, research and development careers	• Of those that were tracked since their training with *icipe*, 6 are currently completing BSc degrees, 31 are pursuing Diploma, MSc or PhD qualifications, 3 are completing an internship with another R&D organisation; 16 are working in development/ R&D/ Higher Education and 12 have research assistant or consultancy positions with *icipe* and 16 are searching for MSc scholarships or employment.	
5. 2000 researchers, mid-level practitioners and extension workers from 30 national systems in Africa trained in non-degree professional development courses during the period 2021-2025.	• At least 50% of trained researchers, mid-level practitioners and extension workers applying acquired knowledge and expertise in Africa each year during the period 2021-2025.	• Number of training courses. • Number of and type of trainees. • Number of organisations benefiting from training • Number of trainees applying acquired knowledge and expertise in Africa	• 140 training courses were held in 2021 for 9,464 researchers, mid-level practitioners and extension workers from 13 Africa countries (Botswana, Comoros, Eswatini, Ethiopia, Kenya, Malawi, Mozambique, Namibia, Rwanda, Tanzania, Uganda, Zambia and Zimbabwe) and 1 non-African country.	
6. At least 10 capacity building activities developed with national and regional research and higher education institutions during the period 2021-2025.	• Research and training capacities strengthened at national and regional research and higher education institutions through the development of partnerships with *icipe*.	• Signed MoUs and collaborative agreements with partners. • Number of collaborative capacity building activities started with national and regional research and higher education institutions.	• In 2021 a collaborative Research Agreement was signed with The Institute of Research for Development (IRD) to support thesis research for a student for 18 months. • During 2014-2021: capacity building activities were developed with national and regional research and higher education institutions, including - KALRO (Kenya), Makerere University (Uganda), KEPHIS (Kenya), TARI-Selian (Tanzania), TARI-MARI (Tanzania), Amhara Regional State Bureau of Agriculture (Ethiopia) for CAP-Africa (Combatting Arthropod Pests for Better Health, Food and Climate Resilience) capacity building. - A postgraduate training programme with Egerton University and Jaramogi Oginga Odinga University of Science and Technology (JOOUST, Kenya for training of students at icipe - An MoU with United States University in Africa, Kenya for capacity building and joint research projects. - A service contract with CABI for students to complete short research projects at *icipe*.	

(vii) BioInnovate Africa Programme: Results Based Management (RBM) Rolling Framework Report

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learned
Specific Objective 1: Develop value added goods and services from biological resources				
Innovative value-added goods that create value for customer segments in rural and urban communities.	Enhanced capacity of Eastern African universities and research organizations to translate modern biosciences into innovations targeting smallholder farmers and agro-process enterprises in the region.	- % change in no. of bioscience value-added goods at different levels of development (undergoing value addition, ready for market, market tested)	1. Market-tested goods: • Approx. 695,000 high-quality clean & certified Sweet potato seeds were sold to smallholder farmers in Kenya, Tanzania & Uganda as part of market testing. A pack of 10 vines cost on average USD 30 cents. The organisations that made the sales include MIMEA International Ltd in Kenya, Tanzania Agricultural Research Institute – Mikocheni, and SENAI Farm Supplies Ltd in Uganda. • Sales of nitrogen-enhanced organic fertilizer by Guavay Co Ltd in Tanzania were approx. USD 44,000 compared with USD31,429 in 2020 (an increase of 40%). Each 50 kg bag is sold for USD17. • 80 kg mushroom substrate blocks (Each block weighs on average 1.5 kgs, and sells between TSh 500 to TSh1,000 per block) and 35 kg of mushrooms (@ between TSh 6000 and 7,000 per kg in Morogoro) were produced and sold by OKOA Ltd in Tanzania. In addition, orders of 52 bottles of spawns were received and sold to small holder farmers (each bottle with a net weight of 160 kgs to 180 kgs sold at TSh 2,500). • Three (3) sorghum-based products were developed by Bomvitae Agro-Industries Ltd in Uganda: Sormaize foundation seed; Sorghum syrup & Bioethanol. • Over one (1) tonne per month of orange-fleshed sweet potato puree (OFSP) is being produced and sold by Biofresh Uganda Ltd in Uganda. (Price is USD 0.82 per kg) • Approx. 50 packets of aroma honey toffees were sold to consumers in Cape Town (@ USD15 per packet). • 500 kg of certified Maseno EH14 parental seeds were produced and licensed to AgriSeed Co in Kenya for seed multiplication and eventual sale. • 412 & 208 sachets of Tsetse repellent & attractant products were market tested in communities around game parks such as Shimba Hills in Kenya, Tanga and Serengeti areas in Tanzania, and Murchison Falls in Uganda.	Maintaining flexibility in planning for and executing activities was important for adapting to and coping with the COVID-19 pandemic situation, and related travel and public health restrictions. Further, a blend of in-person and virtual participation in meetings was useful for ensuring continuity of activities and maintaining contact with implementing partners. Through this blended approach, it was possible to commission biobased ventures as pilot enterprises with value-added products and services in some countries, and engage with a wide range of stakeholders regionally and globally on innovation and bioeconomy development in Eastern Africa.
			2. Goods ready for market-testing: • One (1) two-station batch Refractance Window Dryer (RWD) was fabricated and tested successfully at KIRDI in Kenya.	

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learned
			3. Goods undergoing development: • A reformulated mosquito-repellent catnip-based product is undergoing refinements in Burundi with support from *icipe* in Kenya. • Two (2) new isolates effective against desert locusts and tolerant to high temperatures i.e., ICIPE 19 and 22. • Three (3) herbal drinks with high inflammatory and antioxidant properties were developed and are being refined in Uganda. • A prototype of an indirect monoclonal antibody-based ELISA diagnostic kit that can test SARS CoV-2 was developed by Ethiopian Biotechnology Institute. • A prototype product of a salad dressing with immune-boosting properties was developed by Gudie Leisure Farms in Uganda. • A prototype product of an aqueous concoction (COVIBA) with immune properties against COVID 19 was formulated by Tanzania Industrial Research and Development Organisation in Tanzania.	
Innovative value-added services that create value for customer segments in rural and urban communities.	Enhanced capacity of Eastern African universities and research organizations to translate modern biosciences into innovations targeting smallholder farmers and agro-process enterprises in the region.	- Number of bioscience services at different levels of development (undergoing value addition, ready for market, market tested)	1. Market-tested services: • Four (4) tenders worth approx. USD 185,000 were awarded to BIOCON Africa Limited in Arusha, Tanzania for provision of integrated wastewater treatment services. 2. Services ready for market: • Two (2) Hot Water Treatment protocols for disinfesting French beans and bell pepper are available at *icipe* in Kenya. • Reports of stochastic simulation of Covid-19 pandemic effects on food security and the environment are available at *icipe*. 3. Service under development: • An Artificial Intelligence (AI) based diagnostic kit prototype for detecting sweet potato viruses was developed and tested.	
Bioscience knowledge that addresses the needs of smallholder farmers and agro processors developed	Enhanced capacity of Eastern African universities and research organizations to translate modern biosciences into innovations targeting smallholder farmers and	- % change in no. of bioscience ideas emerging from the projects.	Two (2) bioscience ideas: • Some endophytes and entomopathogenic isolates identified by partners in the project were found to be effective against fall armyworm.	

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learned
	agro-process enterprises in the region.		• Characterisation for functional properties of starch in grain has revealed that sormaize lines can be clustered according to potential niche applications in the food industry. 15 manuscripts are under review and three (3) publications were made as follows: • Two (2) publications on Refractance Window Drying (RWD) have been made in peer reviewed journals. • One (1) publication on sorghum was made in a book chapter. • Four (4) articles on RWD are under consideration for publication in peer reviewed journals. • Seven (7) manuscripts on orange-fleshed Sweet potato puree (OFSP) by the International Potato Centre (CIP) in collaboration with University of Nairobi are being reviewed for publication. • Two (2) manuscripts by *icipe* on fungal biopesticides are being reviewed for publication. • Three (3) manuscripts by *icipe* on hot water treatment protocols are being reviewed for publication. • Two (2) manuscripts on long-horned grasshoppers are being reviewed for publication. • One (1) manuscript on tsetse repellents and attractants is being reviewed for publication.	
		- Quality/service marks or certificates issued. - Number of intellectual properties (including patents) acquired at different levels of product development i.e., applied for, awarded, or in gazette	Awarded: • A product certificate was issued to Hakika™ fertilizer by Tanzania Bureau of Standards (TBS) No. 0541 of March 2021. In addition, an EU/USDA certificate No. C8752321NP was issued for the product. • A quality mark was awarded to Aroma Honey Toffee Limited by Uganda National Bureau of Standards (UNBS) Acquired: • The Kenya Agricultural and Livestock Research Organisation (KALRO) received two patents for Tsetse repellents and Tsetse attractants from Kenya Intellectual Property Institute (KIPI) and the African Regional Intellectual Property Organisation.	
Specific Objective 2: Create new business prospects based on renewable biological resources				
Bio-based business models that help smallholder producers, and agro-processors to gain a competitive	Increased linkages between research institutions, universities, and the private sector (including investors)	- Number of validated bio-based business models.	Four (4) validated business models: 1. Sorghum syrup 2. Orange fleshed sweetpotato puree 3. Tsetse repellent products 4. Coffee waste vermicomposting	

Outputs	Outcomes	Performance Indicator	2021 Progress in Achieving Outcomes	2021 Lessons Learned
advantage in national and regional markets.				
Spin-off companies are developed and supported.		- Number of company registration certificates.	There was none reported in this period.	
Pipeline investors in biobased goods and services are linked to the programme		- Number of investor pitches and meetings organized with potential investors.	One (1) meeting was organised and held on 15 October during the 2021 Bioscience Innovation Bootcamp in which 12 entrepreneurial scientists pitched to investors. The 2021 Bioscience Innovation bootcamp was held on 11-15 October 2021 in which 12 entrepreneurial scientists across seven (7) countries participated. The countries were Burundi, Ethiopia, DRC, Kenya, Rwanda, Tanzania, and Uganda.	
Specific Objective 3: Support the development of local innovation ecosystems				
Institutional innovation frameworks are developed.	Improved prioritization and coordination of policy responses to promote bio-based innovation and entrepreneurship.	- Number of institutional innovation policies drafted.	None (activity was not supported)	
		- Innovation/technology transfer offices established.	None (activity was not supported)	
Networks and partnerships developed.		- Number of contracts and/or agreements signed to engage with various stakeholders.	• Four (4) contracts were awarded by both private and public entities to BioCon Africa Limited in Tanzania to implement various integrated wastewater treatment systems. • A renewed partnership was made between *icipe*/BA and Villgro Africa and with Inclusive Business (IB) Sweden to implement the 2021 Bioscience innovation bootcamp. • A renewed partnership was made between icipe/BA and Thayer School of Engineering at Dartmouth USA for a second cohort of students to strengthen their capacity for technoeconomic analyses in East Africa. • icipe/BA renewed its membership in the Aspen Network of Development Entrepreneurs (ANDE)	
Specific Objective 4: Support the development of local innovation ecosystems				
Relevant policy options to support scientists in their effort to promote bioscience innovations for smallholder farmers and agro processors evaluated.	Improved prioritization and coordination of policy responses to promote bio-based innovation and entrepreneurship.	- Strategies/policies put in place by governments to support and promote biosciences innovations.	1. The second regional eastern Africa Bioeconomy conference was held on 10-11 November 2021. 625 regional and global stakeholders participated in the conference. 2. A Draft Bioeconomy Strategy was tabled at the East African Community (EAC) council of ministers for approval.	
		- Enabling regulations put in place by governments to support and promote biosciences innovations.	None reported in this period	

(viii) Partnership for skills in Applied Sciences, Engineering and Technology (PASET) - Regional Scholarship and Innovation Fund (RSIF): Results Based Management (RBM) Rolling Framework

Outputs	Outcome	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learned
Broad Objective: To develop the capacity for growth and management of a scholarship, research, and innovation fund for sustained financing of scientific and technical talent development in Africa	**Specific Objective:** Growth in the Regional Scholarship and Innovation Fund (RSIF) and foundation laid for the establishment of a permanent fund	• Foundation for permanent fund established and RSIF growing over time	• RSIF has now raised USD 51.7 million from 11 funders comprised of African governments (Benin, Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Mozambique, Rwanda and Senegal), Government of Korea, the ACP Innovation Fund of the European Union and the World Bank. • Of these, three funders with contributions worth USD 12.7 million joined in 2021: European Union (USD 4.7m); Benin (USD 2m) Mozambique (USD 6m). • Funders and partners spoke highly of RSIF design and *icipe*'s role at the virtual pre-conference held in Nov-21, encouraging more investors to join and the establishment of a special committee to support resource mobilization and establishment of the RSIF Permanent Fund.	• Many stakeholders are appreciating RSIF as an effective channel for allocating resources to achieve continental visions and agendas, as well as acceleration of the sustainable development goals (SDGs). • Covid -19 is impacting negatively on the resource mobilization landscape. • Need to strengthen communication and activities to support resource mobilisation.
Broad Objective: To establish scholarships, research and innovation grants for ASET by 2025:	**Specific Objective:** Increased capacity to operate and manage doctoral training scholarships, research and innovation grants	• Number of scholarships and grants successfully administered	• The RSIF Regional Coordination Unit (RCU) was administering 184 doctoral scholarships (39% women) for students from 21 sub-Saharan nationalities, as well as 16 research grants and 21 innovation grants.	• Staff capacity is being aligned to the higher student and grant numbers. Additional staff were recruited to support matching of students • A management information system is under development to enhance efficiency • Student orientation training and review of regular student satisfaction surveys are key for smooth administration • Grant management training support compliance for grantees
Broad Objective: Window 1 - Scholarships for PhD training	**Specific Objective:** RSIF PhD Scholars enrolled in selected PhD programs at RSIF African Host Universities (AHUs)	• At least 200 (60 female and 140 male) RSIF scholars enrol in selected PhD programs at RSIF AHUs	• With cohort 3 joining in 2021, number of scholars enrolled increased to 184 (15 for cohort I, 67 for cohort II and 102 cohort III). Of these, there were 66 female scholars (3 for cohort I, 27 for cohort II, 36 Cohort III) • 1948 (361 females) applied for the fourth cohort and selection progress were ongoing.	• Need for ongoing effort to increase pool of women applicants and retain female scholars, e.g. through mentorship programme targeting female scholars, which is being developed
	Specific Objective: RSIF PhD scholars graduated	• At least 157 (46 female and 111 male) RSIF scholars graduate from PhD programs by 2025	• RSIF reached a major milestone with two (2M, 0F) students from its first cohort successfully graduating in 2021. • RSIF PhD graduate, Dr Noël Gahamanyi, Rwanda was awarded Best Postgraduate Student Research Award 2021	• Attention to be given to meaningful employment for graduates as first cohort is nearing completion • African funding governments put in scholarship contract with the

Outputs	Outcome	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learned
			during the 38th Graduation Ceremony at Sokoine University of Agriculture in Tanzania.	expectation to return to work in national universities and research institutes
Broad Objective: Window 2 – Research grants	**Specific Objective:** Improved research capacity in ASET including in transformative technologies in SSA	• At least 10 grants awarded to faculty of RSIF African Host Universities/ eligible institutions by 2023 • At least 16 research grants awarded to RSIF scholars by 2023	• The quality of research emerging from RSIF research grants to faculty of RSIF AHUs involved in a PhD programme with RSIF scholars are encouraging and expected to be important in solving some key societal challenges. Moreover, the RSIF research awards involve 54 PhD students, thus complementing their doctoral training, contributing to scientific human capital development on the doctoral level. • Ten new research grants awarded to faculty in 2021, bringing total number of research grants to faculty to 16 with a total value of USD 1,368,271. • RSIF graduating students who obtain a position in an academic or research position are eligible to apply for junior investigator research awards (from 2022).	• Involvement of PhD students in the research awards to faculty help them build their own research capacity and future independent scientific careers. • Transition to early career scientists will be further supported by the competitive research awards to RSIF graduates from 2022.
Broad Objective: Window 3 – Innovation grants	**Specific Objective:** Improved innovation capacity in ASET including transformative technologies in SSA	• Number of Innovation grants successfully managed • 10 firms co-finance innovation grants by 2023 • 6 innovations grants awarded to RSIF AHUs/ eligible institutions by 2023 • 5 innovation grants awarded to faculty at RSIF AHUs by 2023 • 12 innovation grants awarded under AGriDI in West Africa	• The RCU continued to support innovation-enabling environments and strengthening the commercialization of research results. This included policy development on innovation and intellectual property management in the RSIF AHUs and strengthening their technology transfer offices. A business incubation workshop for grantees and webinars on venture capital funding opportunities for sci-tech startups in Africa were also conducted. • The total number of RSIF managed innovation grants reached 21 with a total value of USD 2.8 million. • 5 firms co-financed innovation grants. • The 6 institutional innovation capacity building grants awarded to RSIF AHUs for a total value of USD 300,000 progressed well. • Three new cooperability grants awarded to faculty in 2021, bringing total innovation grants awarded to faculty to 5, with a total value of USD 249,990. • 10 new innovation grants with a value of USD 2.2 million awarded for Accelerating Inclusive Green Growth through Agri-based Digital Innovation (AGriDI) in Benin, Cote d'Ivoire, Ghana and Nigeria.	• RSIF innovation ecosystem is responding to pressing pandemic and health related challenges as seen in latest round of awarded projects, which include 3D printing of personal protective equipment; Using geolocation data with machine learning for infectious disease outbreak prediction; and System for diabetes/cancer monitoring. • Sharing of lessons learnt between grantees for creating stronger innovation /entrepreneurial environments. • A course on innovation and entrepreneurship targeting graduate students, and especially female researchers, will also be developed.

Outputs	Outcome	Performance Indicators	2021 Progress in Achieving Outcomes	2021 Lessons Learned
Broad Objective: To strengthen the institutional capacity for quality and sustainable doctoral training, research and innovation in transformative technologies in Sub-Saharan Africa (SSA) by 2025	**Specific Objective:** Quality of doctoral programs and research in ASET enhanced at RSIF African Host Universities	• At least 10 agreements signed with RSIF African Host Universities (AHUs) by 2023 • At least 10 RSIF AHUs with an online application system in place by 2023 • At least 8 RSIF AHUs that start international accreditation process for the PhD programmes by 2023 • 10 cross-cutting training courses/workshops held for RSIF scholars and researchers by 2023 • At least 120 student/staff that take cross-cutting courses, entrepreneurship and / or research commercialization courses supported by the project by 2023	• To cater for the growing number of RSIF students in five thematic areas and language diversity, additional RSIF African Host Universities were selected in 2021. New agreements were signed with University of Abomey-Calavi, Benin and Institute 2iE, Burkina Faso, bringing total AHU agreements to 13, with two more under signature. (https://www.rsif-paset.org/partners/#host-institutions). • All the RSIF AHUs had an online application system in place. • 6 AHUs had started international accreditation process: AUST, UG, Uniport, UR, BUK and UFH-B. • 22 cross-cutting training courses/workshops held for RSIF scholars. • 570 students/staff that take cross-cutting courses, entrepreneurship and/or research commercialization courses supported by the project.	• Agreements with international universities could be further leveraged to strengthen curriculum development and quality assurance • Guest webinars present opportunities for networking and enhance visibility
	Specific Objective: Increase in quality of research publications on ASET in Africa	• At least 20,000 scientific and technological journals can be accessed by RSIF scholars and RSIF AHU researchers by 2023 • At least 35 research papers submitted by staff members or scholars supported by the project for publication to internationally indexed journals by 2023 (of which at least 10 by female authors or co-authors) • At least 10 implemented networks between RSIF AHUs and IPIs for PhD training and research collaboration by 2025.	• AHUs have annual running licenses with Research4Life, giving access to 184,014 scientific and technological journals. RSIF supported subscription access to 45,136 high quality e-resources (41,926 e-books and 3,210 e-journals) for the African Host Universities (AHUs). Usage of these resources was at over 350,000 hits. In addition, biannual Information Literacy and Reference Management training workshops were held. This has equipped the RSIF scholars and faculty with skills in conducting research and identifying credible and high impact journals to publish in. • 60 journal publications by RSIF scholars (of which 16 by female authors or co-authors) in high-quality peer-reviewed journals (https://repository.rsif-paset.org). • 5 networks initiated between RSIF AHUs and partnership agreements in progress.	• Policy for funding acknowledgement will be developed and shared with RSIF supported scholars and faculty. • RSIF will begin to monitor impact factors: ie. number of citations and h-index, as well as impact factor of the scientific journals where work is published.

SECTION 4: LIST OF JOURNAL ARTICLES (PEER REVIEWED) AND CONFERENCE PRESENTATIONS (JANUARY – DECEMBER 2021)

Annex 1 – List of Publications (Journal Articles – Peer Reviewed)

2021 (271)

(Note: Author names shown in italics are *icipe* staff or Graduate Students)

1. Abdool Karim S.S., *Kelemu S*., Baxter C. (2021) COVID-19 in Africa: Catalyzing change for sustainable development. *PLOS Medicine.* **https://doi.org/10.1371/journal.pmed.1003869**.

2. Abdulkadir M., Kajero O. T., *Olarinoye F. O*., Udebhulu D. O., Zhao D., Aliyu A. M. and Al-Sarkhi A. (2021) Investigating the behaviour of air–water upward and downward flows: Are you seeing what I am seeing? *Energies* 14, 7071. **https://doi.org/7010.3390/EN14217071**.

3. Abera D., *Kibet C*., Teshome D., Amenga-Etego L., *Bargul J.* and Golassa L. (2021) Genomic analysis reveals independent evolution of *Plasmodium falciparum* populations in Ethiopia. *Malaria Journal* 20, 129. https://doi.org/110.1186/s12936-12021-03660-y.

4. *Abro Z*., *Kassie M*., *Muriithi B*., *Okal M*., *Masiga D*., Wanda G., Ouedraogo G., Abah S., Nguertoum E., Rock A.N., Mansinsa P., Yahaya A., Mamadou C., Olet P., Boucador D., Jamal S., Garba A.R.I., Ajakaiye J.J., Kinani J.F., Hassan M.A., Nonga H., Daffa J., Gidudu A. and Chilongo K. (2021) The potential economic benefits of controlling trypanosomiasis using waterbuck repellent blend in sub-Saharan Africa. *PLoS ONE* 16, e0254558. https://doi.org/0254510.0251371/journal.pone.0254558.

5. *Abro Z*., *Kassie M*., *Tanga C*., *Beesigamukama D*. and *Diiro G*. (2020) Socioeconomic and environmental implications of replacing conventional poultry feed with insect-based feed in Kenya. *Journal of Cleaner Production* 265, 121871. https://doi.org/121810.121016/j.jclepro.122020.121871.

6. *Abro Z*., *Kimathi E*., De Groote H., *Tefera T*., *Subramanian S*., *Niassy S*. and *Kassie M*. (2021) Socioeconomic and health impacts of fall armyworm in Ethiopia. *PLos One* 16, e0257736.

7. *Adan M*., *Abdel-Rahman E.M*., *Gachoki S*., *Muriithi B.W*., *Lattorff H.M.G*., *Kerubo V*., *Landmann T*., *Mohamed S.A*., *Tonnang H.E.Z*. and *Dubois T*. (2021) Use of earth observation satellite data to guide the implementation of integrated pest and pollinator management (IPPM) technologies in an avocado production system. *Remote Sensing Applications: Society and Environment* 23, 100566. https://doi.org/100510.101016/j.rsase.102021.100566.

8. Adeniji S.A., Cromwell J., Oyewole D.O., Oyelade O.V., *Koech R.K*., Sanni D.M., Oyewole O. K., Babatope B. and Soboyejo W.O. (2021) Pressure-assisted fabrication of perovskite light emitting devices. *AIP Advances* 11, 025112. https://doi.org/025110.021063/025115.0035953.

9. *Adenka, K.D*., *Fening K.O*., *Afreh-Nuamah K*., Wamonje F.O. and Carr J.P. (2021) Susceptibility of five cabbage varieties to attack by aphids (Hemiptera: Aphididae) in the Accra plains of Ghana. *Phytoparasitica* 49, 33–47. https://doi.org/10.1007/s12600-12020-00863-y.

10. *Aduvukha G.R*., *Abdel-Rahman E*., Sichangi A.W., Makokha G.O., *Landmann T*., *Mudereri B.T*., *Tonnang H.E.Z*. and *Dubois T*. (2021) Cropping pattern mapping in an agro-natural heterogeneous landscape using Sentinel-2 and Sentinel-1 satellite datasets. *Agriculture* 11, 530. https://doi.org/510.3390/agriculture11060530.

11. *Afolayan D.O*., Onwualu A.P., Eggleston C.M., Adetunji A.R., Tao M. and Amankwah R.K. (2021) Safe mining assessment of artisanal barite mining activities in Nigeria. *Mining* 1, 224–240. https://doi.org/210.3390/MINING1020015.

12. *Afolayan D.O*., Adetunji A.R., Onwualu A. P., Ogolo O. and Amankwah R. K. (2021) Characterization of barite reserves in Nigeria for use as weighting agent in drilling fluid. *Journal of Petroleum Exploration and Production 11, 2157–2178. https://doi.org/2110.1007/s13202-13021-01164-13208.*

13. *Agbessenou A., Akutse K.S., Yusuf A.A.* et al. (2021) Temperature-dependent modelling and spatial prediction reveal suitable geographical areas for deployment of two *Metarhizium anisopliae* isolates for *Tuta absoluta* management. *Scientific Reports* 11, 23346. https://doi.org/10.1038/s41598-021-02718-w.

14. Aidoo O.F., *Tanga C.M*., *Azrag A.G.A*., *Mohamed S.A*., *Khamis F.M*., *Rasowo B.A*., *Ambajo J*., Sétamou M., *Ekesi S*. and Borgemeister C. (2021) Temperature-based phenology model of African citrus triozid (*Trioza erytreae* Del Guercio): Vector of citrus greening disease. *Journal of Applied Entomology*, https://doi.org/10.1111/jen.12942.

15. *Aidoo O. F*., *Tanga C.M*., *Mohamed S*., *Khamis F.M*., *Opisa S*., *Rasowo B.A*., *Kimemia J.W*., *Ambajo J*., Setamou M., *Ekesi S*. and Borgemeister C. (2021) The African citrus triozid *Trioza erytreae* Del Guercio (Hemiptera: Triozidae):

temporal dynamics and susceptibility to entomopathogenic fungi in East Africa. *International Journal of Tropical Insect Science* 41, 563–573. https://doi.org/510.1007/s42690-42020-00241-42695.

16. *Aigbedion-Atalor P.O.*, Hill M.P., *Ayelo P.M.*, *Ndlela S.*, Zalucki M.P. and *Mohamed S.A.* (2021) Can the combined use of the mirid predator *Nesidiocoris tenuis* and a braconid larval endoparasitoid *Dolichogenidea gelechiidivoris* improve the biological control of *Tuta absoluta*? *Insects* 12, 1004. https://doi.org/1010.3390/insects12111004.

17. *Akinbuluma M.D.*, Ewete F.K. and Oladosu I.A. (2021) Amide alkaloids from *Piper guineense* and its crude extract as protectants against *Sitophilus zeamais*. *Journal of Plant Diseases and Protection*, https://doi.org/10.1007/s41348-41021-00518-y.

18. Akinyemi A.O., *Subramanian S.*, *Mfuti D.K.*, Pope T.W., *Tamiru A.* and Kirk W.D.K. (2021) Mating behaviour, mate choice and female resistance in the bean flower thrips (*Megalurothrips sjostedti*). *Scientific Reports* 11, 14504. https://doi.org/14510.11038/s41598-14021-93891-14505.

19. *Akutse K.S.*, *Subramanian S.*, *Maniania N.K.*, *Dubois T.* and *Ekesi S.* (2020) Biopesticide research and product development in Africa for sustainable agriculture and food security – Experiences from the International Centre of Insect Physiology and Ecology (*icipe*). *Frontiers in Sustainable Food Systems* 4, Article563016. https://doi.org/563010.563389/fsufs.562020.563016.

20. *Alfonce L.*, *Egonyu J.P.*, *Tanga C.M.*, Kyamanywa S., *Tonnang H.E.Z.*, *Azrag A.G.A.*, *Khamis F.M.*, *Ekesi S.* and *Subramanian S.* (2021) Predicting the current and future distribution of the edible long-horned grasshopper *Ruspolia differens* (Serville) using temperature-dependent phenology models. *Journal of Thermal Biology* 95, 102786. https://doi.org/102710.101016/j.jtherbio.102020.102786.

21. *Alfredy T.*, Elisadiki J. and Jande Y.A.C. (2021) Review article: Capacitive deionization: a promising technology for water defluoridation: a review. *Water Supply*, doi: 10.2166/ws.2021.2287. https://doi.org/2110.2166/WS.2021.2287.

22. *Antwi-Agyakwa A.K.*, Yusuf A.A., Pirk C., *Mohamed S.A.*, *Ekesi S.* and *Torto B.* (2021) Exploring non-host plant-based management strategy with lemongrass, garlic and guava volatiles for the African citrus triozid. *Journal of Applied Entomology*, https://doi.org/10.1111/jen.12884.

23. *Anyega A.O.*, Korir N.K., *Beesigamukama D.*, Changeh G.J., *Nkoba K.*, *Subramanian S.*, van Loon J.J.A., Dicke M. and *Tanga C.M.* (2021) Black soldier fly-composted organic fertilizer enhances growth, yield, and nutrient quality of three key vegetable crops in sub-Saharan Africa. *Frontiers in Plant Science* 12, 680312. doi: 680310.683389/fpls.682021.680312.

24. *Asale A.*, *Abro Z., Enchalew B., Teshager A., Belay A.*, *Kassie M.*, and *Mutero C.M.* (2021) Community knowledge, perceptions, and practices regarding malaria and its control in Jabi Tehnan district, Amhara Region, Northwest Ethiopia. *Malaria Journal*. 20: 459. https://doi.org/10.1186/s12936-021-03996-5.

25. Ashraf H.J., *Akutse K.S.*, Mukhtar I., Ramos Aguila L.C., Qasim M., Wang W., Bamisile B.S. and Wang L. (2021) Genetic diversity of *Tamarixia radiata* populations and their associated endosymbiont *Wolbachia* species from China. *Agronomy* 11, 2018. https://doi.org/2010.3390/agronomy11102018.

26. Atemkeng C.C., Tapimo R., Kamdem H.T.T., Tchinda, R. and *Tonnang Z.E.H.* (2021) Radiative transfer technique for retrieving the radiative properties of agricultural soils, *Journal of Quantitative Spectroscopy and Radiative Transfer* 269. https://doi.org/10.1016/j.jqsrt.2021.107698.

27. *Ayelo P.M.*, *Mohamed S.A.*, Chailleux A., Yusuf A.A., Pirk C. and *Deletre E.* (2021) The parasitoid *Dolichogenidea gelechiidivoris* eavesdrops on semiochemicals from its host *Tuta absoluta* and tomato. *Journal of Pest Science*, https://doi.org/10.1007/s10340-10021-01424-w.

28. *Ayelo P.M.*, Pirk C.W.W., Yusuf A.A., Chailleux A., *Mohamed S.A.* and *Deletre E.* (2021) Exploring the kairomone-based foraging behaviour of natural enemies to enhance biological control: A review. *Frontiers in Ecology and Evolution* 9, 641974. https://doi.org/641910.643389/fevo.642021.641974.

29. *Ayelo P.M.*, Yusuf A.A., Pirk C.W.W., Chailleux A., *Mohamed S.* and *Deletre E.* (2021) Terpenes from herbivore-induced tomato plant volatiles attract *Nesidiocoris tenuis* (Hemiptera: Miridae), a predator of major tomato pests. *Pest Management Science*. https://doi.org/10.1002/ps.6568.

30. *Ayelo P.M.*, Yusuf A.A., Pirk C.W.W., *Mohamed S.A.*, Chailleux A. and *Deletre E.* (2021) The role of *Trialeurodes vaporariorum*-infested tomato plant volatiles in the attraction of *Encarsia formosa* (Hymenoptera: Aphelinidae). *Journal of Chemical Ecology*. https://doi.org/10.1007/s10886-10021-01245-10882.

31. *Baleba S.B.S.*, *Agbessenou A.*, *Getahun M.N.*, *Akutse K.S.*, *Subramanian S.* and *Masiga D.* (2021) Infection of the stable fly, *Stomoxys calcitrans*, L. 1758 (Diptera: Muscidae) by the entomopathogenic fungi *Metarhizium anisopliae* (Hypocreales: Clavicipitaceae) negatively affects Its survival, feeding propensity, fecundity, fertility, and fitness parameters. *Frontiers in Fungal Biology* 2, 637817. https://doi.org/637810.633389/ffunb.632021.637817.

32. Bamisile B.S., *Akutse K.S.*, Siddiqui J.A. and Xu Y. (2021) Model application of entomopathogenic fungi as alternatives to chemical pesticides: Prospects, challenges, and insights for next-generation sustainable agriculture. *Frontiers in Plant Science* 12, 741804. https://doi.org/741810.743389/fpls.742021.741804.

33. Bamisile B.S., Siddiqui J.A., *Akutse K.S.*, Ramos Aguila L.C. and Xu Y. (2021) General limitations to endophytic entomopathogenic fungi use as plant growth promoters, pests and pathogens biocontrol agents. *Plants (Basel)* 10, 2119. https://doi.org/2110.3390/plants10102119.

34. *Bargul J.L., Kidambasi K.O., Getahun M.N., Villinger J., Copeland R.S., Muema J.M.,* Carrington M. and *Masiga D.K.* (2021) Transmission of '*Candidatus* Anaplasma camelii' to mice and rabbits by camel-specific keds, *Hippobosca camelina. PLoS Neglected Tropical Diseases* 16;15(8):e0009671. https://doi.org/10.1371/journal.pntd.0009671.

35. Bateman M. L., Day R. K., *Rwomushana I.*, *Subramanian S.*, Wilson K., Babendreier D., Luke B. and Edgington S. (2021) Rapid communication: Updated assessment of potential biopesticide options for managing fall armyworm (*Spodoptera frugiperda*) in Africa. *Journal of Applied Entomology* 145, 384–393. https://doi.org/310.1111/jen.12856.

36. *Beesigamukama D.*, Mochoge B, Korir N.K., *Fiaboe K.K.M.*, Nakimbugwe D., *Khamis F.M.*, *Subramanian S.*, *Musyoka M.W.*, *Dubois T.*, *Ekesi S.* and *Tanga C.M.* (2021) Low-cost technology for recycling agro-industrial waste into nutrient-rich organic fertilizer using black soldier fly. *Waste Management* 119, 183–194. https://doi.org/110.1016/j.wasman.2020.1009.1043.

37. *Beesigamukama D.*, Mochoge B., Korir N., Ghemoh C.J., *Subramanian S.* and *Tanga C.M.* (2021) *In situ* nitrogen mineralization and nutrient release by soil amended with black soldier fly frass fertilizer. *Scientific Reports* 11, 14799. https://doi.org/14710.11038/s41598-14021-94269-14793.

38. *Beesigamukama D.*, Mochoge B., Korir N., *Menale K.*, *Muriithi B.*, *Kidoido M.*, *Kirscht H.*, *Diiro G.*, Ghemoh C.J., *Subramanian S.*, *Nakimbugwe D.*, *Musyoka M.W.*, *Ekesi S.* and *Tanga C.M.* (2021) Economic and ecological values of frass fertiliser from black soldier fly agro-industrial waste processing. *Journal of Insects asFood and Feed.* https://doi.org/10.3920/JIFF2021.0013.

39. Blomme G., *Dusingizimana P.*, Ntamwira J., Kearsley E., Gaidashova S., Rietveld A., van Schagen B. and Ocimati W. (2021) Comparing effectiveness, cost- and time-efficiency of control options for *Xanthomonas* wilt of banana under Rwandan agro-ecological conditions. *European Journal of Plant Pathology* 160, 487–501. https://doi.org/410.1007/s10658-10021-02258-z.

40. *Bokore G.E.*, Svenberg L., *Tamre R.*, Onyango P., *Bukhari T.*, Emmer A. and *Fillinger U.* (2021) Grass-like plants release general volatile cues attractive for gravid *Anopheles gambiae* sensu stricto mosquitoes. *Parasites and Vectors* 14, 552. https://doi.org/510.1186/s13071-13021-04939-13074.

41. Bossert S., Wood T.J., Patiny S., Michez D., Almeida E.A.B., Minckley R.L.R., Packer L., Neff J., *Copeland R.*, Straka J., Pauly A., Griswold T., Brady S., Danforth B., and Murray E. (2021) Phylogeny, biogeography and diversification of the mining beefamily Andrenidae. *Systematic Entomology*, 1–20. https://doi.org/10.1111/syen.12530.

42. Byliole S., Djouda, Frank T., Ndjomatchoua F.M., Moukam K., Tchawoua C., and *Tonnang Z.E.H.* (2021) Understanding biological control with entomopathogenic fungi—Insights from a stochastic pest–pathogen model. *Chaos* 31, 023126. https://doi.org/10.1063/5.0019971.

43. Cerveira A.M. and *Jackson R.R.* (2021) Inter-population variation and phenotypic plasticity in kairomone use by a poly-specialist spider-eating predator. *Journal of Ethology*, https://doi.org/10.1007/s10164-10021-00725-y.

44. Cerveira A.M., Nelson X.J. and *Jackson R.R.* (2021) Spatial acuity-sensitivity trade-off in the principal eyes of a jumping spider: possible adaptations to a 'blended' lifestyle. *Journal of Comparative Physiology A* 207, 437–448. https://doi.org/410.1007/s00359-00021-01486-00352.

45. Channumsin M., Ciosi M., *Masiga D.*, Auty H., Turner C.M., Kilbride E. and Mable B.K. (2021) Blood meal analysis of tsetse flies (*Glossina pallidipes*: Glossinidae) reveals higher host fidelity on wild compared withdomestic hosts. *Wellcome Open Research* 6, 213. https://doi.org/210.12688/wellcomeopenres.16978.12681.

46. *Chebet O.N.*, Omosa L.K., *Subramanian S.*, Nchiozem-Ngnitedem V.-A., Mmari J.O. and *Akutse K.S.* (2021) Mechanism of action of endophytic fungi *Hypocrea lixii* and *Beauveria bassiana* in *Phaseolus vulgaris* asbiopesticides against pea leafminer and fall armyworm. *Molecules* 26, 5694. https://doi.org/5610.3390/molecules26185694.

47. Chemura, A., *Mudereri, B.T.*, Yalew, A.W., Gornott, C., (2021). Climate Change and Specialty Coffee Potential in Ethiopia. *Scientific Reports* 11 (1). https://doi.org/10.1038/s41598-021-87647-4.

48. Chen J., Saqib H.S.A., *Akutse K.S.*, Yang F., Wu X., Xia X., Wang L., Goettel M.S., You M. and Gurr G.M. (2021) Drivers of the taxonomic and functional diversity, and functional composition of fungal endophyte communities in crucifers. *Sydowia 74*, 143 – 152. https://doi.org/10.12905/0380.sydowia74-2021-0143.

49. *Chepchirchir F., Muriithi B.W.*, Langat J., *Mohamed S.A., Ndlela S.*, and *Khamis F.M.* (2021). Knowledge, attitude, and practices on tomato leaf miner, *Tuta absoluta*, on tomato and potential demand for integrated pest management among smallholder farmers in Kenya and Uganda. *Agriculture* 11(12), 1242. https://doi.org/10.3390/agriculture11121242.

50. *Cheruiyot D.*, *Chiriboga X.M.*, *Chidawanyika F.*, Bruce T.J.A. and *Khan Z.R.* (2021) Potential roles of selected forage grasses in management of fall armyworm (*Spodoptera frugiperda*) through companion cropping. *Entomologia Experimentalis et Applicata.* https://doi.org/10.1111/eea.13083.

51. *Chia S.Y.*, *Tanga C.M.*, *Osuga I.M.*, Alaru A.O., Mwangi D.M., Githinji M., *Dubois T.*, *Ekesi S.*, Van Loon J.J.A. and Dicke M. (2021) Black soldier fly larval meal in feed enhances growth performance, carcass yield and meat quality of finishing pigs. *Journal of Insects as Food and Feed.* https://doi.org/10.3920/JIFF2020.0072.

52. Chikowore G., Martin G.D. and *Chidawanyika F.* (2021) An assessment of the invasive alien tree, *Robinia pseudoacacia* canopy traits and its effect on grassland microclimates and subsequent arthropod assemblages. *Journal of Insect Conservation* 25, 429-439. https://doi.org/410.1007/s10841-10021-00311-10840.
53. Chikowore G., Mutamiswa R., Sutton G.F., *Chidawanyika F.* and Martin G.D. (2021) Reduction of grazing index in high elevation grasslands following black locust invasion in South Africa. *Rangeland Ecology and Management* 76, 109-117. https://doi.org/10.1016/j.rama.2021.02.006.
54. Chikowore G., Steenhuisen S., Mutamiswa R., Martin G.D. and *Chidawanyika F.* (2021) Integration of invasive tree, black locust, into agro-ecological flower visitor networks induces competition for pollination services. *Arthropod-Plant Interactions*, https://doi.org/10.1007/s11829-11021-09851-11823.
55. *Chiriboga Morales X.*, *Tamiru A.*, Sobhy I.S., Bruce T.J. A., *Midega C.A.O.* and *Khan Z.* (2021) Evaluation of African maize cultivars for resistance to fall armyworm *Spodoptera frugiperda* (J.E.Smith) (Lepidoptera: Noctuidae) larvae. *Plants (Basel)* 10, 392. https://doi.org/310.3390/plants10020392.
56. *Chiuya T.*, *Masiga D.*, Falzon L., Bastos A, Fevre E. and *Villinger J.* (2021) Tick-borne pathogens, including Crimean-Congo haemorrhagic fever virus, at livestock markets and slaughterhouses in western Kenya. *Transboundary and Emerging Diseases* 68, 2429–2445. https://doi.org/2410.1111/tbed.13911.
57. *Chiuya T.*, *Masiga D.K.*, Falzon L.C., Bastos A.D.S., Fèvre E.M. and *Villinger J.* (2021) A survey of mosquito-borne and insect-specific viruses in hospitals and livestock markets in western Kenya. *PLoS ONE* 16, e0252369. https://doi.org/0252310.0251371/journal.pone.0252369.
58. *Chiuya T., Villinger J., Masiga D.K., Ondifu D.O.*, Murungi M.K., Wambua L., Bastos A.D.S, Fèvre E.M. and Falzon L.C. (2021) Molecular prevalence and risk factors associated with tick-borne pathogens in cattle in western Kenya. *BMC Veterinary Research* 17(1):363. https://doi.org/10.1186/s12917-021-03074-7.
59. *Copeland R.S.*, Mekonnen B. and Delvare G. 2021. Parasitisation of weaver ants by Smicromorpha Girault species (Hymenoptera: Chalcididae: Smicromorphinae) and unequivocal evidence of its presence in the Afrotropical region. Proceedings of the Entomological Society of Washington.
60. *Cross F.R.* and *Jackson R.R.* (2021) Odour priming of a mosquito-specialist predator's vision-based detouring decisions. *Biochemical and Biophysical Research Communications*. https://doi.org/10.1016/j.bbrc.2020.1012.1005.
61. Cuesta E.B., Coulibaly B., *Bukhari T.*, Eiglmeier K., Kone R., Coulibaly M.B., Zongo S., Barry M., Gneme A., Guelbeogo W.M., Beavogui A.H., Traore S.F., Sagnon N., Vernick K.D. and Riehle M.M. (2021) Comprehensive ecological and geographic characterization of eukaryotic and prokaryotic microbiomes in African *Anopheles*. *Frontiers in Microbiology* 12, 635772. https://doi.org/635710.633389/fmicb.632021.635772.
62. Denz A., *Njoroge M.M.*, Tambwe M.M., Champagne C., Okumu F., Van Loon J.J.A., Hiscox A., Saddler A., *Fillinger U.*, Moore S.J. and Chitnis N. (2021) Predicting the impact of outdoor vector control interventions on malaria transmission intensity from semi-field studies. *Parasites and Vectors* 14, 64. https://doi.org/10.1186/s13071-13020-04560-x.
63. *Diabate S.*, *Martin T.*, Murungi L.K., Fiaboe K.K.M., Wesonga J., Kimani J. M. and *Deletre E.* (2021) Push-pull strategy combined with net houses for controlling cowpea insect pests and enhancing crop yields. *Crop Protection* 141, 105480. https://doi.org/105410.101016/j.cropro.102020.105480.
64. *Diallo S.*, Shahbaaz M., *Makwatta J.O.*, *Muema J.M.*, *Masiga D.*, Christofells A. and *Getahun M.N.* (2021) Antennal enriched odorant binding proteins are required for odor communication in *Glossina f. fuscipes*. *Biomolecules* 11, 541. https://doi.org/510.3390/biom11040541.
65. *Diarra H., Makhulu E.E., Odhiambo P.O.*, Irekwa R.M., Kinyua J., *Herren J.K.* and Mobegi V.A. (2021) Molecular investigation of genetic signatures of selection in *Plasmodium falciparum* actin-binding protein coronin, cysteine desulfurase, and plasmepsin 2 gene in Mbita field isolates, Western Kenya. *Open Journal of Genetics* 11, 120-144. https://doi.org/10.4236/ojgen.2021.114011.
66. Dicks L.V., Breeze T.D., Ngo H.T., Senapathi D., An J., Aizen M.A., Basu P., Buchori D., Galetto L., Garibaldi L.A., Gemmill-Herren B., Howlett B.G., Imperatriz-Fonseca V.L., Johnson S.D., Kovács-Hostyánszki A., Kwon Y.J., *Lattorff H.M.G.*, Lungharwo T., Seymour C.L., Vanbergen A.J. and Potts S.G. (2021) A global-scale expert assessment of drivers and risks associated with pollinator decline. *Nature Ecology and Evolution* 5, 1453-1461. https://doi.org/10.1038/s41559-41021-01534-41559.
67. *Diiro G.M.*, *Fisher M.*, *Kassie M.*, *Muriithi B.W.* and *Muricho G.* (2021) How does adoption of labor saving agricultural technologies affect intrahousehold resource allocations? The case of push-pull technology in Western Kenya. *Food Policy* 102, 102114. https://doi.org/102110.101016/j.foodpol.102021.102114.
68. Dongmo K. Michel A, Fiaboe K.K.M., Kekeunou S., Nanga Nanga S., Fotso Kuate A., *Tonnang Z.E.H.*, Gnanvossou D. and Hanna R. (2021). Temperature-based phenology model to predict the development, survival, and reproduction of the oriental fruit fly. *Bactrocera dorsalis*. *Journal of Thermal Biology*. https://doi.org/10.1016/j.jtherbio.2021.102877.
69. Drinkwater L.E., *Midega C.A.O., Awuor R., Nyagol D.* and *Khan Z.R.* (2021). Perennial legume intercrops provide multiple belowground ecosystem services in smallholder farming systems. *Agriculture, Ecosystems and Environment* 320, 107566. https://doi.org/10.1016/j.agee.2021.107566

70. Drosopoulou E., Damaskou A., Markou A., *Ekesi S.*, *Khamis F.*, Manrakhan A., Augustinos A.A., Tsiamis G. and Bourtzis K. (2021) The complete mitochondrial genomes of *Ceratitis rosa* and *Ceratitis quilicii*, members of the *Ceratitis* FAR species complex (Diptera: Tephritidae). *Mitochondrial DNA Part B* 6, 1039–1041. https://doi.org/1010.1080/23802359.23802021.21899073.

71. *Ebhodaghe F.*, Bastos A.D.S., *Kidambasi K.O.*, *Kalayou S.*, *Masiga D.* and *Okal M.* (2021) Molecular characterization of *Trypanosoma vivax* in tsetse flies confirms the presence of the virulent *Tvv4* genotype in Kenya: Potential implications for the control of trypanosomiasis in Shimba Hills. *Infection, Genetics and Evolution* 93, 104953. https://doi.org/104910.101016/j.meegid.102021.104953.

72. *Ebhodaghe F.I, Okal M.N., Kalayou S.*, Bastos A.D.S. and *Masiga D.K.* (2021) Tsetse bloodmeal analyses incriminate the common warthog *Phacochoerus africanus* as an important cryptic host of animal trypanosomes in smallholder cattle farming communities in Shimba Hills, Kenya. *Pathogens* 18;10(11):1501. https://doi.org/10.3390/pathogens10111501.

73. *Egonyu J.P.*, Gitonga K.J., *Khamis F.M.*, *Copeland R.S.*, *Finyange P.*, Odhiambo R., Ddamulira G., *Tanga C.M.* and *Subramanian S.* (2021) Trapping, identification and rearing of edible palm weevils in Kenya and Uganda. *Journal of Insects as Food and Feed*, https://doi.org/10.3920/JIFF2021.0018.

74. *Egonyu J.P.,* Kinyuru J., *Fombong F.T.*, *Ng'ang'a J.*, *Ahmed Y.A.* and *Niassy S.* (2021) Editorial: Advances in insects for food and feed *International Journal of Tropical Insect Science* 41, 1903–1911. https://doi.org/1910.1007/s42690-42021-00610-42698.

75. Egonyu J.P., Miti M.M., Tanga M.C., and Subramanian S. (2021). Cannibalism, oviposition and egg development in the edible long-horned grasshopper, *Ruspolia differens* (Orthoptera: Tettigoniidae) under laboratory conditions. *Journal of Insects as Food and Feed* 7(1): 89-97. https://doi.org/10.3920/JIFF2020.0018.

76. *Egonyu J.P.*, *Sisye S.E.*, *Baguma J.*, Otema M. and Ddamulira G. (2021) Insect flower-visitors of African oil palm *Elaeis guineensis* Jacquin (Arecales: Arecaceae) at different sites and distances from natural vegetation in Uganda. *International Journal of Tropical Insect Science*, https://doi.org/10.1007/s42690-42021-00426-42696.

77. *Egonyu J.P.*, *Subramanian S.*, *Tanga C.M.*, *Dubois T.*, *Ekesi S.* and *Kelemu S.* (2021) Global overview of locusts as food, feed and other uses. *Global Food Security* 31, 100574. https://doi.org/10.1016/j.gfs.2021.100574

78. Faye P.D., Bal A. B., Ndiaye N.M., Diop F., Sangare Y.K., Haddad C., Coly E.M., Dieng E.O. and *Niassy S.* (2021) Field efficacy of *Metarhizium acridum* (Hypocreales: Clavicipitaceae) in the control of *Bactrocera dorsalis* (Diptera: Tephritidae) in citrus orchards in Senegal. *International Journal of Tropical Insect Science* 41, 1185–1195. https://doi.org/1110.1007/s42690-42020-00306-42695.

79. *Fite T.*, Damte T., *Tefera T.* and Mulugeta N. (2021) Brief report: Hymenopteran and dipteran larval parasitoids species of the cotton bollworm, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) in chickpea growing districts of Ethiopia. *Biocontrol Science and Technology* 31, 541–545. https://doi.org/510.1080/09583157.09582020.01859096.

80. *Fombong F.T.*, Kinyuru J., Ngang'a J., Ayieko M., *Tanga C.M.*, Vanden Broeck J. and *Van Der Borght M.* (2021) Affordable processing of edible orthopterans provides a highly nutritive source of food ingredients. *Foods* 10, 144. https://doi.org/110.3390/foods10010144.

81. *Gachoki S.*, Groen T., Vrieling A., *Okal M.*, Skidmore A. and *Masiga D.* (2021) Satellite-based modelling of potential tsetse (*Glossina pallidipes*) breeding and foraging sites using teneral and non-teneral fly occurrence data. *Parasites and Vectors* 28;14(1):506. https://doi.org/10.1186/s13071-021-05017-5.

82. *Gahamanyi N.*, Munyaneza E., Dukuzimana E., Tuyiringire N., Pan C.-H. and Komba E. V.G. (2021) Review: Ethnobotany, ethnopharmacology, and phytochemistry of medicinal plants used for treating human diarrheal cases in Rwanda: A review. *Antibiotics* 10, 1231. https://doi.org/1210.3390/antibiotics10101231

83. *Gahamanyi N.*, Song D.-G., Yoon K.-Y., Mboera L.E.G., Matee M.I., Mutangana D., Amachawadi R.G., Komba E.V.G. and Pan C.-H. (2021) Antimicrobial resistance profiles, virulence genes, and genetic diversity of thermophilic *Campylobacter* species isolated from a layer poultry farm in Korea. *Frontiers in Microbiology*, https://doi.org/10.3389/fmicb.2021.622275.

84. *Gahamanyi N.*, Song D.-G., Yoon K.-Y., Mboera L.E.G., Matee M.I., Mutangana D., Komba E.V.G., Pan C.-H. and Amachawadi R.G. (2021) Genomic characterization of fluoroquinolone-resistant thermophilic *Campylobacter* strains isolated from layer chicken feces in Gangneung, South Korea by whole-genome sequencing. *Genes* 12, 1131. https://doi.org/1110.3390/genes12081131.

85. *Ganatra A.*, *Kandie F.J.*, *Fillinger U.*, *McOdimba F.*, *Torto B.*, Brack W., Liess M., Hollert H. and Becker J.M. (2021) Calibration of the SPEARpesticides bioindicator for cost-effective pesticide monitoring in East African streams. *Environmental Sciences Europe* 33, 58. https://doi.org/10.1186/s12302-12021-00497-12309.

86. *Gashururu R.S.*, Githigia S.M.., Gasana M.N., Habimana R., Maingi N., Cecchi G., Paone M., Zhao W., *Masiga D.K.* and Gashumba J. (2021) An update on the distribution of *Glossina* (tsetse flies) at the wildlife-human-livestock interface of Akagera National Park, Rwanda. *Parasites and Vectors* 14(1):294. https://doi.org/10.1186/s13071-021-04786-3.

87. *Gashururu S.R.*, Maingi N., Githigia S.M., Gasana M.N., *Odhiambo P.O.*, *Getange D.O.*, Habimana R., Cecchi G., Zhao W., Gashumba J., *Bargul J.L.* and *Masiga D.K.* (2021) Occurrence, diversity and distribution of Trypanosoma infections in cattle around the Akagera National Park, Rwanda. *PLoS Neglected Tropical Diseases* 15;15(12):e0009929. https://doi.org/10.1371/journal.pntd.0009929.

88. Gebresamuel G., *Abrha H*., Hagos H., Elias E. and Haile M. (2021) Empirical modeling of the impact of climate change on altitudinal shift of major cereal crops in South Tigray, Northern Ethiopia. *Journal of Crop Improvement*, https://doi.org/10.1080/15427528.15422021.11931608.

89. *Getaneh G*., *Tefera T*., Lemessa F., Ahmed S. and *Villinger J*. (2021) Distribution and mating type characterization of chickpea blight (*Didymella rabiei* (Kov.) v. Arx) in Ethiopia. *Current Plant Biology* 28,100220. https://doi.org/10.1016/j.cpb.2021.100220.

90. *Getaneh G., Tefera T*., Lemessa F., *Ahmed S., Fite T*. and *Villinger J*. (2021). Genetic diversity and population structure of *Didymella rabiei* affecting chickpea in Ethiopia. *Journal of Fungi*, 7(10), 820. https://doi.org/10.3390/jof7100820.

91. *Getange D., Bargul J.L*., Kanduma E., Collins M., Bodha B., Denge D., *Chiuya T.,* Githaka N., Younan M., Fèvre E.M., Bell-Sakyi L. and *Villinger J*. (2021) Ticks and tick-borne pathogens associated with dromedary camels (Camelus dromedarius) in northern Kenya. *Microorganisms* 9(7):1414. https://doi.org/10.3390/microorganisms9071414.

92. Girma H., Ochatum N., Nyeko P., *Niassy S*. (2020) Farmers' experience in termite management in Eastern Uganda. *International Journal of Agricultural Extension* 08 (03) 149-162. https://doi.org/1033687/ijae.008.03.3261.

93. Gugliuzzo A., Biedermann P.H.W., Carrillo D., Castrillo L. A., *Egonyu J.P*., Gallego D., Haddi K., Hulcr J., Jactel H., Kajimura H., Kamata N., Meurisse N.S., Li Y., Oliver J.B., Ranger C.M., Rassati D., Stelinski L.L., Sutherland R., Garzia G.T., Wright M.G. and Biondi A. (2021) Recent advances toward the sustainable management of invasive *Xylosandrus ambrosia* beetles. *Journal of Pest Science*, https://doi.org/10.1007/s10340-10021-01382-10343.

94. *Habinshuti J. B*., Munganyinka J. P., Adetunji A. R., Mishra B., Ofori-Sarpong G., Komadja G. C., Tanvar H., Mukiza J. and Onwualu A. P. (2021) Mineralogical and physical studies of low-grade tantalum-tin ores from selected areas of Rwanda. *Results in Engineering* 11, 100248. https://doi.org/100210.101016/J.RINENG.102021.100248.

95. *Hailu G*., *Niassy S*., Bässler T., Ochatum N., Christoph S., *Salifu D*., Agbodzavu M.K., *Khan Z.R*., *Midega C*. and *Subramanian S*. (2021) Could fall armyworm, *Spodoptera frugiperda*. (J. E. Smith) invasion in Africa be displacing cereal stemborers in maize and sorghum cropping systems? *International Journal of Tropical Insect Science*. https://doi.org/10.1007/s42690-42020-00381-42698.

96. *Hailu G*., *Ochatum N*., Nyeko P. and *Niassy S*. (2020) Farmer's knowledge of termite species and infestation in eastern Uganda. *International Journal of Agricultural Extension* 08 149–162. https://doi.org/110.33687/ijae.33008.33603.33261.

97. *Hakizimana J.N*., Ntirandekura J. B., Yona C., Nyabongo L., Kamwendo G., Chulu J.L.C., Ntakirutimana D., Kamana O., Nauwynck H. and Misinzo G. (2021) Complete genome analysis of African swine fever virus responsible for outbreaks in domestic pigs in 2018 in Burundi and 2019 in Malawi. *Tropical Animal Health and Production* 53, 438. https://doi.org/410.1007/S11250-11021-02877-Y.

98. *Hakizimana J.N*., Yona C., Kamana O., Nauwynck H. and Misinzo G. (2021) *African swine fever virus* circulation between Tanzania and neighboring countries: A systematic review and meta-analysis. *Viruses* 13, 306. https://doi.org/310.3390/v13020306.

99. *Hassaballa I. B*., *Matoke-Muhia D*., *Masiga D. K*., Sole C. L., *Torto B*. and *Tchouassi D.P*. (2021) Behavioural responses of *Phlebotomus duboscqi t*o plant-derived volatile organic compounds. *Medical and Veterinary Entomology*. https://doi.org/10.1111/mve.12541.

100. *Hassaballa I.B*., Sole C.L., *Cheseto X*., *Torto B*. and *Tchouassi D.P*. (2021) Afrotropical sand fly–host plant relationships in a leishmaniasis endemic area, Kenya. *PLoS Neglected Tropical Diseases* 15, e0009041. https://doi.org/0009010.0001371/journal.pntd.0009041.

101. *Hassaballa I.B*., *Torto B*., Sole C.L. and *Tchouassi D.P*. (2021) Exploring the influence of different habitats and their volatile chemistry in modulating sand fly population structure in a leishmaniasis endemic foci, Kenya. *PLoS Neglected Tropical Diseases* 15, e0009062. https://doi.org/0009010.0001371/journal.pntd.0009062.

102. *Hiroyoshi S*., Mitsunaga T., Ganaha-Kikumura T. and Reddy G.V.P. (2021) Effects of age, phase variation and pheromones on male sperm storage in the desert locust, *Schistocerca gregaria*. *Insects* 12, 642. https://doi.org/610.3390/insects12070642.

103. Howard M.M., Bass E., Chautá A., *Mutyambai D*. and Kessler A. (2021) Integrating plant-to-plant communication and rhizosphere microbial dynamics: Ecological and evolutionary implications and a call for experimental rigor. *The ISME Journal*, https://doi.org/10.1038/s41396-41021-01063-41390.

104. Huss M., Brander M., *Kassie M*., Ehlert U. and Bernauer T. (2021) Improved storage mitigates vulnerability to food-supply shocks in smallholder agriculture during the COVID-19 pandemic. *Global Food Security* 28, 100468. https://doi.org/10.1016/j.gfs.2020.100468.

105. Ichwani R., *Koech R*., Oyewole O.K., Huda A., Oyewole D.O., Cromwell J., Martin J. L., Grimm R.L. and Soboyejo W.O. (2021) Interfacial fracture of hybrid organic-inorganic perovskite solar cells. *Extreme Mechanics Letters*. 101515. https://doi.org/10.1016/j.eml.2021.101515.

106. Idrees A., Qadir Z.A., *Akutse K.S.*, Afzal A., Hussain M., Islam W., Waqas M.S., Bamisile B.S. and Li J. (2021) Effectiveness of entomopathogenic fungi on immature stages and and feeding performance of fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) larvae. *Insects* 12, 1044. https://doi.org/1010.3390/insects12111044.

107. Idriss G.E.A., Duplessis H., *Khamis F.*, *Ekesi S.*, *Tanga C.M.* and *Mohamed S.F.* (2020) Host range and effects of plant species on preference and fitness of *Tuta absoluta* (Lepidoptera: Gelechiidae). *Journal of Economic Entomology* 113, 1279–1289. https://doi.org/1210.1093/jee/toaa1002.

108. Igiehone N.O., Babalola O.O., *Cheseto X.* and *Torto B.* (2021) Effects of rhizobia and arbuscular mycorrhizal fungi on yield, size distribution and fatty acid of soybean seeds grown under drought stress. *Microbiological Research* 242, 126640. https://doi.org/126610.121016/j.micres.122020.126640.

109. Isebe T.I., *Bargul J.*, Njunge J.M., Gichuki B.M., Tuju J. and Rono M.K. (2021) Molecular characterization of *Plasmodium falciparum* PHISTb proteins as potential targets of naturally-acquired immunity against malaria. *Wellcome Open Research* 5, 136. https://doi.org/10.12688/wellcomeopenres.15919.2.

110. *Kalayou S., Okal M.N., Odhiambo P.O., Mathenge K.*, Gamba D.O., Kariuki E., McOdimba F. and *Masiga D.* (2021) Prevalence of trypanosome species in cattle near Ruma National Park, Lambwe Valley, Kenya: an update from the historical focus for African trypanosomosis. *Frontiers in Veterinary Science* 2;8:750169. https://doi.org/10.3389/fvets.2021.750169.

111. Kalee N. E., *Gahamanyi N.* and Hoza A. S. (2021) Prevalence and antimicrobial susceptibility profiles of *Staphylococcus aureus* from raw bovine milk in dairy and pastoral farms in Morogoro region, Tanzania. *German Journal of Veterinary Research* 1, 1–7. https://doi.org/10.51585/GJVR.52021.51582.50007.

112. *Kassie M.*, *Fisher M.*, Muricho G. and *Diiro G.* (2020) Women's empowerment boosts the gains in dietary diversity from agricultural technology adoption in rural Kenya. *Food Policy* 95, 101957. https://doi.org/101910.101016/j.foodpol.102020.101957.

113. Kaya C., Generalovic T.N., Ståhls G., Hauser M., Samayoa A.C., Nunes-Silva C.G., Roxburgh H., Wohlfahrt J., Ewusie E.A., Kenis M., Hanboonsong Y., Orozco J., Carrejo N., Nakamura S., Gasco L., Rojo S., *Tanga C.M.*, Meier R., Rhode C., Picard C.J., Jiggins C.D., Leiber F., Tomberlin J.K., Hasselmann M., Blanckenhorn W.U., Kapun M. and Sandrock C. (2021) Global population genetic structure and demographic trajectories of the black soldier fly, *Hermetia illucens*. *BMC Biology* 19, 94. https://doi.org/10.1186/s12915-12021-01029-w.

114. *Khamis F.M.*, *Ombura F.L.*, *Ajene I. J.*, *Akutse K.S.*, *Subramanian S.*, *Mohamed S.*, *Dubois T.*, *Tanga C.* and *Ekesi S.* (2021) Mitogenomic analysis of diversity of key whitefly pests in Kenya and its implication to their sustainable management. *Scientific Reports* 11, 6348. https://doi.org/6310.1038/s41598-41021-85902-41592.

115. *Kidane S.A.*, *Haukeland S.*, Meressa B.H., Hvoslef-Eide A.K. and Coyne D.L. (2021) Planting material of enset (*Ensete ventricosum*), a key food security crop in southwest Ethiopia, is a key element in the dissemination of plant-parasitic nematode infection. *Frontiers in Plant Science*. https://doi.org/10.3389/fpls.2021.664155.

116. Kidane S.A., Meressa B.H., *Haukeland S.*, Hvoslef-Eide A.K. and Coyne D.L. (2021) The Ethiopian staple food crop enset (*Ensete ventricosum*) assessed for the first time for resistance against the root lesion nematode *Pratylenchus goodeyi*. *Nematology*. https://doi.org/10.1163/15685411-bja15610075.

117. Kidane S.A., Meressa B.H., *Haukeland S.*, Hvoslef-Eide A.K., Magnusson C., Couvreur M., Bert W. and Coyne D.L. (2021) Occurrence of plant-parasitic nematodes on enset (*Ensete ventricosum*) in Ethiopia with focus on *Pratylenchus goodeyi* as a key species of the crop. *Nematology*, https://doi.org/10.1163/15685411-bja15610058.

118. *Kimenyi N.*, Kimenyi K., Amugune N., and *Getahun M.* (2021). Genetic connectivity of trypanosomes between tsetse-infested and tsetse-free areas of Kenya. *Parasitology* 1-13. https://doi.org/10.1017/S0031182021001815.

119. *Kinyanjui G.*, *Khamis F.M.*, *Ombura F.L.O.*, Kenya E.U., *Ekesi S.* and *Mohamed S.A.* (2021) Distribution, abundance and natural enemies of the invasive tomato leafminer, *Tuta absoluta* (Meyrick) in Kenya. *Bulletin of Entomological Research*. **https://doi.org/10.1017/S0007485321000304**.

120. *Kiriga A.W.,* Coyne D., Atandi J.G., Beek N.V. and *Haukeland S.* (2021) Diversity and population dynamics of plant parasitic nematodes in commercial and smallholder pineapple production in Kenya. *Nematology*. https://doi.org/10.1163/15685411-bja15610080.

121. Kirk-Spriggs A.H. and *Copeland R.S.* (2021) Mormotomyiidae (terrible hairy flies or frightful hairy flies) pp. 2231–2237. In Manual of Afrotropical Diptera. Brachycera—Cyclorrhapha, excluding Calyptratae. Suricata 8 (edited by Kirk-Spriggs A.H. and Sinclair B.J. (eds). South African National Biodiversity Institute Pretoria. Volume 3.

122. *Kisaakye J.*, Fourie H., Coyne D., Cortada L., *Masinde, S., Subramanian S.* and *Haukeland S.* (2021). Evaluation of the Entomopathogenic Potential of *Beauveria bassiana, Metarhizium anisopliae* and *Isaria fumosorosea* for management of *Cosmopolites sordidus* Germar (Coleoptera: Curculionidae). *Agriculture* 11, no. 12: 1290. https://doi.org/10.3390/agriculture11121290.

123. *Koech R.K.*, Ichwani R., Martin J.L., Oyewole D.O., Oyelade O.V., Olanrewaju Y.A., Sanni D.M., Adeniji S.A., Grimm R.L., Bello A., Oyewole O.K., Ntsoenzok E. and Soboyejo W.O. (2021) A study of the effects of a thermally evaporated nanoscale CsBr layer on the optoelectronic properties and stability of formamidinium-rich perovskite solar cells. *AIP Advances* 11, 095112. https://doi.org/095110.091063/095115.0064398.

124. *Koech R.*K., Ichwani R., Oyewole D.O., Kigozi M., Amune D., Sanni D.M., Adeniji S.A., Oyewole O.K., Bello A., Ntsoenzok E., and Soboyejo W.O. (2021). Tin oxide modified titanium dioxide as electron transport layer in formamidinium-rich perovskite solar cells. *Energies* 14(23), 7870. https://doi.org/10.3390/EN14237870.

125. *Krausa K.*, Hager F.A. and Kirchner W.H. (2021) Guarding vibrations–*Axestotrigona ferruginea* produces vibrations when encountering non-nestmates. *Insects* 12, 395. https://doi.org/310.3390/insects12050395.

126. Krieger M.G.M., Wenham C., Nacif Pimenta D., *Nkya T.*, Schall B., Nunes A.C., De Menezes A. and Lotta G. (2021) How do community health workers institutionalise: an analysis of Brazil's CHW programme. *Global Public Health*, https://doi.org/10.1080/17441692.17442021.11940236.

127. Krueger J.S. and *Mutyambai D.M.* (2020) Restricting pesticides on a traditional crop: The example of khat (*Catha edulis)* and the Njuri Ncheke of Meru, Kenya. *Ecology and Society* 25, 24. https://doi.org/10.5751/ES-11916-250424.

128. Kuhn J.H., Adkins S., Alioto D., Alkhosky S.V., Amarasinghe G.K., Anthony S.J., Avšič-Županc T., Ayllón M.A., Bahl J., Balkema-Buschmann A., Ballinger M.J., Bartonička T., Basler C., Bavari S., Beer M., Bente D.A., Bergeron E., Bird B.H., Blair C, Blasdell K.R., Bradfute S.B., Breyda R., Briese T., Brown P.A., Buchholz U.J., Buchmeier E.J., Bukreyev A., Burt F., Buzkhan N., Calisher C.H., Cao M., Casas I., Chamberlain J., Chandran K., Charrel R.N., Chen B., Chiumenti M., Choi I.R., Clegg J.C.S., Crozier R., da Graça J.V., Dal Bó E., Dávila A.M.R., de la Torre J.C., de Lamballerie X., de Swart R.L., Di Bello P.L., Di Paola N., Di Serio F., Dietzgen R.G., Digiaro M., Dolja V.V., Dolnik O., Drebot M.A., Drexler J.F., Dürrwald R., Dufkova L., Dundon W.G., Duprex W.P., Dye J.M., Easton A.J., Ebihara H., Elbeaino T., Ergünay K., Fernandes J., Fooks A.R., Formenty P.B.H., Forth L.F., Fouchier R.A.M., Freitas-Astúa J., Gago-Zachert S., Gāo G.F., García M.L., García-Sastre A., Garrison A.R., Gbakima A., Goldstein T., Gonzalez J.-P.J., Griffiths A., Groschup M.H., Günther S., Guterres A., Hall R.A., Hammond J., Hassan M., Hepojoki J., Hepojoki S., Hetzel U., Hewson R., Hoffmann B., Hongo S., Höper D, Horie M., Hughes H.R., Hyndman T.H., Jambai A., Jardim R., Jiāng D., Jin Q., Jonson G.B., Junglen S., Karadağ S., Keller K.E., Klempa B., Klingström J., Kobinger G., Kondō H., Koonin E.V., Krupovic M., Kurath G., Kuzmin I.V., Laenen L., Lamb R.A., Lambert A.J., Langevin S.L., Lee B., Lemos E.R.S., Leroy E.L., Li D., Lǐ J., Liang M., Liú W., Liú Y., Lukashevich I.S., Maes P., Marciel de Souza W., Marklewitz M., Marshall S.H., Martelli G.P., Martin R.R., M. S.-Y. L., Massart S., McCauley J.W., Mielke-Ehret N., Minafra A., Minutolo M., Mirazimi A., Mühlbach H.-P., Mühlberger E., Naidu R., Natsuaki T., Navarro B., Navarro J.A., Netesov S.V., Neumann G., Nowotny N., Nunes M.R.T., Nylund A., Økland A.L., Oliveira R.C., Palacios G., Pallas V., Pályi B., Papa A., Parrish C.R., Pauvolid-Corrêa A., Pawęska J.T., Payne S., Pérez D.R., Pfaff F., Radoshitzky S.R., R. A.-u., Ramos-González P.L., Resende R.O., Reyes C.A., Rima B.K., Romanowski V., Robles Luna G., Rota P., Rubbenstroth D., Runstadler J.A., Ruzek D., Sabanadzovic S., Salát J., Sall A.A., Salvato M.S., *Sang R.*, Sarpkaya K., Sasaya T., Schwemmle M., Shabbir M.Z., Shí X., Shí Z., Shirako Y., Simmonds P., Širmarová J., Sironi M., Smither S., Smura T., Song J.-W., Spann K.M., Spengler J.R., Stenglein M.D., Stone D.M., Straková P., Takada A., Takeuchi S., Tchouassi D.P., Teffer A.,Tesh R.B., Thornburg N.J., Tomonaga K., Tordo N., *Torto B.,* Towner J.S., Turina M., Tzanetakis I., Ulrich R.G., Vaira A.M., van den Hoogen B., Varsani A., Vasilakis N., Verbeek M., Wahl V., Walker P.J., Wang H., Wang J., Wang X., Wang L.-F., Wèi T., Wells H., Whitfield A.E., Williams J.V., Wolf Y.I., Wú Z., Yang X., Yu X., Yutin N., Zerbini F.M., Zhang T., Zhang Y.-Z., Zhou G. and Zhou X. (2021) 2020 taxonomic update for phylum *Negarnaviricota (Riboviria: Orthornavirae)*, including the large orders *Bunyavirales* and *Mononegavirales*. *Archives of Virology* 165, 3023–3072. https://doi.org/3010.1007/s00705-00020-04731-00702.

129. *Kusia E.S.*, Borgemeister C., *Khamis F.M.*, *Copeland R.S.*, *Tanga C.M.*, *Ombura F.L.* and *Subramanian S.* (2021) Diversity, host plants and potential distribution of edible saturniid caterpillars in Kenya. *Insects* 12, 600, https://doi.org/610.3390/insects12070600.

130. *Kusia E.S.*, Borgemeister C., *Tanga C.M.*, *Ekesi S.* and *Subramanian S.* (2021) Exploring community knowledge, perception and practices of entomophagy in Kenya. *International Journal of Tropical Insect Science*, https://doi.org/10.1007/s42690-42021-00469-42699.

131. Kwadha C.A., *Okwaro L.A.*, Kleman I., Rehermann G.S.R., Revadi S., *Ndlela S.*, *Khamis F.M.*, *Nderitu P.*, Kasina M., Momanyi G.K., Kithusi G.G., *Mohamed S.A.*, *Lattorff H.M.G.* and Becher P.G. (2021) Detection of the spotted wing drosophila, *Drosophila suzukii*, in continental sub-Saharan Africa. *Journal of Pest Science 94: 251–259*, https://doi.org/10.1007/s10340-10021-01330-10341.

132. *Kyalo R.*, *Abdel-Rahman E.M.*, *Subramanian S.*, *Nyasani J. O.*, Thiel M., Jozani H.J., Borgemeister C., *Mudereri B.T.* and *Landmann T.* (2021) Estimating maize lethal necrosis (MLN) severity in Kenya using multispectral high-resolution data. *Applied Geomatics*. https://doi.org/10.1007/s12518-12021-00357-12514.

133. *Labu S.*, *Subramanian S.*, *Khamis F.*, Akite P., Kasangaki P., Chemurot M., *Tanga C.M.*, *Ombura L.* and *Egonyu J.P.* (2021) Microbial contaminants in wild harvested and traded edible long-horned grasshopper, *Ruspolia differens* (Orthoptera: Tettigoniidae) in Uganda. *Journal of Insects as Food and Feed*. https://doi.org/10.3920/JIFF2020.0069.

134. Lagat M.K., Were S., Ndwigah F., Kemboi V.J., Kipkoech C. and *M. Tanga C* (2021) Antimicrobial activity of chemically and biologically treated chitosan prepared from black soldier fly (*Hermetia illucens*) pupal shell waste. *Microorganisms* 9, 2417. https://doi.org/2410.3390/microorganisms9122417.

135. Lai B., Lin Y., *Akutse K.S.* and Dai R. (2021) *Paenibacillus polymyxa* causes yellow withered spot disease in *Dracaena trifasciata* in the South of China. *Australasian Plant Pathology*. https://doi.org/10.1007/s13313-13021-00808-x.

136. Lin Y., Huang J. and *Akutse K.S.* (2021) Whitefly-induced tomato volatiles enhance the virulence of *Lecanicillium lecanii*. *Journal of Invertebrate Pathology*, 107623. https://doi.org/107610.101016/j.jip.102021.107623.

137. *Magara H. J. O.*, *Mutyambai D.M.*, *Midega C.A.O.*, *Otieno S.A.*, *Nyaga T.M.*, *Niassy S.* and *Khan Z.R.* (2020) Responses of stemborer *Chilo partellus* to volatiles emitted by maize landraces exposed to signal grass (*Brachiria brizantha*). *Journal of Plant Interactions* 15, 345–357. https://doi.org/310.1080/17429145.17422020.11827056.

138. *Magara H.J.O.*, *Niassy S.*, Ayieko M.A., *Mukundamago M.*, *Egonyu J.P.*, *Tanga C.M.*, *Kimathi E.K.*, *Ongere J.O.*, Fiaboe K.K.M., Hugel S., Orinda M.A., Roos N. and *Ekesi S.* (2021) Review: Edible crickets (Orthoptera) around the world: Distribution, nutritional value, and other benefits—A review. *Frontiers in Nutrition* 7, 537915. https://doi.org/537910.533389/fnut.532020.537915.

139. Mahamat A.A., *Linda Bih N.*, Ayeni O., Azikiwe Onwualu P., Savastano H. and Oluwole Soboyejo W. (2021) Development of sustainable and eco-friendly materials from termite hill soil stabilized with cement for low-cost housing in Chad. *Buildings* 11, 86. https://doi.org/10.3390/buildings11030086.

140. *Maina S.*, Ryu D. H., Cho J. Y., Jung D. S., Park J.-E., Nho C. W., Bakari G., Misinzo G., Jung J. H., Yang S.-H. and Kim H.-Y. (2021) Exposure to salinity and light spectra regulates glucosinolates, phenolics, and antioxidant capacity of *Brassica carinata* L. microgreens. *Antioxidants* 10, 1183. https://doi.org/1110.3390/ANTIOX10081183.

141. *Makhulu E.E.*, *Villinger J.*, Adunga V.O., *Jeneby M.M.*, *Kimathi E.M.*, *M. E.*, *Oundo J.W.*, *Musa A.A.* and *Wambua L.* (2021) Tsetse blood-meal sources, endosymbionts, and trypanosome infections provide insight into African trypanosomiasis transmission in the Maasai Mara National Reserve, a wildlife–human–livestock interface. *PLoS Neglected Tropical Diseases* 15, e0008267. https://doi.org/0008210.0001371/journal.pntd.0008267.

142. Mang'era C.M., *Khamis F.M.*, Awuoche E.O., Hassanali A., *Ombura F.L.O.* and Mireji P. (2021) Transcriptomic response of *Anopheles gambiae* sensu stricto mosquito larvae to Curry tree (*Murraya koenigii*) phytochemicals. *Parasites and Vectors* 14, 1. https://doi.org/10.1186/s13071-13020-04505-13074.

143. Mbewe N.J., Sole C.L., Pirk C.W.W., *Masiga D.K.* and Yusuf A.A. (2021) Efficiencies of stationary sampling tools for the tsetse fly *Glossina fuscipes fuscipes* in western Kenya. *Acta Tropica* 223:106092. https://doi.org/10.1016/j.actatropica.2021.106092.

144. *Mekonnen B.*, *Cheseto X.*, Pirk C., Yusuf A., *Ekesi S.*, *Deletre E.* and *Torto B.* (2021) Re-analysis of abdominal gland volatilome secretions of the African weaver ant, *Oecophylla longinoda* (Hymenoptera: Formicidae). *Molecules* 26, 871. https://doi.org/810.3390/molecules26040871.

145. *Mfuti D.K.*, *Tamiru A.*, Kirk W.D.J., Akinyemi A.O., Campbell H., O'Brien M., Drijfhout F.P., Pope T.W., *Niassy S.* and *Subramanian S.* (2021) Exploiting thrips aggregation pheromones to develop a lure-and-kill strategy for the management of the bean flower thrips. *Agronomy* 11, 1269. https://doi.org/1210.3390/agronomy11071269.

146. *Milugo T.K.*, *Tchouassi D.*, Kavishe R.A., Dinglasan R.R. and *Torto B.* (2021) Derivatization increases mosquito larvicidal activity of the sesquiterpene lactone parthenin isolated from the invasive weed *Parthenium hysterophorus*. *Pest Management Science* 77, 659–665. https://doi.org/610.1002/ps.6131.

147. *Milugo T.K.*, *Tchouassi D.P.*, Kavishe R. A., Dinglasan R.R. and *Torto B.* (2021) Root exudate chemical cues of an invasive plant modulate oviposition behavior and survivorship of a malaria mosquito vector. *Scientific Reports* 11, 14785. https://doi.org/14710.11038/s41598-14021-94043-14785.

148. *Milugo T.K.*, *Tchouassi D.P.*, Kavishe R.A., Dinglasan R.R. and *Torto B.* (2021) Naturally occurring compounds with larvicidal activity against malaria mosquitoes. *Frontiers in Tropical Diseases* 2, 718804. https://doi.org/718810.713389/fitd.712021.718804.

149. *Mkiga A.M.*, *Mohamed S. A.*, du Plessis H., *Khamis F. M.*, *Akutse K. S.*, *Nderitu P.*, *Niassy S.*, *Muriithi B.W.* and *Ekesi S.* (2021) Compatibility and efficacy of *Metarhizium anisopliae* and sex pheromone for controlling *Thaumatotibia leucotreta*. *Journal of Pest Science* 94, 393–407. https://doi.org/310.1007/s10340-10020-01281-z.

150. *Mohamed S.A.*, Wamalwa M., *Obala F.*, *Tonnang H.E.Z.*, *Tefera T.*, *Calatayud P-A., Subramanian S.* and *Ekesi S.* (2021) A deadly encounter: Alien invasive *Spodoptera frugiperda* in Africa and indigenous natural enemy, *Cotesia icipe*. *PLoS ONE* 16, e0253122. https://doi.org/0253110.0251371/journal.pone.0253122.

151. *Moirana R. L.*, Kivevele T., Mkunda J., Mtei K. and Machunda R. (2021) Trends towards effective analysis of fluorinated compounds using inductively coupled plasma mass spectrometry (ICP-MS). *Journal of Analytical Methods in Chemistry* 2021, Article ID 8837315. https://doi.org/8837310.8831155/8832021/8837315.

152. *Moirana R. L.*, Mkunda J., Perez M. P., Machunda R. and Mtei K. (2021) The influence of fertilizers on the behavior of fluoride fractions in the alkaline soil. *Journal of Fluorine Chemistry* 250, 109883. https://doi.org/109810.101016/J.JFLUCHEM.102021.109883.

153. Moshobane M.C., Khoza T.T. and *Niassy S.* (2021) Short communication: The period of insect research in the tropics: a bibliometric analysis. *International Journal of Tropical Insect Science*, https://doi.org/10.1007/s42690-42021-00616-42692.

154. Moshobane M.C., *Mudereri B.T., Mukundamago M.* and Chitata T. (2022) Predicting future distribution patterns of *Jatropha gossypiifolia* L. in South Africa in response to climate change. *South African Journal of Botany*. 146, 417–425, https://doi:10.1016/j.sajb.2021.11.031.

155. *Mosomtai G.*, *Azrag A.G.A.*, Babin R., *Abdel-Rahman E.*, Odindi J., Mutanga O., *Tonnang H.E.Z.*, *Landmann T.* and *David G.* (2021) Functional land cover scale for three insect pests with contrasting dispersal strategies in a fragmented coffee-based landscape in Central Kenya. *Agriculture, Ecosystems & Environment* 319, 107558. https://doi.org/107510.101016/j.agee.102021.107558.

156. Mothapo M.C., Dube T., *Abdel-Rahman E.M.* and Sibanda M. (2021) Progress in the use of geospatial and remote sensing technologies in the assessment and monitoring of tomato crop diseases. *Geocarto International.* https://doi.org/10.1080/10106049.10102021.11899303.

157. Mtengwana, B., Dube, T., *Mudereri B.T.*, Shoko, C., (2021). Modeling the geographic spread and proliferation of Invasive Alien Plants (IAPs) into new ecosystems using multi-source data and multiple predictive models in the Heuningnes catchment, South Africa. *GIScience and Remote Sensing.* https://doi.org/10.1080/15481603.2021.1903281

158. *Mudalungu C.M.*, *Tanga C.M.*, *Kelemu S.* and *Torto B.* (2021) An overview of antimicrobial compounds from African edible insects and their associated microbiota. *Antibiotics* 10, 621. https://doi.org/610.3390/antibiotics10060621.

159. *Mudereri B.T.*, *Abdel-Rahman E.M.*, Dube T., *Niassy S.*, *Khan Z.*, *Tonnang H.E.Z.* and *Landmann T.* (2021) A two-step approach for detecting *Striga* in a complex agroecological system using Sentinel-2 data. *Science of the Total Environment* 762, 143151. doi: 143110.141016/j.scitotenv.142020.143151.

160. *Mudereri B.T.*, Chitata T., Chemura A., Makaure J., Mukanga C., *Abdel-Rahman E.M.* and Mukanga J. (2021) Is the protected area coverage still relevant in protecting the southern ground-hornbill (*Bucorvus leadbeateri*) biological niche in Zimbabwe? Perspectives from ecological predictions. *GIScience & Remote Sensing* 58, 405–424. https://doi.org/410.1080/15481603.15482021.11883947.

161. Mugandani R., Murew C.T.F., Chitata T., Chipepa F., *Mudereri B.T.*, Mwadzingeni L. and Mafongoya P.L. (2021) Can the application of item response theory improve the quality of survey items for assessing human fingerprints on climate change? *Transactions of the Royal Society of South Africa.* https://doi.org/10.1080/0035919X.2021.1964105.

162. Muller H., Chebbi M.A., Bouzar C., Périquet G., Fortuna T., *Calatayud P.-A.*, *Le Ru B.*, *Obonyo J.*, Kaiser L.,Drezen J.-M., Huguet E. and Gilbert C. (2021) Genome-wide patterns of bracovirus chromosomal integrationinto multiple host tissues during parasitism. *Journal of Virology*, JVI0068421. https://doi.org/0068410.0061128/JVI.0000684-0068421.

163. Munganyinka J.P., Thiam F., Wairimu S., *Fisher M.*, *Skilton R.*, *Osiru M.*, *Achoka P.* and *Abdulle S.* (2020) Studying abroad during the COVID-19 pandemic: The experiences of three African women PhD students. *The ADVANCE Journal* 2. https://doi.org/10.5399/osu/ADVJRNL.5392.5392.5396.

164. *Muriithi B.W.* and Kabubo-Mariara J. (2021). The dynamics and role of gender in high-value avocado farming in Kenya. *European Journal of Development Research* 1-33. https://doi.org/10.1057/s41287-021-00484-z.

165. *Muriithi B.W.*, *Gathogo N.*, Rwomushana I., *Diiro G.*, *Mohamed S.*, *Khamis F.*, *Tanga C.* and *Ekesi S.* (2021) Farmers' knowledge and perceptions on fruit flies and willingness to pay for a fruit fly integrated pest management strategy in Gamo Gofa Zone, Ethiopia. *International Journal of Agricultural Sustainability.* https://doi.org/10.1080/14735903.14732021.11898178.

166. *Muriithi B.W.*, Gathogo N.G., *Diiro G.*, *Kidoido M.*, *Okal M.N.* and *Masiga D.* (2021) Farmer perceptions and willingness to pay for novel livestock pest control technologies: A case of tsetse repellent collar in Kwale County in Kenya. *PLoS Neglected Tropical Diseases* 15, e0009663. https://doi.org/0009610.0001371/journal.pntd.0009663.

167. *Murugu D.*, *Onyango A.M.*, Ndiritu A.K., Osuga I.M., *Cheseto X.*, Nakimbugwe D. and *Tanga C.* (2021) From farm to fork: Crickets as alternative source of protein, minerals and vitamins. *Frontiers in Nutrition*. https://doi.org/10.3389/fnut.2021.704002.

168. Musungu A. L., Otieno D. J., *Muriithi B. W.*, Nyikal R., *Masiga D.* and *Okal M. N.* (2021) Are the current animal trypanosomiasis management methods in Kenya complementary or substitutes? Evidence from Kwale County. *African Journal of Agricultural and Resource Economics* 16, 46–63. https://doi.org/10.53936/afjare.2021.16(2).04.

169. Mutamiswa R., Machekano H., Singano C., Joseph V., *Chidawanyika F.* and Nyamukondiwa C. (2021) Desiccation and temperature resistance of the larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae): Pedestals for invasion success? *Physiological Entomology* 46, 157-–166. https://doi.org/10.1111/phen.12355.

170. Mutamiswa R., Nyamukondiwa C., Chikowore G. and *Chidawanyika F.* (2021) Overview of oriental fruit fly, *Bactrocera dorsalis* (Hendel)(Diptera: Tephritidae) in Africa: From invasion, bio-ecology to sustainable management. *Crop Protection* 141, 105492. https://doi.org/105410.101016/j.cropro.102020.105492.

171. Muthoni F., Thierfelder C., *Mudereri B.T.,* Manda J., Bekunda M. and Hoeschle-Zeledon I. (2021) Machine learning model accurately predict maize grain yields in conservation agriculture systems in Southern Africa. 9th International Conference on Agro-Geoinformatics (Agro-Geoinformatics), pp. 1-5. https://doi.org/10.1109/Agro-Geoinformatics50104.2021.9530335.

172. Mutisya J.K., Kahato M.M., Mulwa F.M., Langat S., Chepkorir E., Arum S., *Tchouassi D.P.*, Sang R. and Lutomiah J. (2021) Evaluating the vector competence of *Aedes simpsoni sl* from Kenyan coast for Ngari and Bunyamwera viruses. *PLoS One* 16. e0253955. https://doi.org/0253910.0251371/journal.pone.0253955.

173. *Mutisya M.M.*, *Agbodzavu K.*, Mawufe K., Kinyuru J.N., *Tanga C.M.*, Gicheha M., *Hailu G.*, *Salifu D.*, *Khan Z. R.* and *Niassy S.* (2021) Can black soldier fly larvae–*Desmodium intortum*-based diets enhance the performance of

Cobb500® broiler chickens and smallholder farmers' profit in Kenya? *Poultry Science* 100, 420–430. https://doi.org/410.1016/j.psj.2020.1011.1021.

174. Mutuku K.V., Mukhebi A.W., Orinda M.A. and *Tanga C.M.* (2021) Determinants of profitability of black soldier fly farming enterprise in Kenya. *Journal of Insects as Food and Feed*, https://doi.org/10.3920/JIFF2021.0066.

175. Muturi E.M., Dunlap C., *Tchouassi D.P.* and Swanson J. (2021) Next generation sequencing approach for simultaneous identification of mosquitoes and their blood meal hosts. *Journal of Vector Ecology* 46, 116–121. https://doi.org/110.52707/51081-51710-52746.52701.52116.

176. Mwakililu A.D., Mwaikono K.S., Herrera S.L., *Midega C.*, Magingo F., Alsanius B., Dekker T. and Lyantagaye S.L. (2021) Long-term maize-*Desmodium* intercropping shifts structure and composition of soil microbiome with stronger impact on fungal communities. *Plant and Soil*, https://doi.org/10.1007/s11104-11021-05082-w.

177. *Mwamba S., Kihika-Opanda R.*, Murungi L., Losenge T., Beck J.J. and *Torto B.* (2021) Identification of repellents from four non-host Asteraceae plants for the root knot nematode, *Meloidogyne incognita. Journal of Agricultural and Food Chemistry*. https://doi.org/10.1021/acs.jafc.1c06500.

178. Mwando N.L., *Ndlela S.*, Meyhöfer R., *Subramanian S.*, and *Mohamed S.A.* (2021) Hot water treatment for post-harvest disinfestation of *Bactrocera dorsalis* (Diptera: Tephritidae) and its effect on cv. Tommy Atkins mango. *Insects* 12(12), 1070. https://doi.org/10.3390/insects12121070.

179. *Mwangi K.*, *Macharia R.* and *Bargul J.* (2021) Gene co-expression network analysis of *Trypanosoma brucei* in tsetse fly vector. *Parasites and Vectors* 14, 74. https://doi.org/10.1186/s13071-13021-04597-13076.

180. *Mwangi S.J.*, Gwela A., Kioko M., *Bargul J.L.*, Nduati E.W., Ndungu F.M., Bejon P., Rayner J.C. and Abdi A.I. (2021) Impact of *Plasmodium falciparum* small-sized extracellular vesicles on host peripheral blood mononuclear cells. *Wellcome Open Research* 5, 197. https://doi.org/110.12688/wellcomeopenres.16131.12681.

181. *Naitore C., Villinger J., Kibet C.K., Kalayou S., Bargul J.L.*, Christoffels C. and *Masiga D.K.* (2022; published December 28, 2021) The developmentally dynamic microRNA transcriptome of *Glossina pallidipes* tsetse flies, vectors of animal trypanosomiasis. *Bioinformatics Advances* 2(1):vbab047. https://doi.org/10.1093/bioadv/vbab047.

182. Nanga Nanga S., Kekeunou S., Fotso Kuate A., Fiaboe K.K.M., Dongmo Kenfak M.A., *Tonnang Z.E.H.*, Gnanvossou D., Djiéto-Lordon C. and Hanna R. (2021) Temperature-dependent phenology of the parasitoid *Fopius arisanus* on the host *Bactrocera dorsalis*, *Journal of Thermal Biology*. https://doi.org/10.1016/j.jtherbio.2021.103031.

183. *Nattoh G.*, *Bargul J.L.*, Magoma G., Mbaisi L., *Butungi H.*, *Mararo E.*, *Teal E.* and *Herren J.K.* (2021) The fungus *Leptosphaerulina* persists in *Anopheles gambiae* and induces melanization. *PLoS ONE* 16, e0246452. https://doi.org/0246410.0241371/journal.pone.0246452.

184. *Nattoh G.*, *Maina T.*, *Makhulu E.E.*, Mbaisi L., Mararo E., *Otieno F.G.*, *Bukhari T.*, *Teal E.*, *Paredes J.*, *Bargul J.*, Mburu D. M., Onyango E.A., Magoma G., Sinkins S.P. and *Herren J.K.* (2021) Horizontal transmission of the symbiont *Microsporidia MB* in *Anopheles arabiensis*. *Frontiers in Microbiology* 12, 647183. https://doi.org/647110.643389/fmicb.642021.647183.

185. *Ndayisaba P.C.*, Kuyah S., *Midega C.A.O.*, Mwangi P.N. and *Khan Z.R.* (2021) Intercropping desmodium and maize improves nitrogen and phosphorus availability and performance of maize in Kenya. *Field Crops Research* 263, 108067. https://doi.org/108010.101016/j.fcr.102021.108067.

186. Ndemah R., Le Ru B.P., Capdevielle-Dulac C., Schulthess F., Kaiser L., Hanna R., Depoily A., *Obonyo J.*, *Calatayud P.-A.*, Abang A. and Dupas S. (2021) Managing and monitoring genetic isolation and local adaptation of endemic and introduced *Cotesia sesamiae* for the biological control of the cereal stemborer *Busseola fusca* in Cameroon. *Biological Control* 155, 104478. https://doi.org/104410.101016/j.biocontrol.102020.104478.

187. *Ndlela S.*, Azrag A.G and *Mohamed S.A* (2021). Determination of temperature thresholds for the parasitoid *Diachasmimorpha longicaudata* (Hymenoptera: Braconidae), using life cycle simulation modeling: Implications for effective field releases in classical biological control of fruit flies. *Plos One* 16(8), e0255582. https://doi.org/10.1371/journal.pone.0255582.

188. *Ndlela S.*, *Mwando N.L.* and *Mohamed S.A.* (2021) Advances in postharvest disinfestation of fruits and vegetables using hot water treatment technology-updates from Africa. *Intech Open*. http://dx.doi.org/10.5772/intechopen.100351.

189. Nelson X.J., Pratt A.J., *Aluoch S.A.* and *Jackson R.R.* (2021) Effects of phytochemicals on predatory decision making in a spider. *Animal Behaviour* 177, 69–80. **https://doi.org/10.1016/j.anbehav.2021.1004.1022**.

190. *Ng'ang'a P.N.*, *Aduogo P.* and *Mutero C.M.* (2021) Case study: Strengthening community and stakeholder participation in the implementation of integrated vector management for malaria control in western Kenya: A case study. *Malaria Journal* 20, 155. https://doi.org/110.1186/s12936-12021-03692-12934.

191. *Ng'ang'a P.N.*, *Aduogo P.* and *Mutero C.M.* (2021) Long lasting insecticidal mosquito nets (LLINs) ownership, use and coverage following mass distribution campaign in Lake Victoria basin, Western Kenya. *BMC Public Health* 21, 10465. https://doi.org/10410.11186/s12889-10021-11062-10467.

192. Ng'etich A., Voyi K. and *Mutero C.M.* (2021) Evaluation of health surveillance system attributes: the case of neglected tropical diseases in Kenya. *BMC Public Health* 21, 396. https://doi.org/310.1186/s12889-12021-10443-12882.

193. Ng'etich A.K.S., Voyi K. and *Mutero C.M.* (2021) Assessment of surveillance core and support functions regarding neglected tropical diseases in Kenya. *BMC Public Health* 21, 142. https://doi.org/110.1186/s12889-12021-10185-12881.

194. Ng'etich A.K.S., Voyi K. and *Mutero C.M.* (2021) Feasibility of implementing recommendations to improve neglected tropical diseases surveillance and response in Kenya: a modified Delphi study. *BMC Health Services Research*, https://doi.org/10.21203/rs.21203.rs-142063/v142061.

195. Ng'etich A.K.S., Voyi K., Kirinyet R.C. and *Mutero C.M.* (2021) Systematic review: A systematic review on improving implementation of the revitalised integrated disease surveillance and response system in the African region: A health workers' perspective. *PLoS One* 16, e0248998. https://doi.org/0248910.0241371/journal.pone.0248998.

196. *Nganso B.T.* and *Torto B.* (2021) The effects of crude propolis, its volatiles and ethanolic extracts on the ecto-parasitic mite, *Varroa destructor* and health of the African savannah honeybee, *Apis mellifera scutellata*. *Parasitology*, https://doi.org/10.1017/S0031182021000305.

197. *Niassy S.*, *Agbodzavu K.*, *Kimathi E.*, *Mutune B.*, *Abdel-Rahman E.F.M.*, *Salifu D.*, *Hailu G.*, Belayneh Y., Felege E., *Tonnang H.E.Z.*, *Ekesi S.* and *Subramanian S.* (2021) Bioecology of fall armyworm *Spodoptera frugiperda* (J. E. Smith), its management and potential patterns of seasonal spread in Africa. *PLoS ONE* 16, e0249042. https://doi.org/0249010.0241371/journal.pone.0249042.

198. *Njaramba J.K.,* Wambua L., Mukiama T., Amugune N. and *Villinger J.* (2021) Detection of species substitution in the meat value chain by high-resolution melting analysis of mitochondrial PCR products. *Foods* 10(12):3090. https://doi.org/10.3390/foods10123090.

199. *Njeru F.N.* and Kusolwa P. M. (2021) Nanobodies: Their potential for applications in biotechnology, diagnosis and antiviral properties in Africa; focus on application in agriculture. *Biotechnology and Biotechnological Equipment* 35, 1331–1342. https://doi.org/1310.1080/13102818.13102021.11974943.

200. *Njeru N.K.*, *Midega C.A.O.*, Muthomi J., Wagacha J.M. and *Khan Z.R.* (2020) *In vitro* antifungal activity of *Desmodium intortum* and *D. uncinatum* root extracts against growth of toxigenic *Fusarium verticillioides* and *Aspergillus flavus*. *Australian Journal of Crop Science* 14, 1942–1948. https://doi.org/10.21475/ajcs.20.14.12.2792.

201. *Njoroge M.M.*, *Fillinger U.*, Saddler A., Moore S., Takken W., Van Loon J.J.A. and *Hiscox A.* (2021) Evaluating putative repellent 'push' and attractive 'pull' components for manipulating the odour orientation of host-seeking malaria vectors in the peri-domestic space. *Parasites and Vectors* 14, 42. https://doi.org/10.1186/s13071-13020-04556-13077.

202. *Nkya T.E.*, *Fillinger U.*, Dlamini M., *Sangoro P.O.*, *Marubu R.*, Zulu Z., Chanda E., *Mutero C.M.* and Dlamini Q. (2021) Malaria in Eswatini, 2012–2019: A case study of the elimination effort. *Malaria Journal* 20, 159. https://doi.org/10.1186/s12936-021-03699-x.

203. Nnzeru L.R., Tshikhudo, P.P., *Mudereri, B.T.* and Moshobane M.C. (2021). Pest interceptions on imported fresh fruits into South Africa. *International Journal of Tropical Insect Science.* https://doi.org/10.1007/s42690-021-00501-y.

204. Noulèkoun F., Birhane E., Kassa H., Berhe A., Gebremichael Z.M., Adem N.M., Syoum Y., Mengistu T., Lemma B., Hagazi N., *Abrha H.*, Rannestad M.M. and Mensah S. (2021) Grazing exclosures increase soil organic carbon stock at a rate greater than "4 per 1000" per year across agricultural landscapes in Northern Ethiopia. *Science of The Total Environment* 782, 146821. https://doi.org/146810.141016/j.scitotenv.142021.146821.

205. Noulèkoun F., Birhane E., Mensah S., Kassa H., Berhe A., Gebremichael Z.M., Adem N.M., Seyoum Y., Mengistu T., Lemma B., Hagazi N. and *Abrha H.* (2021) Structural diversity consistently mediates species richness effects on aboveground carbon along altitudinal gradients in northern Ethiopian grazing exclosures. *Science of the Total Environment* 776, 145838. https://doi.org/145810.141016/j.scitotenv.142021.145838.

206. *Nyang'au P.N.*, Nzuma J.M., Irungu P., and *Kassie M.* (2021). Evaluating livestock farmers' knowledge, beliefs and management of arboviral diseases in Kenya: A multivariate fractional probit approach. *Plos Neglected Tropical Diseases*. 15(9): e0009786. https://doi.org/10.1371/journal.pntd.0009786.

207. *Nyasembe V.*, *Tchouassi D.*, Muturi M.N., Pirk C., Sole C. and *Torto B.* (2021) Plant nutrient quality impacts survival and reproductive fitness of the dengue vector *Aedes aegypti*. *Parasites and Vectors* 14, 4. https://doi.org/10.1186/s13071-13020-04519-y.

208. *Obila J.O.*, Lei H., Ayieta E.O., Ogacho A.A., Aduda B.O. and Wang F. (2021) Optoelectronic property refinement of FASnI3 films for photovoltaic application. *Materials Letters* 300, 130099. https://doi.org/130010.131016/j.matlet.132021.130099.

209. *Obila J.O.*, Lei H., Ayieta E.O., Ogacho A.A., Aduda B. and Wang F. (2021) Improving efficiency and stability of tin-based perovskite solar cells by anilinium hypophosphite additive. *New Journal of Chemistry*, https://doi.org/10.1039/D1031NJ00602A.

210. Ochieng J., Afari-Sefa V., Muthoni F., Kansiime M., Hoeschle-Zeledon I., Bekunda M. and *Dubois T.* (2021) Adoption of sustainable agricultural technologies for vegetable production in rural Tanzania: trade-offs, complementarities and diffusion. *International Journal of Agricultural Sustainability*, https://doi.org/10.1080/14735903.14732021.11943235.

211. *Ochola J.*, Coyne D., Cortada L., *Haukeland S.*, Ng'ang'a M., Hassanali A., Opperman C. and *Torto B.* (2021) Cyst nematode bio-communication with plants: Implications for novel management approaches. *Pest Management Science* 77, 1150–1159. https://doi.org/1110.1002/ps.6105.

212. *Ochungo P.*, Veldtman R., *Abdel-Rahman E.M.*, *Muli E.*, *Ng'ang'a J.*, *Tonnang H.E.Z.* and *Landmann T.* (2021) Data set: Fragmented landscapes affect honeybee colony strength at diverse spatial scales in agro-ecological landscapes in Kenya. *Dryad Dataset*. https://doi.org/10.5061/dryad.j5063tx5095xdj.

213. *Ochungo P.*, Veldtman R., *Abdel-Rahman E.M.*, *Raina S.*, *Muli E.* and *Landmann T.* (2021) Multi-sensor mapping of honeybee habitats and fragmentation in agro-ecological landscapes in eastern Kenya. *Geocarto International* 36, 839–860. https://doi.org/810.1080/10106049.10102019.11629645.

214. *Ochungo P.*, Veldtman R., Kinyanjui R., *Abdel-Rahman E.M.*, *Muli E.*, *Muturi M.N.K.*, *Lattorff H.M.G.* and *Landmann T.* (2021) Pollen diversity and protein content in differentially degraded semi-arid landscapes in Kenya. *Journal of Apicultural Research* 60, 828-841. https://doi.org/10.1080/00218839.00212021.01899656.

215. *Ocitti P., Ndlela S.*, Akol A.M., Muyinza H. and *Mohamed S.A.* (2021). Non-chemical post-harvest disinfestation of *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) in Tommy Atkins mango using hot-water immersion treatment. *African Entomology* 29(1), 238-247. https://doi.org/10.4001/003.029.0238.

216. Okello A.O., Nzuma J.M., Otieno D.J., Kidoido M. and Tanga C.M. (2021) Farmers' perceptions of commercial insect-based feed for sustainable livestock production in Kenya. *Sustainability* 13, 5359. https://doi.org/5310.3390/su13105359.

217. Okello E.N., Amugune N.O., Mukiama T.K. and *Lattorff H.M.G.* (2021) Abundance and community composition of flower visiting insects of avocado (*Persea americana*) in the East African Region. *International Journal of Tropical Insect Science* 41. 2821-2827. https://doi.org/10.1007/s42690-42021-00463-42691.

218. *Okwaro L.A.*, *Muli E.M.*, Runo S.M. and *Lattorff H.M.G.* (2021) Coexistence of honeybees with distinct mitochondrial haplotypes and hybridised nuclear genomes on Comoros Islands. *Science of Nature* 108, 17. doi: 10.1007/s00114-00021-01729-x.

219. *Olaide O.Y.*, *Tchouassi D.*, Yusuf A.A., Pirk C., *Masiga D.*, *Saini R.* and *Torto B.* (2021) Effect of zebra skin-derived compounds on field catches of the human African trypanosomiasis vector *Glossina fuscipes fuscipes*. *Acta Tropica* 213, 105745. https://doi.org/10.1016/j.actatropica.2020.105745

220. *Omolo M.O.*, Ndiege I.O. and *Hassanali A.* (2021) Semiochemical signatures associated with differential attraction of *Anopheles gambiae* to human feet. *PLoS ONE* 16 (12): e0260149. https://doi.org/10.1371/journal.pone.0260149.

221. *Omuse E.R., Niassy S.*, Wagacha J.M., Ong'amo G.O., Azrag A.G.A. and *Dubois T.* (2021) Suitable models to describe the effect of temperature on conidial germination and mycelial growth of *Metarhizium anisopliae* and *Beauveria bassiana. Biocontrol Science and Technology*, https://doi.org/10.1080/09583157.09582021.01993133.

222. *Omuse E.R.*, *Niassy S.*, Wagacha J.M., Ong'amo G.O., *Lattorff H.M.G., Nkoba K., Mohamed S.A, Subramanian S., Akutse K.S.,* and *Dubois T.* (2021) Susceptibility of the Western honey bee *Apis mellifera* and the African stingless bee *Meliponula ferruginea* (Hymenoptera: Apidae) to the entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria bassiana*. *Journal of Economic Entomology*. https://doi.org/10.1093/jee/toab211.

223. *Osman M.A.A.,* Onono J.O., Olaka L.A., Elhag M.M. and *Abdel-Rahman E.M.* (2021) Climate Variability and Change Affect Crops Yield under Rainfed Conditions: A Case Study in Gedaref State, Sudan. *Agronomy 11, 1680*. https://doi.org/10.3390/agronomy11091680.

224. *Owino B.O.*, *Mwangi J.M.*, *Kiplagat S.*, Mwangi H.N., Ingonga J.M., Chebet A., Ngumbi P.M., *Villinger J.*, *Masiga D.K.* and *Matoke-Muhia D.* (2021) Molecular detection of *Leishmania donovani*, *Leishmania major*, and *Trypanosoma* species in *Sergentomyia squamipleuris* sand flies from a visceral leishmaniasis focus in Merti Sub-county, eastern Kenya. *Parasites and Vectors* 14, 53. https://doi.org/10.1186/s13071-13020-04517-13070.

225. *Oyewole D. O.*, Koech R. K., Ichwani R., Ahmed R., Hinostroza Tamayo J., Adeniji S. A., Cromwell J., Colin Ulloa E., Oyewole O. K., Agyei-Tuffour B., Titova L. v., Burnham N. A. and S. W. O. (2021) Annealing effects on interdiffusion in layered FA-rich perovskite solar cells. *AIP Advances* 11, 065327. https://doi.org/065310.061063/065325.0046205.

226. *Paradza V.M.*, *Khamis F.M.*, Yusuf A.A., *Subramanian S.* and *Akutse K.S.* (2021) Virulence and horizontal transmission of *Metarhizium anisopliae* by the adults of the greenhouse whitefly *Trialeurodes vaporariorum* (Hemiptera: Aleyrodidae) and the efficacy of oil formulations against its nymphs. *Heliyon* 7, e08277.

227. *Paradza V.M.*, *Khamis F.M.*, Yusuf A.A., *Subramanian S.*, *Ekesi S.* and *Akutse K. S.* (2021) Endophytic colonisation of *Solanum lycopersicum* and *Phaseolus vulgaris* by fungal endophytes promotes seedlings growth and hampers the reproductive traits, development, and survival of the greenhouse whitefly, *Trialeurodes vaporariorum*. *Frontiers in Plant Science*, https://doi.org/10.3389/fpls.2021.771534.

228. Patrick E.M., Koomen I., *Ndlela S.* and Wesonga J.M. (2021). Effect of moisture stress on the development of false codling moth *Thaumatotibia leucotreta* (Lepidoptera: Tortricidae) on two tomato varieties. *Neotropical Entomology*, 50(5), 828-834. https://doi.org/10.1007/s13744-021-00904-z.

229. Rahmann G., Azim K., Brányiková I., Chander M., David W., Erisman J.W., Grimm D., Hammermeister A., Li J., Kuenz A., Loes A.-N., Wan-Mohtar W.A.L.Q., Neuhoff D., *Niassy S.*, Olowe V., Schoeber M., Shade J., Ullmann

J. and van Huis A. (2021) Innovative, sustainable, and circular agricultural systems for the future. *Organic Agriculture* 11, 179–185. https://doi.org/110.1007/s13165-13021-00356-13160.

230. Ramos Aguila L.C., *Akutse K.S.*, Ashraf H.J., Bamisile B.S., Lin J., Dai J., Wang H. and Wang L. (2021) The survival and parasitism rate of *Tamarixia radiata* (Hymenoptera: Eulophidae) on its host exposed to *Beauveria bassiana* (Ascomycota: Hypocreales). *Agronomy* 11, 1496. https://doi.org/1410.3390/agronomy11081496.

231. Ramos Aguila L.C., *Akutse K.S.*, Bamisile B.S., Sanchez Moreano J.P., Ashraf H.J., Zhou C., Li X. and Wang Liande (2021) Endophytically colonized *Citrus limon* seedlings by *Beauveria bassiana* hampered development, reproduction and progeny fitness of *Diaphorina citri*. *Journal of Applied Entomology* 00, 1–4. https://doi.org/10.1111/jen.12960.

232. *Rao I.M.*, Delhaize M. and Chen C.C. (2021) Editorial: Root adaptations to multiple stress factors. *Frontiers in Plant Science* 11, 626960. https://doi.org/626910.623389/fpls.622020.626960.

233. Rhodes AC, Plowes RM, Goolsby JA, Gaskin JF, *Musyoka B, Calatayud P-A*, Cristofaro M, Grahmann ED, Martins DJ, Gilbert LE (2021) The dilemma of Guinea grass (*Megathyrsus maximus*): a valued pasture grass and a highly invasive species. *Biological Invasions*. https://doi.org/10.1007/s10530-021-02607-3.

234. Ruíz-Rivero O., Garcia-Lor A., Rojas-Panadero B., Carlos Franco J., *Khamis F.M.*, Kruger K., Cifuentes D., Bielza P., Tena A., Urbaneja A. and Pérez-Hedo M. (2021) Insights into the origin of the invasive populationsof *Trioza erytreae* in Europe using microsatellite markers and mtDNA barcoding approaches. *Scientific Reports* 11, 18651. https://doi.org/10.1038/s41598-021-97824-0.

235. Sagib H.S.A., Chen J., Chen W., Posgai G., *Akutse K.S.*, Ashraf F., You M. and G. G.M. (2020) Local management and landscape structure determine the assemblage patterns of spiders in vegetable fields. *Scientific Reports* 10, 15130. https://doi.org/10.1038/s41598-020-71888-w.

236. *Sagwe R.N.*, Peters M., *Dubois T.*, Steffan-Dewenter I. and *Lattorff H.M.G.* (2021) Pollinator supplementation mitigates pollination deficits in smallholder avocado (*Persea americana* Mill.) production systems in Kenya. *Basic and Applied Ecology* 56: 392-400. https://doi.org/10.1016/j.baae.2021.08.013.

237. *Sangoro P.O., Fillinger U.*, Saili K., *Nkya T., Marubu R.*, Masaninga F., Trigo S.C., Tarumbwa C., Hamainza B., Baltazar C., Mberikunashe J., Chisanga B., *Kassie M.*, Chanda E. and *Mutero C.* (2021) Study protocol: Evaluating the efficacy, impact, and feasibility of community-based house screening as a complementary malaria control intervention in southern Africa: a study protocol for a household randomized trial. *Trials* 22, 883. https://doi.org/10.1186/s13063-021-05768-7

238. Santer R.D., *Okal M.N.*, Esterhuizen J. and Torr S.J. (2021) Evaluation of improved coloured targets to control riverine tsetse in East Africa: A Bayesian approach. *PLoS Neglected Tropical Diseases* 15, e0009463. https://doi.org/0009410.0001371/journal.pntd.0009463.

239. Savi M.K., Callo-Concha D., *Tonnang H.E.Z.* et al. (2021) Emerging properties of malaria transmission and persistence in urban Accra, Ghana: evidence from a participatory system approach (2021). *Malaria Journa*l 20, 321. https://doi.org/10.1186/s12936-021-03851-7.

240. Scheidegger L., *Niassy S.*, *Midega C.*, *Chiriboga X.*, Delabays N., Lefort F., Zürcher R., *Hailu G.*, *Khan Z.R.* and *Subramanian S.* (2021) The role of *Desmodium intortum*, *Brachiaria* sp. and *Phaseolus vulgaris* in the management of fall armyworm *Spodoptera frugiperda* (J. E. Smith) in maize cropping systems in Africa. *Pest Management Science*, https://doi.org/10.1002/ps.6261.

241. Schlum K.A., Lamour K., de Bortoli C.P., Banerjee R., Meagher R., Pereira E., Murua M.G., Sword G. A., Tessnow A.E., Dillon D.V., Linares Ramirez A.M., *Akutse K.S.*, Schmidt-Jeffris R., Huang F., Reisig D., Emrich S.J. and Jurat-Fuentes J.L. (2021) Whole genome comparisons reveal panmixia among fall armyworm (Spodoptera frugiperda) from diverse locations. *BMC Genomics* 22, 179. https://doi.org/110.1186/s12864-12021-07492-12867.

242. Scolari F., *Khamis F.M.* and Pérez-Staples D. (2021) Mini Review: Beyond sperm and male accessory gland proteins: Exploring insect reproductive metabolomes. *Frontiers in Physiology* 12, 729440. https://doi.org/729410.723389/fphys.722021.729440.

243. Sengendo F., *Subramanian S.*, Chemurot M., *Tanga C.M.* and *Egonyu J.P.* (2021) Efficient harvesting of safe edible grasshoppers: Evaluation of modified drums and light emitting diode bulbs for harvesting *Ruspolia differens* (Orthoptera: Tettigonidae) in Uganda. *Journal of Economic Entomology*, toab025. https://doi.org/010.1093/jee/toab1025.

244. *Sengendo F.*, *Subramanian S.*, *Kidoido M.*, Chemurot M., *Tanga C.M.* and *Egonyu J.P.* (2021) Cost–benefit analysis of improved light trap for harvesting the edible grasshopper, *Ruspolia differens* (Orthoptera: Tettigoniidae): Evidence from Uganda. *International Journal of Tropical Insect Science*. https://doi.org/10.1007/s42690-42021-00505-42698.

245. *Shumo M.*, *Khamis F.M.*, *Ombura F.L.*, *Tanga C.M.*, Fiaboe K.K.M., *Subramanian S.*, *Ekesi S.*, Schlüter O.K., van Huis A. and Borgemeister C. (2021) A molecular survey of bacterial species in the guts of black soldier fly larvae (*Hermetia illucens*) reared on two urban organic waste streams in Kenya. *Frontiers in Microbiology* F12, 687103. https://doi.org/687110.683389/fmicb.682021.687103.

246. *Sokame B.M.*, *Malusi P.*, *Subramanian S.*, Kilalo D.C., Juma G. and *Calatayud P.-A.* (2021) Do the invasive fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), and the maize lepidopteran stemborers compete when sharing the same food? *Phytoparasitica*, https://doi.org/10.1007/s12600-12021-00952-12606.

247. *Sokame B.M.*, *Musyoka B.*, *Obonyo J.*, Rebaudo F., *Abdel-Rahman E.M.*, *Subramanian S.*, Kilalo D.C., Juma G. and *Calatayud P-A.* (2021) Impact of an exotic invasive pest, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), on resident communities of pest and natural enemies in maize fields in Kenya. *Agronomy* 11, 1074. https://doi.org/1010.3390/agronomy11061074.

248. *Sokame B.M.*, *Tonnang H.E.Z.*, *Subramanian S.*, *Bruce A.Y.*, *Dubois T.*, *Ekesi S.* and *Calatayud P-A.* (2021) A system dynamics model for pests and natural enemies interactions. *Scientific Reports* 11, 1401. https://doi.org/1410.1038/s41598-41020-79553-y.

249. Ssepuuya G., Sengendo F., Ndagire C.T., Karungi J., *Fiaboe K.K.M.*, Efitre J. and Nakimbugwe D. (2021) Effect of alternative rearing substrates and temperature on growth and development of the cricket *Modicogryllus conspersus* (Schaum). *Journal of Insects as Food and Feed*, 163–172. https://doi.org/110.3920/JIFF2020.0014.

250. Sterkel M., Haines L.R., Casas-Sànchez A., *Adung'a V.O.*, Vionette-Amaral R.J., Quek S., Rose C., dos Santos M.S., Garcia Escude N., Ismail H.M., Paine M.I., Barribeau SM., Wagstaff S., MacRae J.I., *Masiga D.*, Yakob L., Oliveira P.L. and Acosta-Serrano A. (2021) Repurposing the orphan drug nitisinone to control the transmission of African trypanosomiasis. *PLoS Biology* 19, e3000796. https://doi.org/3000710.3001371/journal.pbio.3000796.

251. *Sumbule E.K.,* Ambula M.K., Osuga I.M., Changeh J.G., Mwangi D.M., *Subramanian S., Salifu D.,* Alaru P.A.O., Githinji M., Van Loon J.J.A., Dicke M. and *Tanga C.M. (2021)* Cost-effectiveness of black soldier fly larvae meal as substitute of fishmeal in diets for layer chicks and growers. *Sustainability* 13, 6074. https://doi.org/6010.3390/su13116074.

252. Tadesse M., Tolera K., Bayissa W., Hunde D., Mendesil E., *Kassie M.*, Mutungi C. and *Tefera T.* (2020) Assessment of quantitative and qualitative losses of stored grains due to insect infestation in Ethiopia. *Journal of Stored Products Research* 89, 101689. **https://doi.org/101610.101016/j.jspr.102020.101689**.

253. *Tanga C.M.*, *Egonyu J. P.*, *Beesigamukama D.*, *Niassy S.*, *Kimathi E.*, *Magara H. J. O.*, *O. E.R.*, *Subramanian S.* and *Ekesi S.* (2021) Review article: Edible insect farming as an emerging and profitable enterprise in East Africa. *Current Opinion in Insect Science* 48, 64–71. https://doi.org/10.1016/j.cois.2021.1009.1007.

254. *Tanga C.M.*, *Ghemoh C.J.*, *T. H.E.Z.*, Suresh S., *Kimathi E.K.*, *Mohamed S.A.*, Govender P., *Dubois T.* and *Ekesi S.* (2021) Eco-climatic matching to guide foreign exploration and optimal release strategies for biological control agents of *Rastrococcus iceryoides* in Africa and Asia. *Biological Control* 158, 104603. https://doi.org/10.1016/j.biocontrol.2021.104603.

255. *Tanga C.M.*, *Waweru J. W.*, *Tola Y.H.*, *Onyoni A A.*, *Khamis F M.*, *Ekesi S.* and *Paredes J.* (2021) Organic waste substrates induce important shifts in gut microbiota of black soldier fly (*Hermetia illucens* L.): Co-existence of conserved, variable, and potential pathogenic microbes. *Frontiers in Microbiology - Food Microbiology*, https://doi.org/10.3389/fmicb.2021.635881.

256. Tawich S., *Bargul J.L.*, *Masiga D.* and *Getahun M.* (2021) Supplementing blood diet with plant nectar enhances eggs fertility in *Stomoxys calcitrans*. *Frontiers in Plant Science*, **https://doi.org/10.3389/fphys.2021.646367.**

257. Tepa-Yotto G.T., *Tonnang H.E.Z.*, Goergen G., *Subramanian S.*, *Kimathi E.*, *Abdel-Rahman E.M.*, D. Flø, *Thunes K.H.*, Fiaboe K.K.M., *Niassy S.*, Bruce A., *Mohamed S.*, Tamò M., *Ekesi S.* and Sæthre M.G. (2021) Global habitat suitability of *Spodoptera frugiperda* (JE Smith) (Lepidoptera, Noctuidae): Key parasitoids considered for its biological control. *Insects* 12, 273. https://doi.org/210.3390/insects12040273.

258. *Tola Y.H.*, *Waweru J.C.*, *Ndung'u N.*, *Nkoba K.*, Slippers B. and *Paredes J.* (2021) Loss and gain of gut bacterial phylotype symbionts in Afrotropical stingless bee species (Apidae: Meliponinae). *Microorganisms* 9(12), 2420. https://doi.org/2410.3390/microorganisms9122420.

259. *Torto B.* and *Tchouassi D.P.* (2021) Grand challenges in vector-borne disease control targeting vectors. *Frontiers in Tropical Diseases* 1, 635356. **https://doi.org/635310.633389/fitd.632020.635356**.

260. *Torto B.*, *Kirwa H.*, *Kihika R.* and *Niassy S.* (2021) Odor composition of field versus laboratory desert locust populations. *Journal of Insect Physiology* 134, 104296. https://doi.org/10.1016/j.jinsphys.2021.104296.

261. Tshabalala T., *Abdel-Rahman E.M.*, Ncube B., Ndhlala A.R. and Mutanga O. (2021) Leveraging of hyperspectral remote sensing on estimating biomass yield of *Moringa oleifera* Lam medicinal plant. *South African Journal of Botany* 140, 37–49. https://doi.org/10.1016/j.sajb.2021.1003.1035.

262. Tshabalala T., *Abdel-Rahman E.M.*, Ncube B., Ndhlala A.R. and Mutanga O. (2021) Predicting medicinal phytochemicals of *Moringa oleifera* using hyperspectral reflectance of tree canopies. *International Journal of Remote Sensing* 42, 3955–3980. https://doi.org/3910.1080/01431161.01432021.01887541.

263. Vacek A.T., Goolsby J.A., *Calatayud P.-A., Le Ru B., Musyoka B.,* Kariyat R.R. (2021) Importation and preliminary evaluation of the stem boring moth *Buakea kaeuae* as a potential biological control agent of invasive guineagrass, *Megathyrsus maximus*. Southwestern Entomologist 46(1): 257-260. https://doi.org/10.3958/059.046.0125.

264. *Wachira M.N.*, *Osuga I.M.*, Munguti J.M., Ambula M.K., *Subramanian S.* and *Tanga C.M.* (2021) Efficiencyand improved profitability of insect-based aquafeeds for farming Nile tilapia fish (*Oreochromis niloticus* L.).*Animals* 11, 2599. https://doi.org/2510.3390/ani11092599.

265. Wang Y., Halbert S., *Mohamed S.A*, Delatte H., Reynaud B., Beattie G.A., Holford P., Lu J. and Cen Y. (2021). Mitochondrial genomes reveal diverse lineages of *Diaphorina citri* Kuwayama (Hemiptera: Sternorrhyncha: Psyllidae) in Kenya and La Réunion. *Biological Invasions* 1-9. https://doi.org/10.1007/s10530-021-02560-1.

266. *Wangithi C.M.*, *Muriithi B.W.* and Belmin R. (2021) Adoption and dis-adoption of sustainable agriculture: A case of farmers' innovations and integrated fruit fly management in Kenya. *Agriculture* 11, 338. https://doi.org/310.3390/agriculture11040338.

267. *Wanjiku C.*, *Tchouassi D.*, Sole C.L., Pirk C.W.W. and *Torto B.* (2021) Biological traits of wild caught populations of *Aedes aegypti* in dengue endemic and non-endemic ecologies of Kenya. *Journal of Vector Ecology* 46, 19–23. https://doi.org/10.52707/51081-51710-52746.52701.52719.

268. *Wanjiku C.*, *Tchouassi D.P.*, Sole C.L., Pirk C. and *Torto B.* (2021) Plant sugar feeding patterns of wild-caught *Aedes aegypti* from dengue endemic and non-endemic areas of Kenya. *Medical and Veterinary Entomology*, https://doi.org/10.1111/mve.12514.

269. Yeboa S., Ennin S.A., Ibrahim A., Oteng-Darko P., *Mutyambai D.*, *Khan Z.R.*, Mochiah M. B., *Ekesi S.* and *Niassy S.* (2021) Effect of spatial arrangement of push–pull companion plants on fall armyworm control and agronomic performance of two maize varieties in Ghana. *Crop Protection* 145, 105612. https://doi.org/105610.101016/j.cropro.102021.105612.

270. Yisehak B., Shiferaw H., *Abrha Y.*, Gebremedhin A., Hagos H., Adhana K. and Bezabh T. (2021) Spatio-temporal characteristics of meteorological drought under changing climate in semi-arid region of northern Ethiopia. *Environmental Systems Research* 10, 21. **https://doi.org/10.1186/s40068-40021-00226-40064**.

271. Younan M., *Ouso D.*, Bodha B., Keitany E.K., Wesonga H.O., Satiwa R., Kimutai J., Kuria W., Sori Sake W., Svitek N., *Landmann T.*, Wako D.D. and *Villinger J.* (2021) Short communication: Are *Ehrlichia* spp. close to *Ehrlichia ruminantium*, *Ehrlichia canis,* and "Candidatus *Ehrlichia regneryi*" linked to heartwater-like disease in Kenyan camels (*Camelus dromedarius*). *Tropical Animal Health and Production* 53, 147. https://doi.org/https://doi.org/10.1007/s11250-020-02524-y.

Annex 2 – List of Conference Presentations

2021 (65)

2021 (*Prepared but not presented as conference was postponed indefinitely*) (4)

1. Abdel-Rahman E. (2021): Landscape habitat suitability of *Spodoptera frugiperda* (Smith) in East Africa using a maximum entropy modeling approach. Presented at Developing Smallholder Oriented Integrated Pest Management (IPM) Strategies for Fall Armyworm Management, 24 – 26 August 2021, Lilongwe, Malawi and online.
2. Abro Z. (2021): Push-pull technology as a climate-smart integrated pest management strategy in Southern Ethiopia. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online.
3. Aduvukha G.R. (2021): Mapping development challenges and solutions for a better world. Presented at the Regional Centre for Mapping of Resources for Development (RCMRD) International Conference 2021: Reflecting on Resilience, 17 – 19 August 2021, Nairobi, Kenya, and online.
4. Agbessenou A., Akutse K.S., Yusuf A. and Khamis F.M. (2021): *Trichoderma asperellum* M2RT4 induces systemic release of methyl salicylate and (Z)-jasmone in tomato plant affecting host location and herbivory of the tomato leafminer, *Tuta absoluta*. Presented at the Annual General Meeting, Department of Zoology and Entomology, University of Pretoria, 2 – 3 December 2021, Pretoria, South Africa, and online.
5. Agbessenou A., Akutse K.S., Yusuf A.A., Wekesa S.W. and Khamis F.M. (2021): Making the right decision: Temperature-dependent modelling approach and spatial prediction reveal suitable areas for deployment of two *Metarhizium anisopliae* isolates for sustainable management of *Tuta absoluta*. Presented at the International Congress on Invertebrate Pathology and Microbial Control and 53rd Annual Meeting of the Society for Invertebrate Pathology, SIP 2021, Le Stidium Conferences, 28 June – 2 July 2021, Tours, Loire Valley, France, and online. http://www.lestudium-ias.com/event/2021-international-congress-invertebrate-pathology-and-microbial-control-53rd-annual-meeting
6. Amare B.S. and Tamiru A. (2021): Role of host plant odours in oviposition and host finding of fall armyworm (*Spodoptera frugiperda*). Presented at Developing Smallholder Oriented IPM Strategies for Fall Armyworm Management, 24 – 26 August 2021, Lilongwe, Malawi and online.
7. Ayelo P.M (2021): Identification of kairomones for the biological control of *Tuta absoluta* (Meyrick) and *Trialeurodes vaporariorum* (Westwood), major pests of tomato *Solanum lycopersicum* L. Prestige (seminar/PhD thesis defense). Presented at the Department of Zoology and Entomology, University of Pretoria, 26 August 2021, Pretoria, South Africa, and online.

8. Chepchirchir F. (2021): Knowledge, attitude, and practices of tomato leaf miner (*Tuta absoluta*) and potential demand for integrated pest management among smallholder farmers in Kenya and Uganda. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online.
9. Chidawanyika F., Cheruiyot D., Pittchar J. and Khan Z.R. (2021): Controlling fall armyworm *(Spodoptera frugiperda)* using push-pull. Presented at the 36th Annual Meeting of the International Society of Chemical Ecology. 5 – 10 September 2021, Stellenbosch, South Africa, and online.
10. Chisanga B. (2021): Impact of the fall armyworm (FAW) on the nutrition security of children and mothers in Eastern Uganda. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online.
11. Dubois T., Toukem N., Lattorff H.M.G., Sagwe R.N., Yusuf A.A., Abdel-Rahman E.M., Adan M.S. and Muriithi B. (2021): Integrated pest and pollinator management (IPPM) as a novel tool to merge ecosystem services: lessons learnt from avocado in Kenya. Presented at Tropentag 2021, 15 – 17 September 2021, Hohenheim, Germany and online.
12. Dzekashu F.F., Yusuf A.A., Pirk C.W.W., Steffan-Dewenter I., Lattorff H.M.G. and Peters M.K. (2021): Seasonality in bee communities varies with elevation on East African mountain slopes. Presented at the Early Career Biogeographers Conference (ECBC), 22 – 24 October 2021, Amsterdam, The Netherlands, and online.
13. Ebhodaghe F. (2021): First molecular confirmation of the pathogenic *Trypanosoma vivax* genotype Tvv4 in wild-caught vectors of animal African trypanosomiasis from Kenya, East Africa, and characterising the risk for tsetse-borne animal African trypanosomosis at the wildlife-livestock interface of the Shimba Hills National Reserve, East Africa: a case for targeted control. Presented at the 28th International Conference of the World Association for the Advancement of Veterinary Parasitology WAAVP, 19 – 22 July 2021, Dublin, Ireland, and online.
14. Fetene G.M. and Kassie M. (2021): The economics of trypanosomiasis: empirical evidence on its impacts on livestock production and welfare. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online.
15. Getaneh M. (2021): Health-seeking behaviour of rural households, malaria, and productivity in Northwestern Ethiopia. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online.
16. Haukeland S. (2021): Entomopathogenic nematodes in Africa. Presented at the Impact of Pathogens on Agricultural Production, Future Africa's Early Career Research Leader Fellowship (ECRLF) Dissemination Workshop, 9 November 2021, Kampala, Uganda.
17. Haukeland S. (2021): Management of nematodes in horticultural crops. Presented at the Nematode Management Webinar organised by Syngenta Kenya, 9 June 2021, Nairobi, Kenya, and online.
18. Haukeland S. (2021): Potato cyst nematodes in East Africa. Presented at the Association of Applied Biologists (AAB) Conference on Advances in Nematology, 14 December 2021, The Linnean Society in Central London and online.
19. Haukeland S. and Coyne D. (2021): Evaluating biocontrol agents for management of potato cyst nematode (PCN) in Kenya. Presented at the 23rd Symposium of the Nematological Society of Southern Africa (NSSA), 19 – 23 September 2021, Tulbagh, Western Cape, South Africa.
20. Herren J. (2021): Breaking the wall to symbiont-based transmission blocking for malaria. Presented at Falling Walls Annual Conference, Breakthrough of the Year 2021, 8 November, Berlin, Germany.
21. Herren J. (2021): Symbiont-based transmission blocking for malaria. Presented at the ANTi-VeC (Application of Novel Transgenic technology and Inherited symbionts to Vector Control) 2021 Annual Meeting, 9 December 2021, Glasgow, United Kingdom, and online.
22. Holger K. (2021): Gender relations and power in agricultural production. Presented at Tropentag 2021, 15 – 17 September 2021, Hohenheim, Germany, and online.
23. Kandie F. (2021): Prioritisation of organic micropollutants in freshwater systems of Western Kenya based on risk assessment. Presented at the 10th Young Environmental Scientists (YES) Meeting organised by the Society of Environmental Toxicology and Chemistry (SETAC) for students and young scientists, 22 – 27 February 2021, Brussels, Belgium, and online.
24. Karanja E.N. (2021): Harnessing agroecology research and knowledge to inform policies and practices. Presented at the Kenya Agroecology Anchor Hub Independent Food Systems Dialogue, 13 – 14 July 2021, Nairobi, Kenya.
25. Kassie M. (2021): The economic, food security, and health effects of fall armyworm in Ethiopia. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online.
26. Kassie M., Abro Z., Tanga C.M. and Ibrahim M. (2021): Insects for green growth and development (symposia). Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online.

27. Khaemba C. (2021): Determinants of consumers' perception of eggs derived from layer chickens fed commercial insect-based feeds. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online.

28. Koech S.J., Mokaya H.O., Kurgat J.K., Karanja R. and Lattorff H.M.G. (2021): Flowering seasons affect diversity, quality and levels of pesticide residue contamination on honeybee-collected pollen. Presented at the SETAC Africa 10th Biennial Conference, 20 – 22 September 2021, Brussels, Belgium, and online.

29. Krausa K. and Kirchner W.H. (2021) The role of stingless bees in pollination of wild and cultivated plants. Presented at the SETAC Africa 10th Biennial Conference, 20 – 22 September 2021, Brussels, Belgium, and online.

30. Krausa K., Hager F.A., Kirchner W.H. (2021): Foraging and recruitment communication of African stingless bees. Presented at the inauguration symposium of the African Section of the International Union for the Study of Social Insects (IUSSI), 25 November 2021, online.

31. Lattorff H.M.G. and Dzekashu F.F. (2021): Bees and pollen – a relationship more than pollination alone. Presented at the inauguration symposium of the African Section of the International Union for the Study of Social Insects (IUSSI), 25 November 2021, online.

32. Mathari F. and Mwende N. (2021): Companion cropping and biopesticides in management of pests in vegetables and legumes under organic farming system. Presented at the Biovision Foundation Symposium, 20 November 2021, Zürich, Switzerland.

33. Mukundamago M. (2021): Stakeholder inclusion for climate change and environmental sustainability: Pollinators in sustainable agriculture: Approaches to Bridging the gap Between Science and Societal Needs. Presented at the SETAC Africa 10th Biennial Conference, 20 – 22 September 2021, Brussels, Belgium, and online.

34. Muriithi B.W. (2021): Economic benefits of biological control to local economies. Presented at the Second International Congress of Biological Control, ICBC2, 26 – 30 April 2021, Davos, Switzerland, and online.

35. Muriithi et al (2021): Farmer perceptions and willingness to pay for novel livestock pest control technologies: A case of tsetse repellent collar in Kwale County in Kenya (based on https://doi.org/10.1371/journal.pntd.0009663). Presented at ISNTD BITES 2021, Vector Control and Vector Borne Diseases, 27 October 2021, online.

36. Muriithi et al (2021): Micro-economic impact of tsetse and trypanosomiasis control interventions on farmers' livelihoods in Kwale County, Kenya. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online.

37. Mutuku J. (2021): Telling the full story: using mixed methods to better understand women's empowerment and its correlates in central Kenya. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online.

38. Mwangi E. (2021): Improving phosphate rock use efficiency in organic farming. Presented at the Organic World Congress 2021, 6 – 10 September 2021, Rennes, France, and online.

39. Mwende N. (2021): Comparative studies on the efficacy of selected botanicals against diamond buck moth (DBM) *Plutella xylostella* L. on kales. Presented at the Organic World Congress 2021, 6 – 10 September 2021, Rennes, France, and online

40. Ndlela S., Mwando N.L., and Mohammed S.A. (2021): Advances in non-chemical postharvest disinfestation of fruits and vegetables using hot water treatment phytosanitary measures: Status and future. Presented at the Third International Phytosanitary Conference, 13 – 16 September 2021, Nairobi, Kenya, and online.

41. Ndung'u N.N., Yusuf A.A., Raina S.K., Masiga D.K., Pirk C.W.W and Kiatoko N. (2021): Nest architecture as a tool for species discrimination of Hypotrigona species (Hymenoptera: Apidae: Meliponini). Presented at the inauguration symposium of the African Section of the International Union for the Study of Social Insects (IUSSI), 25 November 2021, online.

42. Nkoba K., Pozo M.I., Oystaeyen A.V., ´van Langevelde F., Wäckers F., Kumar R.S. and Jaramillo J. (2021): Effective pollination of greenhouse Galia musk melon (*Cucumis Melo* L. Var. *reticulatus* Ser.) by Afrotropical stingless bee species. Presented at the SETAC Africa 10th Biennial Conference, 20 – 22 September 2021, Brussels, Belgium, and online.

43. Nyang'au P.N., Nzuma, J.M., Irungu P. and Kassie, M. (2021): Evaluating knowledge, beliefs and management of arboviral diseases in Kenya: a multivariate fractional probit approach. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 – 31 August 2021, Toronto, Canada, and online.

44. Ogutu F. (2021): Assessment of the feasibility of stocking a fungal based biopesticide (*Metarhizium anisopliae*) by agro-dealers in Kirinyaga County, Kenya. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online.

45. Omuse E.R., Dubois T., Wagacha J.M.., Lattorff H.M.G., Kiatoko N., Ong'amo G.O., Mohamed S.A., Subramanian S., Akutse K.S. and Niassy S. (2021): Assessment of the impact of biopesticides on the Western honeybee *Apis mellifera* and African stingless bee *Meliponula ferruginea* using laboratory and semi-field approaches. Presented at the SETAC Africa 10th Biennial Conference, 20 – 22 September 2021, Brussels, Belgium, and online.

46. Peter E. (2021): Selection and release of parasitoids and predators for mass production and release for FAW control. Presented at the Association of Southeast Asian Nations (ASEAN) Action Plan on Fall Armyworm (FAW) Biocontrol Workshop Series, organised by Grow Asia, 28 Jan 2021, online.

47. Sagwe R.N., Peters M.K., Steffan-Dewenter I. and Lattorff H.M.G. (2021): Pollinator supplementation mitigates pollination deficits in smallholder avocado (*Persea americana* Mill.) production systems in Kenya. Presented at the SETAC Africa 10th Biennial Conference, 20 – 22 September 2021, Brussels, Belgium, and online.

48. Saili K. (2021): The role of *Anopheles funestus, Anopheles arabiensis* and *Anopheles rufipes* in indoor and outdoor malaria transmission in Nyimba District, Zambia. Presented at the Insecticide Resistance Technical Advisory Committee, 20 – 21 January 2021**,** National Malaria Elimination Centre, Lusaka, Zambia.

49. Subramanian S., Akutse K.S., Mfuti D.K., Murunde R. and Ekesi S. (2021): Development of biopesticides for sustainable management of fall armyworm in East Africa. Presented at the International Congress on Invertebrate Pathology and Microbial Control and 53rd Annual Meeting of the Society for Invertebrate Pathology, SIP 2021, Le Stidium Conferences, 28 June – 2 July 2021, Tours, Loire Valley, France, and online. http://www.lestudium-ias.com/event/2021-international-congress-invertebrate-pathology-and-microbial-control-53rd-annual-meeting.

50. Tamiru A. (2021): Deciphering the chemical ecology of push-pull intercropping system in mitigating fall armyworm, *Spodoptera frugiperda*, herbivory. Presented at the 36th Annual Meeting of the International Society of Chemical Ecology, 5 – 10 September 2021, Stellenbosch, South Africa, and online.

51. Tamiru A. (2021): Exploiting thrips aggregation pheromones to develop a lure-and-kill strategy for the management of the bean flower thrips. Presented at the 6th Symposium on Palaearctic Thysanoptera, 14 September 2021, Zamardi, Hungary, and online.

52. Tamiru A. (2021): Fall armyworm induced early herbivory cues: implications for parasitoid recruitment. Presented at Research on biological control of FAW in Africa using parasitoids and predators: A meeting of the sub-group fall armyworm of the IOBC-Global International Working Group of Ostrinia and other maize pests (IWGO), 16 – 17 March 2021, Delémont, Switzerland, and online.

53. Tamiru A. (2021): Fall armyworm oviposition suppresses volatile emission in maize: effects on recruitment of egg parasitoid. Presented at the 36th Annual Meeting of the International Society of Chemical Ecology, 5 – 10 September 2021, Stellenbosch, South Africa, and online.

54. Tamiru A. (2021): Suitability of cereals and grasses as hosts of fall armyworm (*Spodoptera frugiperda* J. E. Smith). Presented at Developing smallholder oriented IPM strategies for fall armyworm management, 24 – 26 August 2021, Lilongwe, Malawi, and online.

55. Taye B. (2021): The impact of beekeeping on household per capita income: evidence from Southwest, Ethiopia. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online.

56. Tchouassi D. (2021): Bionomics of Rift Valley fever vectors associated with large wildlife herbivore loss: A simulation study. Presented at the International Branch Virtual Symposium of the Entomological Society of America, 31 October – 3 November 2021, Annapolis, Maryland, United States of America, and online.

57. Tchouassi D. (2021): Non-human primate and human-derived attractants for Aedes mosquitoes. Presented at the 36th Annual Meeting of the International Society of Chemical Ecology, 5 – 10 September 2021, Stellenbosch, South Africa, and online.

58. Teklewold H., Kassie M., Zewdu A., Mulungu K. and Sevgan S (2021): The role of pollination services and disrupting cropping patterns in closing nutrition gap in sub-Saharan Africa. Presented at the 31st International Conference of Agricultural Economists (ICAE 31), 17 –31 August 2021, Toronto, Canada, and online. https://ageconsearch.umn.edu/record/315241.

59. Tonnang H. (2021): Effect of climate change on insect pests. Presented at Unleashing the potential of plant health: CGIAR International Year of Plant Health Webinar Series, 28 January 2021. https://www.cgiar.org/iyoph-2020-webinar-series/climate-change-plant-health/

60. Torto B. (2021): An invasive weed and vectorial attributes of the malaria mosquito *Anopheles gambiae*. Presented at the Department of Plant Pathology and Entomology, North Carolina State University virtual seminar, 18 October 2021, North Carolina, United States of America, and online.

61. Torto B. (2021): Chemical ecology of native African fruit flies: pheromone discovery, development and field-validation. Presented at the Department of Zoology and Entomology Seminar Series, University of Pretoria, 4 June 2021, Pretoria, South Africa and online.

62. Torto B. (2021): Insights into use of semiochemicals for management of disease vectors in Kenya. Presented at the 36th Annual Meeting of the International Society of Chemical Ecology, 5 – 10 September 2021, Stellenbosch, South Africa, and online.

63. Torto B. (2021): Semiochemical management of fruit flies. Presented at the 75th Annual Meeting of the Subtropical Agriculture and Environments Society (SAES 2021), 12 February 2021, Texas, United States of America, and online.

64. Wangithi C. and Muriithi B.W (2021): Informal food supply chain response to COVID-19 pandemic: a case study from Nairobi, Kenya. Presented at the Early Career Research Leader Fellowship Conference, 6 – 8 July 2021, Laikipia University, Kenya.

65. Wesonga Z., Lattorff H.M.G. and Paredes J.C. (2021): Impact of acute oral exposure to paraquat and glyphosate on the African honeybee, *Apis mellifera* Lepeleiter. Presented at the SETAC Africa 10th Biennial Conference, 20 – 22 September 2021, Brussels, Belgium, and online.

The following presentations were prepared by *icipe* scientists, but the conference was postponed indefinitely just before convening:

1. Baguma J., Otema M., Ddamulira G., Naluyimba R. and Egonyu J.P. (2021): Distribution and incidence of the oil palm weevil *Rhynchophorus phoenicis* (Fabricius, 1801) (Coleoptera: Curculionidae) in selected agro-ecological zones of Uganda. An oral presentation in the Book of Abstracts of the 24th African Association of Insect Scientists Conference; Addis Ababa, Ethiopia; pp. 75.
2. Egonyu J.P., Bemwari A.R., Olubowa R.R., Nyamu F., Tanga M.C. and Subramanian S. (2021): Exploring the possibility of domestic mass production of edible flower chafer *Pachnoda ephippiata* grub (Coleoptera: Scarabaeidae). An oral presentation in the Book of Abstracts of the 24th African Association of Insect Scientists Conference; Addis Ababa, Ethiopia; pp. 123.
3. Mutisya M.M., Baleba S.B.S., Kinyuru J.N., Tanga C.M., Gicheha M., Egonyu J.P., Hailu G., Salifu D., Khan Z. and Niassy S. (2021): Effects of black soldier fly larvae and Desmodium-based diets on the sensory and physico-chemical properties of broiler chicken meat. An oral presentation in the Book of Abstracts of the 24th African Association of Insect Scientists Conference; Addis Ababa, Ethiopia; pp. 130.
4. Ochieng B.O., Anyango J.O, Nduko J.M., Khamis F.M., Egonyu J.P., Subramanian S., Cheseto X., Nakimbugwe D., Ssepuuya G., Mudalungu C.M. and Tanga M.C. (2021): Changes in bioactive compounds and nutrient composition of edible long-horned grasshopper (*Ruspolia differens* Serville) during thermal processing. An oral presentation in the Book of Abstracts of the 24th African Association of Insect Scientists Conference; Addis Ababa, Ethiopia; pp. 125.

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