



Annual Report 2023



The **Orange tortricid moth**, *Loboschiza koenigiana* (Fabricius) (Tortricidae: Lepidoptera)

Location photographed: *icipe* Thomas Odhiambo Campus, on the shores of Lake Victoria, western Kenya

This brilliantly coloured moth is a tortricid, whose larvae feeds on the leaves of the neem tree (*Azadirachta indica*). Its wing design is reminiscent of the designs of the "Kanga", a wrapper worn by women, and at time men, in the great lakes region of Africa. This insect is largely an Asian species, which is very infrequently reported in Africa. It could have been introduced along with neem tree into the continent.



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April 2024



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We also recognise specific restricted project donors, as presented in each chapter of this report.

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We appreciate the immeasurable contribution of the entire *icipe* team to this report.

Cover image: The black soldier fly, *Hermetia illucens*, has distinguished itself, within the context of mainstreaming insects in the transition to greener agriculture and circular economies. The flies do not transmit diseases or damaging plants. Also, black soldier flies are efficient organic waste recyclers – their larvae can devour a wide range of organic waste material, quickly converting it into protein and nutrient-rich organic fertilisers. The black soldier fly larvae or the proteins derived from them, can be used in livestock feeds.

All photos have been used with permission and unless otherwise specified, they belong to *icipe*.

The full-page insect photos have all been taken by our budding macro photographer, Dr Sevgan Subramanian, Principal Scientist and Head, Environmental Health Theme.

Contents

FOREWORD	04	PLANT HEALTH THEME	38	TECHNOLOGY TRANSFER UNIT	88
PREFACE	05	Push-Pull Integrated Pest Management	40	DATA MANAGEMENT MODELLING AND GEO-INFORMATION UNIT (DMMG)	94
MANAGEMENT AND LEADERSHIP	06	Push-Pull Impact on Soil Health	42	CAPACITY BUILDING AND INSTITUTIONAL DEVELOPMENT PROGRAMME	100
2023 Timeline	08	Fall Armyworm Management	43	BIOINNOVATE AFRICA PROGRAMME	106
Resource Mobilisation	10	Fruit Pests IPM	46	REGIONAL SCHOLARSHIP AND INNOVATION FUND (RSIF)	114
New Partnerships	11	Vegetable IPM	50		
Communications	14	Tomato Leafminer Management	52		
Scientific Publications	15	Research on Nematodes	54		
Awards and Recognitions	16	ENVIRONMENTAL HEALTH THEME	58		
Acknowledgement	17	Bee Research	60		
HUMAN HEALTH THEME	18	More Young Entrepreneurs in Silk and Honey (MOYESH) Project	64		
Malaria Research	20	Bioprospecting	67		
Neglected Tropical Diseases	23	Biosystematics	68		
Emerging and Re-Emerging Viruses	26	INSECTS FOR FOOD, FEED AND OTHER USES PROGRAMME	70		
One Health	28	Insects for Food	72		
ANIMAL HEALTH THEME	30	Insects for Soil Health	76		
Tsetse Fly Management	32	Insects for Other Uses	78		
Tick Management	34	SOCIAL SCIENCE AND IMPACT ASSESSMENT UNIT	80		
Biting Flies Management	36				
Livestock Rumen Mechanisms	36				

Foreword



Prof. Kym Anderson
Chair,
icipe Governing Council

The “turbulent twenties”. This is a moniker that the 2020s decade has already aptly earned.

Indeed, according to the *Global Risks Report 2023*, published by the World Economic Forum, we are seeing a return of old risks against a backdrop of new concerns, all converging to create a unique, uncertain and tumultuous scenario. The top current risks, as presented in that report, are energy and security, inflation and the overall cost of living. During the next two years, the cost-of-living crisis will be the number one threat, followed by natural disasters and trade and technology wars. In 10 years, climate and environmental risks, with biodiversity loss and ecosystem collapse, will be the most rapidly increasing global risks.

But as that report notes, there is still a window for the world to shape a more secure future through better foresight and preparedness. While cautioning against context-specific, defensive, fragmented and crisis-oriented approaches, the review proposes four principles for preparedness. As we present this Annual Report, we at *icipe* reflect on these principles, their rationale according to the *Global Risks Report*, and our Centre's current and potential contributions to the expected outcomes.

Improving risk identification and foresight:

While a wide range of disciplines are being employed worldwide to gather intelligence about the future, improvements are needed to enable strategic decision-making, agenda-setting and resilience measures, to prioritise data collection, and to monitor risk control, resources and redundancies. Using novel tools, methods and research strategies, *icipe* is generating insights on factors such as the surging risk of indigenous and invasive crop pests and disease vectors, emerging and reemerging viruses, and threats to insect biodiversity; the interdependencies with aspects such as climate change, human activities and landscape changes; and the consequences for food and livelihood security.

Rethinking future risks:

Cognitive biases channel public policy and response attention towards recent “catastrophic” events. As a result, the world is still largely unprepared for the most severe global risks – especially those pertaining to climate and nature. *icipe's* prediction, modelling and quantification studies can serve as proxies to rescript risk. They offer a holistic view of food systems disruptors and stressors such as insects, poor soils, drought and climate change; risk-reducing interventions; reciprocity of diseases; and the imperative to incorporate vectorborne diseases into healthcare systems strengthening.

Investing in multi-domain, cross-sector risk preparedness:

Actions taken to address current challenges should avoid exacerbating future risks such as the potential trade-off between food security, nature loss and climate change. Thus, preparedness should be a shared responsibility between sectors. With over 300 partners across Africa and beyond, *icipe* has entrenched interdisciplinary and multidisciplinary, participatory, collaborative approaches in all its activities. We have demonstrated that One Health, nature-based approaches that balance and optimise benefits for people, animals and the environment are impactful in tackling many global risks.

Re-building and strengthening global risk preparedness cooperation:

While national risk preparedness can enhance the ability of societies and economies to rebound from shocks, many risks require coordinated global action. While international organisations will continue to play a key role, cooperation at sectoral, bilateral and regional levels also is vital. *icipe* is a recognised partner in international efforts to deal with various threats associated with the current crisis. We aim to continue playing this role, alongside our regional leadership in bolstering collaborative action and frameworks and boosting Africa's capacity to use science, technology and innovation to tackle global risks.

Preface



Dr Abdou Tenkouano
Director General, *icipe*

In January 2024, I commenced my tenure as the Director General of *icipe*. I am honoured to join this eminent institution, as well as the rhythm of harmony and evolution set by my predecessors.

This annual report reinforces two indisputable facts: *icipe*'s prime place in the global knowledge hub, and the Centre's contribution to Africa's socio-economic transformation.

The publication is segmented around 12 chapters. The prelude is the Management and Leadership chapter, which opens with a 2023 timeline – a snapshot of the events that *icipe* hosted or participated in, and the visitors that we received. The chapter also outlines growing investments, collaborations, publicity and visibility, as well as recognitions of the Centre and its staff, by national, regional and global partners.

Five chapters of this report are dedicated to *icipe*'s research and development achievements across our 4Hs thematic areas: Human Health, Animal Health, Plant Health and Environmental Health; as well as the emerging Insects for Food, Feed and Other Uses programme.

In these chapters, we highlight our progress to bolster Africa's preparedness to tackle insect-transmitted ailments such as malaria, neglected tropical diseases, including leishmaniasis and tungiasis, as well as emerging and re-

emerging viruses, which are causing a resurgence of diseases like yellow fever, dengue fever and Rift Valley fever. *icipe*'s breakthroughs in the control of tsetse flies, biting flies and ticks, and novel insights on the mechanisms in animal rumen, will contribute to sustainable livestock keeping in Africa.

Meanwhile, we are tackling many historical and emerging burdens faced by African farmers, including a plethora of indigenous and invasive crop pests, poor soils and climate change, while reducing overreliance on synthetic pesticides and inorganic fertilisers.

Through modern, integrated beekeeping and sericulture value chains, *icipe* is boosting environmental rehabilitation and protection of vulnerable landscapes, while creating profitable, inclusive business models.

We are also mainstreaming insect biodiversity protection, and demonstrating beneficial insects as an excellent example of a One Health platform that extends from crop improvement, to the health of people, animals and the environment.

icipe's innovations are nature-based, and climate-smart. They are aiding the production of more, safer and nutritious food, creating novel income generation opportunities especially for women, youth and marginalised communities, and pivoting circular economies.

Three chapters of this report focus on the pivotal roles played by the: Social Science and Impact Assessment Unit, which continues to flag factors around the adoption, economic benefits, and gender inclusiveness of our technologies and strategies; the Technology Transfer Unit, which is critical in re-aligning our dissemination efforts for better upscaling of our innovations; and the Data Management, Modelling and Geo-Information Unit that is integrating advanced data analytics and approaches into our initiatives.

icipe's commitment to nurturing young African scientific talent and to bolstering research and innovation excellence in Africa, is captured under the Capacity Building and Institutional Strengthening Unit; BioInnovate Africa Programme; and Regional Scholarship and Innovation Fund (Rsif) chapters.

All the chapters of this report are prefixed by overviews of *icipe*'s contributions to: world class scientific knowledge; inclusive innovations; policy; One Health; and the creation of circular economies.

MANAGEMENT AND LEADERSHIP

Core donors: Swedish International Development Cooperation Agency (Sida); Swiss Agency for Development and Cooperation (SDC); Australian Centre for International Agricultural Research (ACIAR); Norwegian Agency for Development Cooperation; Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ); and Government of the Republic of Kenya (Ministry of Education, State Department of University Education and Research).

icipe Governing Council

Prof. Kym Anderson (Australia) Chair	(Left in 2023)
Dr Ylva Hillbur (Sweden) Vice Chair	Mr Jim Park (USA) Chair, Audit and Finance Committee
Prof. Ted Turlings (Netherlands) Chair, Programme Committee	Prof. Hamadi Boga (Kenya)
Dr Ignace Gatara (Rwanda) Chair, Nominating Committee	
Dr Michel Eddi (France) Chair, Audit and Finance Committee	
Prof. Dr-Ing. Alexander Mathys (Switzerland)	
Prof. Daniel Chamovitz (Israel)	
*Prof. Faith Osier (Kenya)	
*Prof. Folasade Ogunsola (Nigeria)	
*Dr Francine Ntoumi (Congo)	
Dr Morven A. McLean (United States)	
Prof. Ingrid Öborn (Sweden)	
Ambassador (Dr) Amina C. Mohamed, EGH, CAV. (Kenya)	
Abdou Tenkouano (Burkina Faso) Director General, Governing Council and Ex-officio Member	
*Joined in 2023	

2023 IN BRIEF

Timeline

A snapshot of events we hosted or participated in, and visitors to *icipe*.

Resource mobilisation

Overview of donor agreements; core donors; new donors and project donors.

Partnerships

New memoranda of understanding; project partner agreements; material transfer agreements; and contractual agreements.

Communications

News mentions; top stories; audience reach; geographical reach and social media reach.

Scientific publications

Peer-reviewed journal articles; and books, other publications and poster presentations.

Awards

External and internal awards and recognitions made to *icipe*, staff and students of the Centre.

Staff news

67 new staff recruited, bringing the total to 571.

Acknowledgement

Dr Segenet Kelemu, *icipe* Director General (November 2013 – December 2023); and Mr Gatigwa Kimana, *icipe* Director of Finance and Administration (May 2014 – April 2024)

2023 Timeline

The Director General (DG) visited *icipe* projects in Ethiopia and held meetings with partners and senior Government officials. *icipe* researchers participated in the One CGIAR TAFS-WCA stakeholders' engagement meeting; WHO Department of Control of NTDs and the End Fund meeting on elimination of visceral leishmaniasis in East Africa; and the Kenya Ministry of Health, Division of Vector Borne and NTD commemoration of the world NTDs. Visitors to *icipe* included: Members of Parliament of Canada, and partners from IDRC and Canadian Foodgrains.

The DG participated in: a roundtable on Embracing Equity in Research and Development at the World University Services of Canada, in line with the International Women's Day 2023 campaign and the IDRC Strategy 2030; the launch of DELTAS Africa II; and the Science for Africa partners' group. Visitors to *icipe* included: Dr Mirjam Macchi Howell, Policy Advisor, 2030 Agenda and Research, Analysis and Research Division, SDC; representatives from Google Research; members of the Tropical Medicine Research Centers; and officials from the IGAD Center for Pastoral Areas & Livestock Development. *icipe* researchers participated in the MRS4DM project update meeting at the European Space Agency headquarters; One Health conference organised by GIZ in Hargeisa, Somaliland; and workshop on the use of biopesticides on fall armyworm, organised by CNRADA, Mauritania.

The DG received an Honorary Doctor of Philosophy degree from Ben Gurion, University of Negev, Israel, and was decorated with the title of Officer in the National Order of Merit, of France. She participated in the Visions for a Sustainable Agriculture meeting at the University of Neuchâtel, Switzerland; and in the virtual Stockholm Environment Institute Board meeting. Visitors to *icipe* included: Dr Claes Kjellström and Dr AnnaKarin Norling (Sida); Prof. Wondwossen Gebreyes, Ohio State University, Global One Health Initiative; and Dr Patrice Grimaud, Regional Director –Eastern Africa, CIRAD. *icipe* participated in Tsetse Fly Population Genetic Studies training, supported by IAEA; the Crimean Congo Haemorrhagic Fever Africa meeting; Malaria Gordon Research Seminar and Conference; and the 28th International Working Group on Ostrinia and other maize pests meeting at KEPHIS.

January

February

March

April

May

June

The DG participated in the PASET Governing Council meeting; AIRCA meeting of DGs; and held discussions with a team from ICBA. Ms Silje Maria Hanstad, Senior Adviser, Department for Climate and Environment, Norad, visited *icipe*. The Centre's researchers participated in the annual meeting of the RBM Partnership Working Group on Malaria Vector Control; inception meeting of the AgEcolPM project; symposium on African Livestock Trypanosomiasis, Tanzania (SALT-Tz); colloquium on 'Harnessing mosquito symbionts for malaria transmission blocking' at Princeton University; H3ABioNet symposium, celebrating 10 years of advancing bioinformatics research in Africa; and UPSCALE project second general assembly and regional stakeholders meeting.

The DG participated in the European Initiative for Agricultural Research for Development dialogue meeting and the ACIAR Policy Advisory Council meeting; and met with Dr Sarah M. Schmidt, Advisor, GIZ. Visitors to *icipe* included: Dr Kathrin Knodel, Programme Officer – Africa, DFG; Dr Jimmy Smith, Director, International Programs, University of Maryland, USA; Dr Thierry Brevault, insect ecologist, CIRAD; Dr Meredith C. Schuman and Dr Daria Maria Odermatt, UPSCALE project partners, University of Zurich; and a delegation from the National Universities Commission of Nigeria.

The DG participated in the Animal Health Governance and Policy Workshop, organised by the University of Tennessee, USA; and held virtual discussions with the US Department of State on *icipe*'s One Health activities, and Dr Nathalie Gabala, Executive Director, Mastercard Foundation. Visitors to *icipe*: (from ACIAR) – Dr Julianne Biddle, Director of Multilateral Engagement, Ms Eleanor Dean, Global Manager, Outreach and Capacity Building and Dr Leah Ndungu, Regional Manager for Eastern and Southern Africa. *icipe* researchers participated in the CultiAF conference themed: 'Enabling Resilient, Equitable and Sustainable Food Systems; and the CAP-Africa end-of-project meeting. *icipe* and FAO hosted the Global Forum on Biological Control and training workshop.

2023 Timeline

The DG participated in the Science Foo Camp organised by Digital Science, Google and O'Reilly Media in California, USA; and the UN Food Systems Summit +2 Stocktaking Moment in Rome, Italy. The Centre's researchers participated in the 'Bioeconomy in action' forum organised by the Colombian Ministry of Science, Technology and Innovation and SEI Centre of Latin America; workshop on 'Locust outbreaks and new technologies to improve monitoring, forecasting and control'; IALE 2023; and the 2023 IEEE International Geoscience and Remote Sensing Symposium (IGARSS); annual Geo-Zone workshop of the regional plant protection task force organized by FAO. Visitors to *icipe* included: Mr Johan Sävström, Science Communicator / Research Advisor, Sida; and officials of the Italian Agency for Development Cooperation.

July

August

September

October

November

December

The DG participated in the SEI Board Meeting in Sweden, and Regional Council meeting in Latin America; and the ACIAR Policy Advisory Council meeting. Visitors to *icipe*: Directors of the IKEA Foundation; Dr Sophie Thévenon, CIRAD Deputy Director of INTERTRYP; and a team from VIB-International Plant Biotechnology Outreach (IPBO). *icipe* researchers participated in the International Scientific Council for Trypanosomiasis Research and Control (ISCTRC); Tropentag 2023 conference; Biovision Foundation Annual Partners Convening Workshop and 25th anniversary celebrations; 9th PAMCA Conference and Exhibition; INSECTA 2023; and African Association of Agricultural Economics conference.

The DG participated (as a juror) in the Falling Walls Lab Finale; the Food and Land Use Coalition ambassadors COP28 planning; and launch of the AWARD Strategy 2023-2027. Visitors included Dr Kjersti Thorkildsen, Senior Adviser, Norad; delegation from Swedish Embassy bilateral Kenya division; Dr Mariana Kim, Program Officer, Bill & Melinda Gates Foundation; and journalists from Germany. *icipe* hosted the Horticultural Association of Kenya annual workshop; and participated in: the 2023 Global One Health Symposium; Biovision Foundation Annual Symposium; Earth Observation and Environmental Sensing for Climate-Smart Sustainable Agropastoral Ecosystem Transformation in East Africa seminar and workshop; 40th General Assembly of the ICSC – World Laboratory at the European Organization for Nuclear Research (CERN); Consortium Meeting of the Data Science for Health Discovery and Innovation in Africa (DS-I Africa).

The DG met with Ms Wambui Chege, Director, Agrifood Systems and Climate, Mastercard Foundation; held virtual discussions with representatives of the Mastercard Foundation on expansion of collaboration and participation in the Africa Climate Week 2023 Summit; and participated in the Plant Health 2023 meeting themed, 'LINKS to a Sustainable Future'. *icipe* researchers participated in the Leishmaniasis Vector Biology Course; and Rockefeller Foundation Partners' Reception; and the American Chemical Society (ACS) Fall 2023. Dr Bill S. Hansson, Director, Max Planck Institute for Chemical Ecology, Germany gave two seminars at *icipe* on insect communication and migratory locusts.

The DG delivered a lecture on innovations in insect science at the 59th Nobel conference; participated in the Food and Land Use Coalition cross party group meeting; and the Annual Meeting of the National Council for Science and Technology, Rwanda. *icipe* researchers participated in the: Breaking barriers: Advancing the One Health Agenda meeting; Global Symposium on Sustainable Fall Armyworm Management; Innovation Platform and Advocacy Group workshop in Ethiopia; 8th African Livestock Exhibition and Congress; the Norman E. Borlaug International Dialogue hosted by the World Food Prize Foundation and the Global Youth Institute; and the Bioeconomy and Food Systems at the FAO science summit.

The DG participated in the PABRA and Africa Food Prize event, during AGRF 2023; and in the Food and Land Use Coalition cross party group meeting. *icipe* researchers attended the Wellcome Infection & Immunobiology Early-Career Advisory Group; and the Mass Youth Employment in Apiculture (MaYEA) programme onboarding meeting, and Partners Annual Learning Summit, with the Mastercard Foundation. Visitors included: Dr Lénaïg Halos, Senior Program Officer, Bill & Melinda Gates Foundation. Rsif and the Ministry of Science, Technology and Higher Education, Mozambique hosted a project implementers forum.

Resource Mobilisation

Overview

USD 30.3 million: Total value of signed donor agreements for strategic long-term funding and restricted projects.

USD 15.4 million: Total value of contracts for restricted projects approved by donors, pending signatures.

USD 16.2 million: Total value of restricted projects proposals submitted to various donors, which were at various stages of review.

Core donors

Swedish International Development Cooperation Agency (Sida); Swiss Agency for Development and Cooperation (SDC); Australian Centre for International Agricultural Research (ACIAR); Norwegian Agency for Development Cooperation; Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ); and Government of the Republic of Kenya (Ministry of Education, State Department of University Education and Research).

New donors

James Huton Institute; One CGIAR Secretariat through International Food Policy Research Institute (IFPRI); Grand Challenges Canada (GCC); Leibniz Centre for Agricultural Landscape Research (funding from European Space Agency).

Investors in PASET-Rsif

African governments: Benin, Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Mozambique, Nigeria, Rwanda and Senegal. In addition: World Bank; Government of South Korea; ACP Innovation Fund of the European Union through the Organisation of African, Caribbean and Pacific States (OACPS); and Carnegie Corporation of New York.

Project donors

African Union; African Academy of Sciences; Bertha Foundation; Bill & Melinda Gates Foundation; BioInnovate Africa Programme; Biotechnology and Biological Sciences Research Council, UK, through Rothamsted Research and Keele University (both in the UK); Biovision Africa Trust; Biovision Foundation for Ecological Development, Switzerland; British Council-Newton Fund Institutional Links; Canadian Executive Service Organization (CESO-SACO); Cambridge Africa ALBORADA Research Fund; Chalmers University of Science Technology; Children's Investment Fund Foundation (CIFF); Code for Science & Society (CS&S); Cordaid; Cultivate Africa's Future Fund (CultiAF), a partnership between the International Development Research Centre (IDRC) and the Australian Centre for International Agricultural Research (ACIAR); Danish International Development Agency (DANIDA); Desert Locust Control Organization of Eastern Africa (DLCO-EA); ETH Zurich; Ethiopian Catholic Church Social Development Commission (ECC-SDCBOM); European Union; Federal Ministry for Economic Cooperation and Development (BMZ), Germany, through the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ); German Aerospace Centre; German Research Foundation (DFG); Food and Agriculture Organization of the United Nations (FAO); French National Research Institute for Sustainable Development (IRD); French Agricultural Research Centre for International Development (CIRAD); Bayer: Science for a Better Life; German Academic Exchange Service (DAAD); Global Challenges Research Fund (GCRF); Impaxio GMBH; Innovate UK; Institute of Research for Development (IRD); InsectiPro Ltd; International Atomic Energy Agency (IAEA); International Development Research Centre (IDRC); International Fund for Agricultural Development (IFAD); IKEA Foundation; iMC Worldwide; JRS Biodiversity Foundation; Keele University, UK; Kenya Education Network; LEAP-Agri (A Long-term EU-Africa research and innovation partnership on food and nutrition security and sustainable agriculture); Mastercard Foundation; Max Planck Institutes, Germany; Medical Research Council, UK; Mozilla Foundation; Ministry for Primary Industries, New Zealand; National Geographic Society; National Research Fund (NRF), Kenya; National Science Foundation (NSF), USA; Netherlands Organisation for Scientific Research (NWO); Norwegian Agency for Development Cooperation (Norad); Norwegian Refugee Council (NRC); Novo Nordisk Foundation, Denmark, through Impact Designs; One CGIAR Secretariat through CIMMYT and ILRI; Open Philanthropy; Participatory Ecological Land Use Management, Kenya; Pennsylvania State University, USA; Research Institute of Organic Agriculture (FiBL); The Rockefeller Foundation; Rothamsted Research, UK; Remote Sensing Solutions (RSS) GmbH, Germany; Scottish Funding Council; Swedish International Development Cooperation Agency (Sida); Swedish University of Agricultural Sciences (SLU); Swiss Agency for Development and Cooperation (SDC); Swiss National Science Foundation (SNSF); The Curt Bergfors Foundation Food Planet Prize; The Royal Society, UK; The Royal Society to Future Leaders – African Independent Research (FLAIR); The Stichting IKEA Foundation through Biovision Foundation for Ecological Development; TWAS, The World Academy of Sciences through the Organization for Women in Science for the Developing World (OWSD); United Nations Environment Programme (UNEP); United Nations Office for Project Services (UNOPS); United States Agency for International Development (USAID); USAID-Partnerships for Enhanced Engagement in Research (USAID-PEER) Science program with funding from the National Academy of Sciences (NAS); United States Department of Agriculture (USDA); United States National Institutes of Health (NIH); University of Bern, Switzerland, through GIZ; University of Cambridge, UK; University of Glasgow, Scotland, UK; University of Eastern Finland; University of Leeds, UK; United States Agency for International Development (USAID)-funded IPM Innovation Lab (Feed the Future Innovation Lab for Integrated Pest Management) of Virginia Tech, USA; Wageningen University & Research, The Netherlands; Wellcome Trust, UK; World Federation of Scientists; World Health Organization (WHO); World Trade Organization (WTO) – Enhanced Integrated Framework (EIF).

*All information as of December 2023

New Partnerships

Project Partnership Agreements

Organisation/partner	Project
Farm Concern International Makerere University, Uganda Kenya Marine and Fisheries Research Institute (KMFRI) Total Land Care National Agricultural Research Organisation (NARO), Uganda	Upscaling the benefits of insect-based animal feed technologies for sustainable agricultural intensification in Africa (PROTeinAfrica)
Kenya Marine and Fisheries Research Institute	Development and scaling of sustainable feeds for resilient aquatic food systems in sub-Saharan Africa
Kenya Agriculture and Livestock Research Organization (KALRO)	Long term comparison of organic and conventional farming systems in the tropics (SysCom)
Liverpool School of Tropical Medicine, UK	Ecological and genetics drivers of persistent <i>Plasmodium</i> transmission by <i>Anopheles Funestus</i> , a major malaria vector in Kenya
National Agricultural Research Organisation (NARO), Uganda	Development, testing and scaling of maize and vegetable IPM in Eastern Africa
Tanzania Agricultural Research Institute (TARI)	Demand-driven interventions for implementing agroecological based and gender inclusive IPM technologies to enhance safe fruit production and among smallholder farmers in East Africa

Memoranda of Understanding (MoUs)

Party	Purpose
Kisii University, Kenya	Collaboration in scientific research, knowledge exchange, capacity and institutional development
Bonga University, Ethiopia	Collaboration in scientific research, knowledge exchange, human capacity and institutional development
Rheinische Friederich-wilhelms-University of Bonn (ZEF), Germany	Collaboration in scientific research, knowledge exchange, capacity and institutional development
Ethiopian Public Health Institute, Ethiopia	Collaboration in scientific research, knowledge exchange and capacity development
Prezode (Preventing Zoonotic Disease Emergence)	Declaration of intent in support of the Prezode International Initiative
Jerusalem Children and Community Development Organisation (JECCDO), Ethiopia	Collaboration in the MOYESH project joint implementation in Zegie Peninsula, West Gojjam Zone, Amhara Region
The African Organisation for Standardisation (ARSO)	Collaboration in standardisation and conformity assessment in the field of insects for food and feed and bee farming
Rwanda Biomedical Centre	Collaboration in scientific research, knowledge exchange and capacity development
Faculty of Sciences of the University of Maroua, Cameroon	Collaboration in scientific research, knowledge exchange, capacity and institutional development under the JRS Biodiversity Grant N70054
Institute of Agricultural Research for Development, Cameroon	Collaboration in scientific research, knowledge exchange, capacity and institutional development under the JRS Biodiversity Grant N70054

New Partnerships

Material Transfer Agreement (MTA)

Party	Purpose
University of Melbourne, Australia	An investigation of drivers of virus transmission and the potential for Wolbachia-based transmission blocking in Kenya
Foundation for Innovative New Diagnostics (FIND), Geneva, Switzerland	Confidentiality Agreement: Exchange confidential or commercially sensitive information concerning data on leishmaniasis from areas of Kenya
Mastercard Foundation	Data transferor desires to share personal data to data recipients to carry out the impact Monitoring and Evaluation works in relation to the program by the data recipients
Kenya Medical Research Institute – Centre for Vector-Borne Disease Control (KEMRI-CVBDC)	Transfer of 2000 <i>Anopheles Arabiensis</i> eggs (Mwea strain)
World Mosquito Program Ltd	Strain of mosquito transfected with the wMel strain of Wolbachia bacterium sample acquire
Global Alliance for Livestock Veterinary Medicines (GALVMed)	To explore potential collaborations for developing and commercialising a biomarker-based diagnostic test for Africa Animal Trypanosomiasis
Global Biodiversity Information Facility (GBIF)	Provide Data Centre with a DOI provisioning service identified by a unique DOI prefix
BEI Resources	Request for clinical isolates of two antibiotic-resistant bacteria
Michigan State University, USA	Request for Material-(Wolbachia wAlbB-infected <i>Aedes aegypti</i> WBH line)
Mpala Research Centre Laikipia Conservancy Association, Kenya; Princeton University, USA; Wildlife Research and Training Institute (WRTI) and Kenya Wildlife Service (KWS)	MoA - Disentangling Ecological Cascades. Prior Informed Consent (PIC) - Access and utilization of dung beetle biological resources and covariate information in Kenya
Global Alliance For Livestock Veterinary Medicines	Material transfer agreement for the collaborative project of the research programme
KEMRI; Pwani University, Kenya; <i>icipe</i> ; Genome Research Limited (GRL); KWS; University Court of the University of Glasgow, Scotland; Liverpool School of Tropical Medicine (LSTM), UK; and WRTI	Mosquito Genetic Diversity, Bionomics Insecticide Resistance in Kenya

New Partnerships

Bioinnovate Africa Programme Collaboration agreements

Organisation	Project
IITA, <i>icipe</i> , Bio-Corn Products EPZ Ltd, Kenya and International Fertilizer Development Center (IFDC)	Deployment of a novel biodegradable carrier for efficient crop protection
Egerton University, Kenya, Farmtrack Consulting Ltd, Kenya, <i>icipe</i> , The Open University of Tanzania and University of Rwanda	Developing plant-based insecticides for controlling maize storage insect pests and other insect pests of economic relevance to farmers in East Africa

Rsfif Junior Investigator Research Award (JIRA)

Organisation	Project
Mt Kenya University, Kenya	Innovative steps for utilising seaweeds along the Kenya coast as a source of sustainable food and health-promoting bioactive components
Masinde Muliro University of Science and Technology, Kenya	Profiling of earthworm microbiota and enzymes for vermicomposting ability

PASET-Rsif

Tripartite agreements with international partner institutions (IPIs)

for the sandwich placement of Rsif PhD scholars from African host universities (AHUs) in the IPIs with *icipe* as the Regional Coordination Unit (RCU) of Rsif

IPi	AHU
Korea Institute of Science and Technology	Sokoine University of Agriculture (SUA), Tanzania
Mohammed VI Polytechnic University	Nelson Mandela African Institution of Science (NM-AIST), Tanzania
Korea Institute of Energy and Research	Nelson Mandela African Institution of Science (NM-AIST), Tanzania
Worcester Polytechnic institute (WPI), Massachusetts, USA,	Sokoine University of Agriculture (SUA), Tanzania
Worcester Polytechnic institute (WPI), Massachusetts, USA,	Université Gaston Berger of Saint-Louis, Senegal
Worcester Polytechnic institute (WPI), Massachusetts, USA,	Kenyatta University, Kenya
Korea Institute of Energy Research (KIER),	Kenyatta University, Kenya
IMT MINES ALBI (IMTA), France,	Kenyatta University, Kenya
International Livestock Research Institute (ILRI),	Sokoine University of Agriculture, Tanzania
Korea Institute of Science and Technology	African University of Science and Technology, Abuja, Nigeria.
Nestlé	Nelson Mandela African Institution of Science (NM-AIST), Tanzania
International Livestock Research Institute (ILRI)	Université Félix Houphouët-Boigny, Côte d'Ivoire
Rochester Institute of Technology (RTI), New York, USA,	University of Rwanda
Mohammed VI Polytechnic University, Morocco	University of Rwanda
University of Pretoria, South Africa	Sokoine University of Agriculture (SUA), Tanzania
Karlsruhe Institute of Technology, Germany	Nelson Mandela African Institution of Science (NM-AIST), Tanzania

Communications

Media Publicity

1.14 billion people

potential reach

of the *icipe* media coverage

1031

media mentions

of *icipe* in items that were published and broadcast locally and internationally in 258 publications, in 49 countries worldwide

236K

*social media impressions

- 6306 mentions on Twitter
- 614 mentions on Facebook
- 80 mentions in Blogs

10

top countries

in which *icipe* received media coverage were: United States, Kenya, Sweden, Switzerland, South Africa, United Kingdom, Uganda, India, Nigeria, Australia, China and Ghana

top media

All the leading Kenyan print and electronic media; eastern African media including: The Independent, Uganda; New Times, Rwanda and Ethiopian Herald; regional media including: Farmers Review Africa, AllAfrica.com, The Herald Zimbabwe and Zimbabwe Star; international media including: Sweden Posts, CNBC, HydroWorld, Seedquest.com, Vietnam Explorer News Channel and Mongabay, Indonesia

68,570

website visits

and 497,142 page views registered on the *icipe* website. The top countries (ranked in order of visitor numbers) were: Kenya, United States, Ethiopia, Netherlands, India, United Kingdom, Germany, Uganda, China, South Africa

*Mentions are the number of posts that refer to *icipe*
Impressions are the number of times the posts have been viewed.

Scientific Publications

In 2023, *icipe* published and produced:

290 Peer-reviewed journal articles

223 Articles in open access or open access model journals

210 Articles in high impact factor journals, including niche journals (impact factor above 2)

179 Articles in collaboration with national agricultural research systems (NARs)

4 Book chapters

3 Editorial articles

18 Conference proceedings

The peer-reviewed journal articles received:

283 citations

200,704 abstract views

214,725 full-text views/downloads

Top 9 ranked papers based on impact factor and online attention:

****Tanga, C. M., & Ekesi, S. (2024).** Dietary and therapeutic benefits of edible insects: A global perspective. *Annual Review of Entomology*, 69(1). <https://doi.org/10.1146/annurev-ento-020123-013621>

IF 23.8 (1 citation)
ALTMETRIC (43 readers on ResearchGate)

****Torto, B., & Tchouassi, D. P. (2024).** Chemical ecology and management of dengue vectors. *Annual Review of Entomology*, 69(1). <https://doi.org/10.1146/annurev-ento-020123-015755>

IF 23.8 (1 citation)
ALTMETRIC (113 readers on ResearchGate)

Khamis, F. M. (2023). Combating the unseen enemy of yam. *Nature Food*, 4(2), 141. Springer Nature. <https://doi.org/10.1038/s43016-023-00709-w>

IF 23.2 (117 accesses, 1 citation)
ALTMETRIC (33 readers on ResearchGate)

****Kariim, I., Park, J. Y., Kazmi, W. W., Swai, H., Lee, I. G., & Kivevele, T. (2024).** Solvothermal liquefaction of orange peels into biocrude: An experimental investigation of biocrude yield and energy compositional dependency on process variables. *Bioresource Technology*, 391, 129928. <https://doi.org/10.1016/j.biortech.2023.129928> (Rsif)

IF 11.4 (1 citation)
ALTMETRIC (5 readers on Mendeley, 32 readers on ResearchGate)

Tarus, B. K., Jande, Y. A. C., & Njau, K. N. (2023). Electrospun carbon nanofibers for use in the capacitive desalination of water. *Carbon*, 203, 897. <https://doi.org/10.1016/j.carbon.2022.11.089> (Rsif)

IF 10.9 (5 citations)
ALTMETRIC (29 readers on ResearchGate)

*Names in italics denote *icipe* authors **Published in 2023, issue date 2024

Mbouteu Megaptche, C. A., Moses Musau, P., Virginie Tjahè, A., Kim, H., Waita, S., & Odhiambo Aduda, B. (2023). Demand response-fuzzy inference system controller in the multi-objective optimization design of a photovoltaic/wind turbine/battery/supercapacitor and diesel system: Case of healthcare facility. *Energy Conversion and Management*, 291, 117245. <https://doi.org/10.1016/j.enconman.2023.117245> (Rsif)

IF 10.4 (2 citations)
ALTMETRIC (17 readers on Mendeley, 22 readers on ResearchGate)

Ullah, Z., Yoon, N., Tarus, B. K., Park, S., & Son, M. (2023). Comparison of tree-based model with deep learning model in predicting effluent pH and concentration by capacitive deionization. *Desalination*, 558, 116614. <https://doi.org/10.1016/j.desal.2023.116614> (Rsif)

IF 9.9 (3 citations)
ALTMETRIC (12 readers on Mendeley, 16 readers on ResearchGate)

Beesigamukama, D., Tanga, C. M., Sevgan, S., Ekesi, S., & Kelemu, S. (2023). Waste to value: Global perspective on the impact of entomocomposting on environmental health, greenhouse gas mitigation and soil bioremediation. *Science of The Total Environment*, 902, 166067. <https://doi.org/10.1016/j.scitotenv.2023.166067>

IF 9.8 (1 citation)
ALTMETRIC (57 readers on Mendeley, 253 readers on ResearchGate)

Mwelwa, S., Chungu, D., Tailoka, F., Beesigamukama, D., & Tanga, C. (2023). Biotransfer of heavy metals along the soil-plant-edible insect-human food chain in Africa. *Science of the Total Environment*, 881, 163150. <https://doi.org/10.1016/j.scitotenv.2023.163150>

IF 9.8 (15 citations)
ALTMETRIC (25 Facebook pages, 34 readers on Mendeley, 84 readers on ResearchGate)

Awards and Recognitions

In 2023, *icipe* and several of the Centre's staff received a variety of external and internal awards and recognitions:

7

awards and recognitions given to *icipe* staff by external institutions

10

awards given to *icipe* scholars by external institutions

6

awards given by the *icipe* Governing Council to the Centre's scholars for research publications and posters

Notable awards

icipe Director General, **Segenet Kelemu** received an honorary degree of Doctor of Philosophy Honoris Causa from Ben-Gurion University of the Negev, Israel, for her outstanding scientific leadership in helping build a food secure Africa. She was also decorated with the title of Officier de L'Ordre national du Mérite (Officer in the National Order of Merit). In addition, she was appointed by the Government of Sweden as a Board member of Stockholm Environment Institute (SEI) and was elected Fellow of the International Society of Plant Pathology.

Sunday Ekesi, Head, Capacity Building and Integrated Sciences, received the TWAS Award in Agricultural Sciences, conferred by The World Academy of Sciences, for his impactful contributions to fruit fly management, thus facilitating the growth of the horticulture industry in Africa.

Baldwyn Torto, Head, Behavioural and Chemical Ecology Unit (BCEU), was elected as an International Member of the United States National Academy of Sciences (NAS).

Beatrice Nganso, Scientist, Environmental Health Theme, was a 2023 COLOSS Panuwan Chantawannakul awardee, for a proposal titled: "A survey of managed honeybee colony losses in two sub-Saharan African countries".

Robert Jackson, Visiting Scientist, Research Predatory Arthropods, was awarded an honorary membership to the International Society of Arachnology.

Seven *icipe* scientists were in the 'World Ranking of Top 2% Scientists' (2023) list released by Elsevier. They are: Sunday Ekesi, Zeyaur Khan, Menale Kassie, Tanga Mbi, Tadele Tefera, Dan Masiga and Baldwyn Torto.

Julia Muita (MSc scholar, Kenya), was ranked first for her poster titled: 'The Role of *Stomoxys* spp. in animal trypanosomosis transmission dynamics', at the 36th General Conference of the International Scientific Council for Trypanosomiasis Research and Control (ISCTRC), held in Mombasa, Kenya, in September 2023.

Stella Gachoki (PhD scholar, Kenya), was awarded the 2023 – 2024 Schlumberger Foundation Faculty for the Future Fellowship, in line with the programme's long-term goal to accelerate gender equality in STEM.

Steeven Belvinos Affognon (Benin), PhD student, Data Management, Modelling and Geo-Information (DMMG) Unit, received the Best Modelling Team award at the ICMS and MAC-MIGS Modelling Camp 2023, held in Edinburgh, UK, in April 2023.

Acknowledgement

On 31 December 2023, Dr Segenet Kelemu completed her 10-year tenure as the Director General of *icipe*, having been at the helm of the Centre since 1 November 2023. Mr Gatigwa Kimana, who served as *icipe* Director of Finance and Administration from May 2014, left the Centre in April 2024, having attained retirement age.

We gratefully acknowledge the leadership and contribution of Dr Kelemu and Mr Kimana to *icipe*.



Prof. Kym Anderson (left), Chair, *icipe* Governing Council, presenting tokens of appreciation to Dr Kelemu (second left) and Mr Kimana (right), on behalf of the the entire *icipe* family.

HUMAN HEALTH THEME

The *icipe* Human Health Theme contributes to the reduction, elimination and eradication of vector-borne diseases. The Centre aims to achieve this goal by generating knowledge and developing sustainable tools and strategies that control vectors, break the cycle of transmission, and which can be integrated into other disease management efforts.

Donors: Bill & Melinda Gates Foundation; Biovision Foundation for Ecological Development, Switzerland; Cambridge-Africa ALBORADA Research Fund; Children's Investment Fund Foundation (CIFF); German Academic Exchange Service (DAAD); German Research Foundation (DFG); Global Environment Facility (GEF)/United Nations Environment Programme (UNEP); Institute for Research and Development (IRD), France; Kenya National Research Fund; Medical Research Council (MRC), UK; National Institutes of Health (NIH), USA; Norwegian Agency for Development Cooperation (Norad); Open Philanthropy Project, USA; Swedish Research Council, Sweden; Swiss National Science Foundation (SNSF); Wellcome Trust, UK; and World Health Organization-Regional Office for Africa (WHO-AFRO).

A comprehensive list of partners is included in the annexes.

2023 IN BRIEF



New knowledge

Insights for design of a strategy for site-specific release of mosquitoes with the malaria parasite transmission-blocking *Microsporidia MB* microbe; and integration with other malaria control interventions.

Geographical expansion of leishmaniasis; active unnoticed circulation of Crimean–Congo haemorrhagic fever virus and the involvement of livestock, rodents and people in its circulation; presence of the novel Cuacua virus (CuCuV) in Kenya.

New knowledge on the ecology of *Aedes aegypti* mosquito that sheds light on risk of spread of associated pathogens such as dengue virus.

Efficient tool to identify tungiasis-causing fleas in their off-host stage; evidence of key tungiasis infection areas in homes; impact of tungiasis on children's neurocognitive functioning; and flea jumping capability.



Inclusive innovations

Advances in development of *Microsporidia MB*-based malaria control intervention; further insights on insect-specific flaviviruses, their composition and effect on pathogen transmission, could be integrated in the control of mosquito-borne diseases such as dengue fever, yellow fever and Rift Valley fever. One Health tools including Mazao TickOff® biopesticide and healthy homes concept.



Policy/Recommendations contributions

Evidence to support: better adoption of house screening as a malaria control strategy; better targeted and more effective use of resources for tungiasis management; integration of tungiasis management into children's growth and welfare; need to address diverse transmission pathways of leishmaniasis and other neglected tropical diseases.



One Health

Our findings stress the need for One Health approaches to tackle insect-transmitted diseases, due to the interlinkage with animals, the environment, ecosystems, human activity, land use changes and climate change.



Malaria Research

Malaria transmission blocking

In early 2020, *icipe* researchers and partners made the groundbreaking discovery of a microbe, which they named *Microsporidia MB*, in *Anopheles* mosquitoes. The researchers established that mosquitoes carrying *Microsporidia MB* do not harbour malaria parasites either in nature, or after experimental infection in the laboratory. Further, studies by *icipe* and partners have demonstrated that *Microsporidia MB* can spread through mosquito populations from mother to offspring and via sexual transmission.

We found *Microsporidia MB*, which is related to fungi, occurring naturally inside the cells of the malaria transmitting *Anopheles* mosquitoes in parts of Kenya. By studying the ways through which the microbe is propagated between mosquitoes, we believe we can develop a tool to efficiently spread it through mosquito populations, thus limiting their ability to infect people with the parasite that causes malaria.

PROGRESS IN 2023

We have developed three modeling approaches, and used them to investigate the dynamics between *Microsporidia MB* and *Plasmodium*, the malaria-causing parasite. Of the three, a systems dynamics model has enabled us to investigate how mosquito releases and various *Microsporidia MB* transmission rates affect the prevalence of the microbe and, in turn, malaria cases. The model will help to develop a *Microsporidia MB* release strategy that is tailored to specific malaria transmission settings. It will also assist to determine how to integrate the microbe most effectively with existing control interventions.

We found that:

Microsporidia MB equilibrium levels and impact on malaria incidence could be achieved by releasing novel strains, different from the strain type already present in a region, or through sustained release of endemic strains.

The optimal implementation strategy could be a hybrid of the scenarios described above.

It is possible to use *Microsporidia MB* as a *Plasmodium* blocking tool, and the strategy can work synergistically with other existing mosquito and malaria control tools.

Assuming that the transmission rates observed in the laboratory also apply in the field, a higher *Microsporidia MB* infection prevalence is expected in practical settings. Thus, more research is needed on transmission rates and fitness of the microbe in the field.

We have observed that *Microsporidia MB* can naturally infect between 0-70% of mosquitoes in different settings. Understanding the factors that determine the prevalence of the microbe will be key to using it as a sustainable malaria control strategy.

WAY FORWARD

This knowledge has laid the foundation for field trials on *Microsporidia MB*-infected mosquitoes releases.

We plan to incorporate a spatial component to the systems dynamics model. This will help us to prioritize efforts, such as releases in regions where the most significant impact on reducing malaria transmission is likely to be achieved.

Also, spatial data will enable us to understand the environmental conditions that influence the spread and survival of *Microsporidia MB*, and to align the release strategies with favourable environmental conditions.



*icip*e researchers: Tracy Maina (left), an MSc scholar, and Joseph Gichuhi (right), a Postdoctoral Fellow, conducting an experiment on *Microsporidia MB*. The male *Anopheles* mosquitoes have been marked with a fluorescent dye to determine the females that have mated with them and the success of the process. The study led to findings that *Anopheles* males harbouring *Microsporidia MB* have higher mating success than their uninfected counterparts, which could enable the symbiont to spread through mosquito populations.

– Photo credits/copyright: Frank Messmer



Malaria Research

Integrated vector management

Despite progress towards achievement of the goals and targets for malaria elimination (2016 – 2030) set by the World Health Organization (WHO) and the Roll Back Malaria Partnership, the international malaria community is wary of setbacks, particularly due to rising insecticide resistance by malaria vectors and residual malaria transmission. Thus, there is increased promotion of integrated vector management (IVM).

From 2017 – 2023, *icipe* supported six southern African countries to implement IVM approaches. The aim was to demonstrate the potential benefits of combining readily available, but not-widely used vector control tools like winter larviciding and house screening, in Botswana, Namibia, Mozambique, Eswatini, Zambia and Zimbabwe, to sustain malaria control and elimination.

PROGRESS IN 2023

icipe and partners have evaluated the incorporation of house screening; and the impact of this tactic on the health of communities, socio-economic conditions, gender and the environment.

We found that:

Housing modifications, including closing eaves and screening doors and windows using non-insecticide treated netting, reduces the indoor density of mosquitoes, including the malaria-transmitting *An. funestus*, *An. arabiensis*, and culicine mosquitoes, which transmit yellow fever and dengue fever and West Nile virus. Thus, house screening can reduce incidences of malaria and other mosquito-transmitted diseases, with additional benefits such as decreasing the nuisance of mosquito bites.

House screening is absent in national malaria programmes, despite its recognition by WHO as a supplementary malaria vector control intervention. This is possibly because of a knowledge gap in durability or longevity of the screens based on climatic conditions, as well as community acceptance under specific cultural practices and socio-economic contexts.



Community members partnering with *icipe* in Zambia during a house screening exercise.

RECOMMENDATION

The concerns about damage to screens is warranted. For example, screened doors are more likely to be damaged, mainly by children, domestic animals, rust and termites, especially the bottom half. Thus, we recommend investments to enable communities to use durable screening materials, for example PVC fibre glass, to increase durability of the technology and its acceptability by communities.



Neglected Tropical Diseases

Managing tungiasis

Tungiasis, known more commonly as jiggers, is a painful, debilitating, parasitic skin disease caused by the penetration of female sand fleas, *Tunga penetrans*, into the skin. The disease leads to physical disability and severe emotional and mental impacts. *icipe*'s aim is to generate knowledge on a neglected aspect of tungiasis; the ecology of sand fleas, while also investigating the environmental, social and individual determinants of the disease.

To eliminate tungiasis, treatment efforts must be complemented by proper understanding of the transmitting insect. Like all fleas, *T. penetrans* undergoes a complete metamorphosis, and it also has a stage when it develops in the environment (off-host stage). Indeed, all juvenile flea stages (eggs, larvae and pupa) are found in sandy soil, while the adults survive on their hosts, with females penetrating the skin to breed. The off-host stage is a constant source of tungiasis re-infection. Thus, it is important to understand the ecology of the sand flea, and to identify where its off-host development stage occurs. But investigations on the *T. penetrans* off-host stage are hindered by lack of efficient methods.

PROGRESS IN 2023

icipe researchers have modified the Berlese-Tullgren funnel method, a well-established tool that uses heat to extract and quantify tiny arthropods, for example from bird nests, leaf litter and soil. We established the balance between the heat gradient based on bulb wattage, and effective extraction of juvenile fleas from soil samples. Our modifications allow simultaneous, high-throughput of small soil samples, maximising the number of extracted fleas.

We have also created a morphological key to distinguish various flea larvae species in the *Siphonaptera* family.

Using these two sets of innovations, we conducted studies in rural homes in Kenya and Uganda, which confirmed that indoor sleeping areas are the major developmental sites for *T. penetrans*.

For the first time, through studies conducted in Kenya and Uganda, we have provided evidence that tungiasis is associated with poor neurocognitive functioning in children. Since tungiasis is a chronic disease with frequent re-infections, such negative effects may impair the development and life achievements of affected children.

It has been anecdotally assumed that the *T. penetrans*, unlike its relatives in the *Siphonaptera* family, have limited jumping ability and potential to reach higher parts of the body.

PROGRESS IN 2023

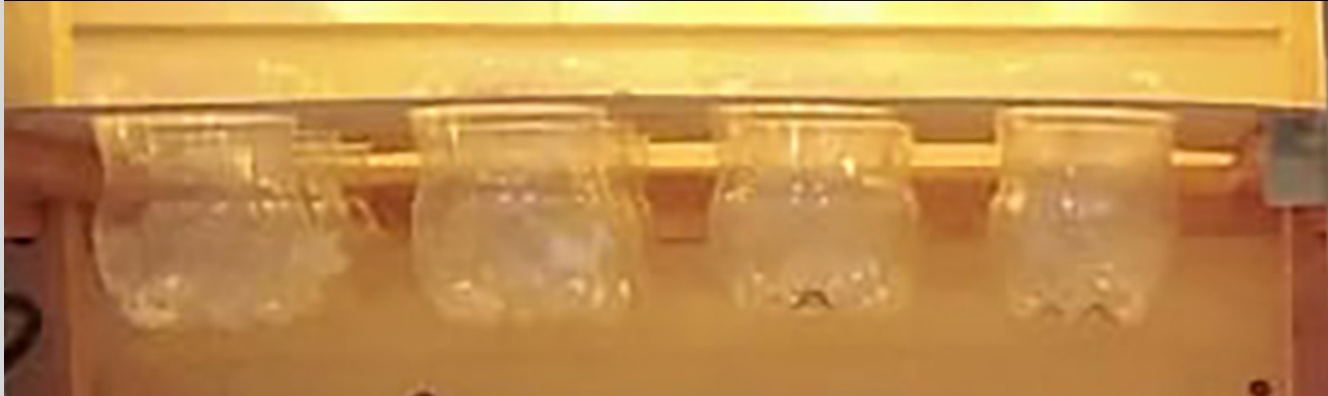
icipe and partners have shown that sand fleas have equal jumping abilities as their counterpart fleas.

RECOMMENDATION

The aggregation of sand fleas on people's feet is not likely a result of the poor jumping ability of the insects. Possibly, it is an adaptation to the behaviour of their hosts. This means that in tungiasis control, in addition to the feet, it is important to target other body parts as well.



We have constructed simple, low-cost units of multiple funnels to allow the extraction of more than 60 soil samples in parallel. The modified method uses a temperature gradient created over the samples in the funnel by the heat emitted from a light bulb which causes the juvenile flea stages as well as any adult fleas that might be present in the soil to burrow down and away from the light and heat source as they fall through a mesh into a collecting container at the bottom of the set-up. This mechanism is based on the natural self-preservation behaviour of the flea larvae.





Neglected Tropical Diseases

Leishmaniasis

Leishmaniasis is caused by *Leishmania* parasites, which are transmitted by sand flies, tiny blood-sucking insects. The disease occurs in three forms: the visceral form, kala-azar, which affects the spleen and liver; the cutaneous type that affects the skin leading to permanent scarring and disfigurement; and mucocutaneous leishmaniasis, which produces lesions that spread to the mucous membranes of the nose, mouth and pharynx causing severe disfigurement and suffering. Leishmaniasis is expensive to treat, and medications are not always available.

PROGRESS IN 2023

Kenya has several recognised leishmaniasis hotspots. However, recently, through our routine surveillance of viruses, *icipe* researchers have noted geographical expansion of leishmaniasis, based on the presence of *Leishmania*, sand flies and active infections, in new regions. This shift is probably due to the impacts of climate change, and the extensive movement of people and livestock.

Recently, we have discovered the presence of the sandfly species *Phlebotomus (Artemievus) alexandri* Sinton, 1928, in Marsabit County, northern Kenya. This is the first report of this vector in Kenya. In addition, we also discovered in the region one of the major parasites causing cutaneous leishmaniasis, *Leishmania major*. We also detected *Leishmania adleri*, which is primarily a parasite of reptiles, but can also cause a transient skin infection in people.

We will communicate our findings to relevant authorities for the necessary interventions.

The discovery of new vectors and parasites shows the complexity of leishmaniasis transmission. To progress towards WHO's elimination targets for neglected tropical diseases, it is important to identify all transmission pathways, to guide meaningful design of tools and methods.



A CDC light trap set by *icipe* in a rock crevice to trap sand flies, in Nyandarua County, a leishmaniasis hotspot in Kenya. Rock crevices are breeding and resting sites for rodents, which also provide blood meals to sustain sand flies. Continuous surveillance provides valuable information on the presence and abundance of sand flies that transmit leishmaniasis. This knowledge assists diseases control agencies to evaluate the disease's risk levels.



Emerging and Re-Emerging Viruses

Arboviral diseases are infections caused by a group of viruses that are spread to people through the bite of infected arthropods, such as mosquitoes and ticks. The ailments include yellow fever, Rift Valley fever and dengue fever. In recent years, there has been a resurgence of new and old arboviruses. *icipe* continues to produce extensive knowledge on factors such as the abundance of the transmitting insects, their interactions with disease-causing agents, the ability of the insects to transmit pathogens transmission and the risk of respective diseases in people and animals.

PROGRESS IN 2023

Dengue fever is a mosquito-borne disease that is frequently symptomless. When symptoms occur, they include high fever, headache, vomiting, muscle and joint pains, and a characteristic skin itch and rash.

The *Aedes aegypti* mosquito species is the primary vector of dengue virus which causes dengue fever. The virus exists as four distinct strains, DENV 1-4. There are two forms of *Ae. aegypti* mosquitoes: the sylvan *Ae. aegypti formosus* and the domestic *Ae. aegypti aegypti* that vary in vectoring abilities. The matrix of vectors and virus genotypes leads to a diverse transmission landscape of the disease.

Our studies at the Kenyan coast (an urban, highly endemic dengue fever region) reveal the occurrence of the domestic form the domestic *Ae. aegypti*, which is also highly susceptible to both DENV 2 and 3 serotypes. The mosquitoes also survive better and live longer as adults than those in our second study site, Kerio Valley, Kenyan Rift Valley (a rural and low dengue fever risk area). Mosquitoes in the latter area have lower abundance and ability to bite people.

These findings indicate that DENV transmission risk is related to the degree of urbanisation, influenced by the biology and ecology of the mosquito vector.

INNOVATION

We have successfully evaluated promising attractants, which could be used to trap the *Aedes* mosquitoes, in two ecologies in Kenya.

Crimean–Congo haemorrhagic fever virus causes a fatal viral haemorrhagic fever disease in people. Certain tick species are considered vectors and reservoirs of the virus. Diverse animals are suspected as amplifiers.

PROGRESS IN 2023

We established active infection and circulation of Crimean–Congo haemorrhagic fever virus in patients with fever symptoms, livestock not showing any signs, and peridomestic rodents, in the pastoralist-dominated Baringo and Kajiado counties, Kenya.

POLICY IMPLICATION

Our findings suggest active unnoticed circulation of Crimean–Congo haemorrhagic fever virus and the involvement of livestock, rodents and people in its circulation.

Mosquitoes harbour a rich and diverse assemblage of viruses, including those termed as insect-specific flaviviruses, which are distinct to their insect hosts and they cannot replicate in people. However, such flaviviruses can modulate the transmission of arboviruses by mosquitoes. The infection of mosquitoes with insect-specific flaviviruses may reduce or enhance the insect's ability to transmit viruses to people.

PROGRESS IN 2023

Through studies in Kenya, we detected and sequenced the genomes of Cuacua virus (CuCuV), a novel virus discovered through previous global research, in the mosquito species that transmit yellow fever, dengue and Rift Valley fever viruses, including *Aedes aegypti*, *Mansonia africana* and *Culex univittatus*.

WAY FORWARD

Further studies will help to understand how (CuCuV) influences the transmission of the arboviruses listed above.



Latrine



Cross ventilation helps cool the house and reduces respiratory illnesses.
 → cooler air goes in
 → warmer air goes out

Latrines prevent diseases including diarrhoea, cholera and typhoid because they spread to others when faeces contain germs, water, hands, food or flies.

Tippy tap to wash hands after latrine use.

A fenced waste pit helps prevent breeding of flies and rats which may spread disease to people in the community.

Smooth walls prevent hiding places for bedbugs and mosquitoes.

Screened windows, doors and eave gaps prevent insects from entering the house.

Smooth floor protects from parasites, like figgers, and bacteria.

Bednets protect from mosquito bites that bring malaria and dengue.

Dish rack to keep utensils away from the floor to keep them clean.

Kitchen should be clean and ventilated to prepare food.

Tippy tap to wash hands before handling food.

Chickens must be kept separately from the house and kitchen to prevent diseases.

Toilet system breaks down toilet waste and does not need maintenance. This system is safe for use in sandy soil and high water table.

Vertical kitchen garden allows for mixed vegetable farming beneficial for dietary needs while needing little space and conserving water.

Work top to prepare food off the floor.

Improved cook stoves need less fuel and produce less smoke.

Healthy Home

Demonstration of simple, affordable improvements of rural homes to prevent diseases

Resource Centre for Community Teaching and Learning.

One Health

Since 2021, in two sites, Kwale County along the Kenyan coast; and Busia County, western Kenya, *icipe* and partners have been implementing a One Health initiative, as a model for the simultaneous control of insect vectors of diseases that affect people and animals.

We are testing novel products and strategies. The first is an environmentally friendly biopesticide, Mazao TickOff®, which has been developed from a strain of *Metarhizium anisopliae* fungus. Our previous studies have shown that although originally developed for the control of ticks, the product can control a range of disease-transmitting insects including mosquitoes, ticks and biting flies. Thus, we are using cattle as decoys, treating them with the biopesticide, thus protecting the animals as well as people.

Second, by combining lessons from *icipe* disease vector control initiatives, as well as community participation, we conceptualised and built two healthy homes. The structures feature simple improvements using locally available materials to prevent people and animal diseases. The healthy home concept has been received with great enthusiasm by communities and stakeholders.

PROGRESS IN 2023

We have conducted baseline studies of the prevalence of mosquitoes, ticks and biting flies.

We are using a community participatory approach to raise awareness and formulate the most optimum application strategies of the Mazao TickOff biopesticide and to improve its effectiveness.

In 2023, we completed a two-year long, all seasons trial of the biopesticide, to determine optimum applications and its safety on cattle.

The results indicate that application of Mazao TickOff does not have any negative effects on cattle. Using indicators provided by health agents, we noted that the product improves the condition of the animals. These outcomes will advance commercial registration of Mazao TickOff.

We have also conducted training on the healthy homes, with demos constructed in Kwale and Busia that are used as community training centres on disease prevention and health management.



Mazao TickOff® biopesticide is effective against several pests across One Health: the fall armyworm on cereal, ticks on livestock and mosquitoes on people. In addition, the use of biopesticides is safe for people, animals, plants, the environment and biodiversity, for example natural enemies and other ecosystem service providers such as pollinators.

Jewel beetle: *Acmaeodera subprasina* Marseul (Buprestidae: Coleoptera)

Location: *icipe* Duduville campus, Nairobi, Kenya

This small and beautiful jewel beetle is widely observed in Southeast Africa. Often, it is observed on yellow Asteraceae flowers, as in this image.



ANIMAL HEALTH THEME

The *icipe* Animal Health Theme aims to develop effective solutions to improve the health, productivity and sustainable farming of livestock in Africa. Our 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, our 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. We develop locally-adapted technologies to manage vector-borne diseases, conduct operational research for vector-borne livestock diseases, and support capacity building and extension services.

Donors: Biovision Foundation for Ecological Development, Switzerland; European Union; Federal Ministry For Economic Cooperation and Development (BMZ), Germany, through the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ); German Research Foundation (DFG); International Atomic Energy Agency (IAEA); Max Planck Institutes, Germany; United States Agency for International Development’s Partnerships for Enhanced Engagement in Research (USAID-PEER) grants program.

A comprehensive list of partners is included in the annexes.

2023 IN BRIEF



New knowledge

Potential of expanding algorithm using species distribution model and satellite-derived data, to identify tsetse fly breeding and foraging sites; compounds in urine that are present in trypanosome-infected cattle; pathogen infections in ticks, which cause diseases in animals and people; beneficial bacteria in ticks; and tick attractants in camel.

Ability of stable flies to become infected with, and to transmit trypanosomes, and the extent to which the flies can be incriminated in trypanosome transmission.

Livestock microbes and secondary metabolites and their role in resilience, feed conversion and greenhouse gas emissions.



Inclusive innovations

Leads to design and deployment of cost-effective tsetse fly control tools, update risk maps of tsetse flies and animal trypanosomosis in East Africa, improve the *icipe* NGU traps, use beneficial bacteria to block transmission of disease-causing agents from ticks to livestock; and non-invasive and field-based surveillance tool for ticks.



Policy/Recommendations contributions

Importance of biting flies in livestock diseases and need for equal emphasis on their management, vis-à-vis tsetse flies, towards achieving sustainable livestock keeping in Africa.



One Health

Our progress is extremely important, against the background of the growing need to improve the health and productivity of livestock, a vital resource for many communities in Africa, while addressing its polarised role in greenhouse gas emissions and environmental degradation.



Tsetse Fly Management

Every year in Africa, an estimated three million cattle succumb to African animal trypanosomosis, a debilitating disease of livestock that is caused by trypanosome parasites that are mainly transmitted by tsetse flies, and mechanically by other biting flies. Known as nagana in cattle, goats and sheep, and as surra in camels, the disease's symptoms include anaemia, fever, swelling of the lymph nodes and decreased appetite; leading to weight loss, lethargy, abortions, a suppressed immune system and increased chances of concurrent infections.

The productivity of infected animals is reduced and thus, the availability of livestock products and services like tilling of agricultural land, while livestock production costs are escalated due to investments for treatment. African animal trypanosomosis causes direct and indirect losses of approximately USD 4.75 billion per year in East Africa alone.

Tsetse fly prediction model

Tsetse flies occupy a vast area of Africa, currently estimated at 9 million square kilometres. The ability to accurately predict habitats that are suitable for tsetse flies is important; it can boost surveillance of the insects and guide the setting of intervention priorities.

PROGRESS IN 2023

In 2022, *icipe* developed an algorithm that combines a species distribution model with satellite-derived data, to identify tsetse fly breeding and foraging sites. We successfully used the model to predict high-risk, tsetse-infested areas in Shimba Hills National Reserve, Kenya. In 2023, we conducted further trials that confirmed that the model can be applied in other tsetse fly inhabited areas, in geographically separated regions, by extending the algorithm to Ruma National Game Reserve in western Kenya, and Akagera National Park in Rwanda.

WAY FORWARD

We will expand the model across East Africa, and possibly across other regions of Africa affected by tsetse flies, to support surveillance, and guide the design and deployment of cost-effective control tools and to update the risk maps of tsetse flies and animal trypanosomosis in the region.

Improved tsetse fly trapping

Trapping tsetse flies is an important strategy for sampling, monitoring and managing the flies. Indeed, one of *icipe*'s key innovations is the NGU trap, which is built on visual aspects (shape and colour) and smell-based cues (for example, cow urine and acetone), that attract tsetse flies. We continue to improve the efficiency of the NGU trap, through research and insights on scents in animals, which attract tsetse flies to their hosts.

PROGRESS IN 2023

We have identified signature scent of cows that are infected with trypanosomes. We have developed and tested a potent blend of these compounds, which selectively captures infected tsetse flies that can be integrated into the trapping systems.

INNOVATION

We aim to incorporate the blend of compounds into the *icipe* NGU traps, to increase the effectiveness of the tool, while also exploring the development of a trypanosome transmission blocking strategy.



The *icipe* NGU trap
The blue colour attracts tsetse flies. After landing on the blue coloured cloth, the flies move on to the black target and while trying to escape, they are captured at the top in a plastic container, where the heat of the sun kills them.



Tick Management

Ticks – small, blood-sucking 8-legged creatures (arachnids) – are external parasites and are among the most important pests, and disease vectors of livestock. They transmit important livestock diseases, including East Coast fever (also known as theileriosis), which kills at least one million cattle every year in Africa. Although about 160 tick species exist in Africa, the two most important are *Rhipicephalus appendiculatus* (the brown ear tick), and *Amblyomma variegatum* (the variegated tick). Resistance to chemical acaricides is a growing threat. Thus, *icipe* aims to develop approaches that include biological control agents like biopesticides and botanicals control strategies that can be used in conjunction with conventional products like acaricides in an integrated manner. Our approach is guided by research on the ecology and behaviour, as well as the interactions between ticks and the animals that they parasitize.

Ticks, tick-borne pathogens and diseases

icipe is part of a multi-disciplinary alliance that aims to identify, PREDict and prePARE for Emerging Vector-Borne Diseases (PREPARE4VBD). The consortium, which brings together 10 university and ministerial partners from five African and three European countries, aims to develop new knowledge, detection tools and surveillance systems for diseases transmitted to livestock and people by mosquitoes, ticks and freshwater snails.

PROGRESS IN 2023

Through previous studies, we determined the diversity and prevalence of tick-borne diseases circulating among livestock in selected regions of Africa, as well as the specific tick species transmitting them.

We have now obtained insights on how tick-borne pathogens are conveyed, the ability of different tick species to transmit them, and the occurrence of the disease-causing agents within tick tissues.

We have established that diverse tick species are extensively infected with many pathogens that cause diseases in livestock, and in some cases people, for example, the bacterium *Ehrlichia minasensis*, *Rickettsia africae* and *Coxiella burnetii*; and *Theileria parva* and *T. velifera* parasites.

We have also identified certain bacteria species that live in a mutually beneficial manner within ticks, helping to block the transmission of harmful, disease causing bacteria in people and animals.

INNOVATIONS

We aim to develop a non-invasive and field-based surveillance tool for ticks. The insights on beneficial bacteria, the tick endosymbionts, may be exploited to develop tools to prevent the ability of ticks to transmit diseases.



Tick Management

Tick control in camel

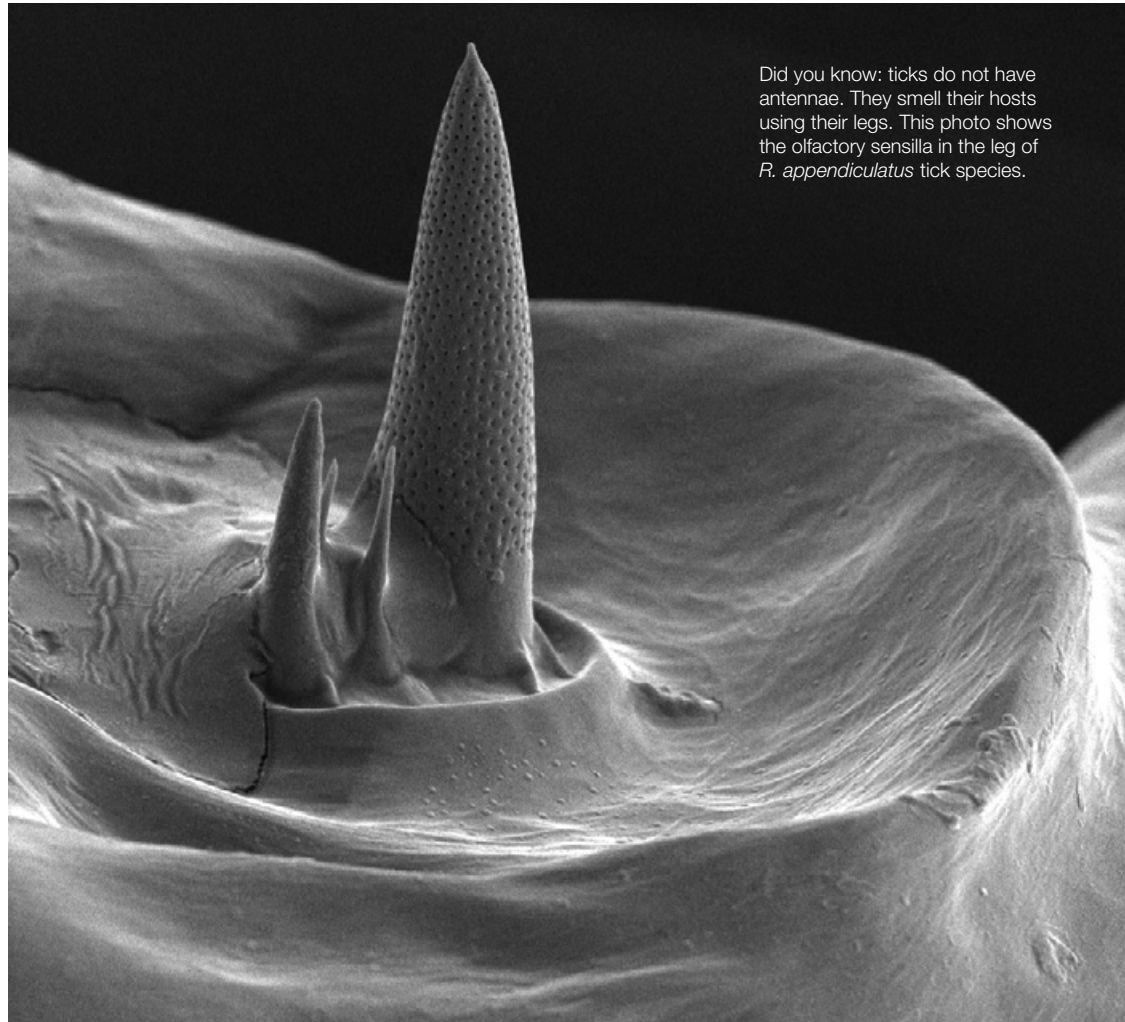
Ticks infest most livestock including goats, cattle, sheep and camels, with the latter being the most preferred host. Interestingly, *icipe* studies have shown that the camel's nostril is the tick's most preferred feeding and mating site. However, because the nose has very sensitive tissue, it is difficult to treat it with synthetic acaricides.

PROGRESS IN 2023

Our studies have identified signature odours in the breath and body of camels that attract ticks. We will explore the possibility of formulating these odours into an attractant for ticks.

INNOVATIONS

This knowledge builds on our previous findings that confirmed that essential oils from *Tagetes minuta* (stinking Roger; khakiweed), a locally available plant, have acaricidal and repellent properties against ticks. We continue studies on the possibility of developing an ointment as a safe botanical based acaricide for tick management in the camel nostril.



Did you know: ticks do not have antennae. They smell their hosts using their legs. This photo shows the olfactory sensilla in the leg of *R. appendiculatus* tick species.



Biting Flies Management

Stable flies-pathogens-livestock interaction

Stable flies, *Stomoxys calcitrans*, are a major challenge for livestock and people across the world in general, and in Africa specifically. These blood-sucking insects transmit various pathogens. For example, in the absence of tsetse flies, they mechanically transmit trypanosomes, the parasites that cause the deadly trypanosomosis. The painful bites of the flies lead to loss of blood, reduced weight gain and poor lactation in afflicted livestock, thus diminishing productivity. *icipe* is advancing knowledge on *Stomoxys* flies, including their ability to become infected with, and to transmit trypanosomes. We are also conducting studies to understand the extent to which the flies can be incriminated in trypanosome transmission cycles.

PROGRESS IN 2023

Our results show that stable flies feed on various wild and domestic animals and that they harbour several pathogens that are significant in livestock health. In laboratory experiments, we have confirmed that the flies transmit trypanosomes.

POLICY RECOMMENDATION

Our results indicate that, though underrecognised, stable flies are an important factor in livestock diseases. We recommend equal emphasis for the management of non-tsetse biting flies, towards the overall goal of sustainable livestock keeping in Africa.

Livestock Rumen Mechanisms

Livestock-rumen-microbes interaction

Livestock possess a unique digestive system, with a complex microbiota community that facilitates the production of various odours that are significant in the interactions between the animals and disease-transmitting insects. Also, the livestock rumen, the so-called first stomach, is the organ of greenhouse gases production. The conversion of feed and the production of secondary metabolites for energy, growth and reproduction in livestock, depends on animal feed and microbes, such as bacteria, in the rumen.

PROGRESS IN 2023

Our studies show that each livestock species has signature microbes and secondary metabolites, natural products that increase the competitiveness of the animals. We have identified these microbes and metabolites and their role in livestock resilience, feed conversion and greenhouse gas emissions.

INNOVATIONS

These findings are extremely important, against the background of the growing need to improve the health and productivity of livestock, a vital resource for many communities in Africa, while addressing its polarised role in greenhouse gas emissions and environmental degradation.

These results are part of *icipe*'s growing wealth of knowledge on the drivers of the variations in the livestock rumen environment, which make the animals less susceptible to disease-carrying insects.

Our insights may enable the manipulation of these pathways to make livestock production efficient, sustainable and environmentally friendly.



Stomoxys niger niger, is one of the stomoxys fly species that is widely distributed in Africa. The insect feeds on diverse wild and domestic animals, and it can transmit several disease-causing agents.

PLANT HEALTH THEME

The Plant Health 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. Our strategic objectives include basic and applied research on native and invasive, below- and above-ground, pre- and postharvest pests, under changing climate and habitats. We harness the synergies in plant-insect-soil interactions through integrated pest management (IPM) options that are ecologically sustainable and economically feasible. Our 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. We disseminate our research results, transfer technologies, influence policies and empower communities through partnerships with national agricultural research organisations, the private sector and other stakeholders. And we build excellence in plant health research in Africa through training of students and scientists.

Donors: African Union; Bill & Melinda Gates Foundation; Biotechnology and Biological Sciences Research Council (BBSRC), UK, through Rothamsted Research and Keele University (both in the UK); BioInnovate Africa Programme; Biovision Foundation for Ecological Development, Switzerland; Department for International Development, UK; European Union; Federal Ministry for Economic Cooperation and Development (BMZ), Germany, through the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ); Food and Agriculture Organization of the United Nations (FAO); French Agricultural Research Centre for International Development (CIRAD); French National Research Institute for Sustainable Development (IRD); Global Affairs Canada; Government of Kenya; International Atomic Energy Agency (IAEA); International Development Research Centre (IDRC), Canada; International Fund for Agricultural Development (IFAD); IKEA Foundation; Norwegian Agency for Development Cooperation (Norad); One CGIAR through CIMMYT and International Food Policy Research Institute (IFPRI); Research Executive Agency; Research Institute of Organic Agriculture (FiBL), Switzerland; Royal Society, UK; Swiss National Science Foundation (SNSF); Swedish Research Council through Swedish University of Agricultural Sciences; United States Agency for International Development (USAID), USA, through the IPM Innovation Lab; United States Department of Agriculture (USDA); and Wageningen University, The Netherlands.

A comprehensive list of partners is included in the annexes.

2023 IN BRIEF



New knowledge

Insights for third-generation push-pull and evolution of the climate-smart version of the technology; impact of the technology on soil conditioning, rhizosphere microbiome, plant-soil feedback and on maize phytochemistry. Identification of natural enemy to manage the invasive spotted wing fruit fly in Africa; prediction of fruit tree mealy bug expansion in East and Southern Africa. Breakthroughs on postharvest treatment of the false codling moth in compliance to export requirements, and on beneficial bacteria in natural enemies of fruit flies.



Inclusive innovations

Expansion of *icipe* IPM technologies across Africa; combined black soldier fly farming and vegetable integrated push-pull technology; intensification of the push-pull technology, including incorporation of agroforestry; and sure bet innovations for fall armyworm management. Risk maps to prevent invasion of fruit tree mealy bug. International standards protocol for the false codling moth in roses. Beneficial bacteria to improve mass rearing and use of fruit fly natural enemies. Stronger value chains and agroecology to boost mango production. Biological control for vegetable pests and diseases; banana fibre technology, resistant potato varieties and chitin-fortified insect frass fertiliser, to control nematodes and other soil dwelling pests. Biopesticides for tomato leafminer; and identification of effective pheromone lure and trap design to monitor the fall armyworm.



Policy contributions/ Recommendations

Evidence and strategies for increased farmer awareness of the benefits of agroecological farming; regulation on the use of harmful chemicals and pesticides; and gender-sensitive policies in agriculture. Insights that support scaling-up of the agroecological approach to mango production in Ethiopia, with a special focus on young people. Progress towards registration of the banana fibre technology in Kenya. Proof of the need to balance pest control prioritisation between existing and invasive species.



One Health / Circular economy

icipe plant health technologies and innovations are nature-based solutions for climate-smart agriculture. They are also models for circular economies that control pests, increase crop yield, and, overall, contribute towards a more resilient regenerative food system and eco-conscious farming future, providing novel income generation and job creation opportunities especially for women, youth and marginalised communities.



Push-Pull Integrated Pest Management

Developed by *icipe*, Rothamsted Research, UK, and partners in East Africa and beyond over two decades ago, the push-pull technology was originally targeting stemborer pests. It is an agroecological approach that exploits insect-plant, and insect-insect interactions. The technology involves intercropping cereal crops with plants, for example legumes of the *Desmodium* genus, which produce defence compounds that repel (push) stemborer moths away from the target food crop. In addition, a fodder grass, for instance *Brachiaria* or Napier (*Pennisetum purpureum*), is planted as a border crop, and it releases chemicals that attract (pull) and trap the stemborers. As a result, the cereal crop is protected from the pests, thus offering an elegant, economical and environmentally safe pest management tool. An additional benefit is the ability of *Desmodium* to reduce the *Striga* sp., a parasitic weed that is a major scourge plaguing African smallholder farms. *Desmodium* produces two sets of compounds: one that stimulates the germination of *Striga* seeds and another that inhibits their growth after germination. Most recently, the push-pull technology has been shown to control the fall armyworm (*Spodoptera frugiperda*), a major insect-pest threatening crops that was first reported in Africa in 2016.

Evolution of climate-smart push-pull

Previously, *icipe* developed a climate-smart push-pull, incorporating greenleaf desmodium (*Desmodium intortum*) as an intercrop and *Brachiaria* cv Mulato II as a border crop.

PROGRESS IN 2023

icipe developed a third-generation push-pull by incorporating additional *Brachiaria* and *Desmodium* species into the climate-smart version of the technology. Through a participatory process with farmers, *Brachiaria brizantha* cvs Xaraes and Piata, were identified as the most stable and improved species that are more drought-tolerant and pest resistant, while retaining the key traits of the technology. *D. incanum* and *D. ramosissimum* were selected as the “push” plants due to their high drought-tolerance, biomass yield, and ability to flower and produce seeds across various agro-ecological environments.

INNOVATION

We are currently exploring new frontiers to intensify the push-pull technology, including incorporation of agroforestry to enhance biodiversity conservation and ecosystem services, such as pollination.

Vegetable integrated push-pull

icipe studies have shown that *Desmodium* repels vegetable pests. The legume also attracts the natural enemies of the pests. Thus, we have begun to integrate farmer-preferred vegetables like kale, African nightshade, cabbage, cowpea, tomato and onion, into push-pull systems. The vegetables will supplement household nutrition and provide income during off-seasons of maize cultivation.

PROGRESS IN 2023

In 2022, *icipe* started to harness the vegetable integrated push-pull technology and black soldier fly farming, into a One Health package that will increase production of cereals, the main staples for most households; as well as high-value vegetables, poultry and fish, which will augment the region’s largely starch-based diets, thus countering malnutrition and hidden hunger while protecting the environment. We completed a review of system-level integration of the two technologies. We also developed conceptual system models to analyse and quantify the interconnectedness along the crop-to-health system pathway.

INNOVATION

Our research so far shows that the vegetable integrated push-pull technology and black soldier fly farming contributes to plant, animal, human and environmental health. It also provides a platform for a resilient, circular and regenerative food system, while creating novel income generation and job creation opportunities especially for women and the youth, in eastern Africa.

Push-Pull Integrated Pest Management

Push-pull technology in Ethiopia

The *icipe* push-pull technology is reputed for its superiority as an agroecological technology that exploits natural insect–plant and insect–insect interactions. In Ethiopia, we are aiming for nationwide expansion of the technology. We have been addressing one of the major constraints in the adoption of the technology, which is the inadequate availability of *Desmodium* and *Brachiaria* seeds. Through a participatory process, we have improved seed availability of the push-pull intercrops through community and private sector production, training, experience sharing and awareness creation and push-pull demonstration plots.

PROGRESS IN 2023

We reached **2150** farmers and started to support them to intensify the push-pull technology by cultivating different crops, including soybeans, cabbage, chickpeas, that are compatible with maize. This approach is boosting the benefits from the push-pull technology, including improved maize yields, nutrition, incomes, fodder and the climate change resilience of small-scale maize farmers.

WAY FORWARD

We have now established close to **600** push-pull technology demonstration plots. We continue to provide training in IPM, crop diversification, farm management and market linkages.



A thriving push-pull field in Central Ethiopia

Push-Pull Impact on Soil Health

Impact on soil health

The push-pull technology has a myriad of benefits, including reducing mycotoxins contamination, a major food safety hazard, and provision of high-quality livestock fodder. The technology also improves soil fertility, moisture and overall soil health while enhancing biodiversity and ecosystem services..

PROGRESS IN 2023

We generated new evidence on the resilience, sustainability and adaptability of the climate-smart pull-pull technology, its impact on soil conditioning, rhizosphere microbiome, plant-soil feedbacks and on maize phytochemistry. Our studies show that the technology's companion crops, *Brachiaria* and *Desmodium*, which are both perennial plants, restore soil function and fertility, and increase soil organic carbon and nitrogen, while also improving availability of phosphorus to plants and reversing soil degradation.

INNOVATION

The push-pull technology provides about 70% soil surface cover. Through its biomass, the technology recycles five times more nitrogen, phosphorus and potassium than maize monocrops. In addition, the technology enriches the diversity of soil microbiome community that is associated with important ecological services, while reducing those related to plant diseases, mycotoxin production and removal of nitrogen from the soil.



Desmodium uprooted from a push-pull plot

Fall Armyworm Management

For long, the fall armyworm, a destructive moth that causes devastating damage to over 100 plant species, including cereals, grasses and a variety of horticultural crops was confined to its native origin, the Western Hemisphere (from the United States of America to Argentina). However, in January 2016, the fall armyworm was reported in Nigeria, and it has since spread at an alarming rate across Africa and beyond. Its presence now is confirmed in most African countries. By 2022, the fall armyworm had caused an average annual loss of 36% in maize production alone; and a total economic loss of between USD 1– 4.6 billion per year in Africa.

PROGRESS

icipe, jointly with national and international partners, has conducted extensive basic and applied research on the ecology of the fall armyworm in Africa, to guide the development of sustainable management strategies suited for African conditions. As a result, *icipe* has developed a climate-smart, agroecological management package that addresses the direct damage of the fall armyworm, as well as the range of obstacles affecting cereal production in Africa. These control efforts have helped to reduce the use of chemical pesticides and enhanced crop productivity.

INNOVATIONS

The *icipe* fall armyworm integrated management package consists of:

The push-pull technology, which, in 2017, became the first documented, readily available technology that could efficiently manage the fall armyworm in an environmentally friendly and cost-effective manner.

Natural enemies: Though the fall armyworm is an alien invasive pest, *icipe* has identified widely distributed native parasitoid species in Africa (namely *Telenomus remus*, *Trichogramma chilonis* and *Cotesia icipe*) and their ability to parasitize and kill the invasive pest.

Biopesticides, which include two *icipe* isolates of the insect-infecting *Metarhizium anisopliae* fungi. We have obtained approvals for the registration of Achieve OD® (ICIPE 78) in Kenya, Mazao Achieve® (ICIPE 78); and Mazao Detain® (ICIPE 7), in Uganda and Tanzania.

Others: community-based monitoring and early warning, trapping using fall armyworm sex pheromones, and the training of numerous stakeholders including extension officers, researchers and community focal persons.

GLOBAL CONTRIBUTION

icipe has also been an active participant in major global and regional initiatives, aimed at the management of the fall armyworm. These fora include the Global Action on Fall Armyworm Control, led by Food and Agriculture Organization of the United Nations (FAO). In June 2023, *icipe* and FAO co-organised the ‘Global Forum on Biological Control’, in Nairobi, which brought together more than 80 participants from over 30 countries, including researchers, government, extension agents and private-sector partners.

RECOMMENDATIONS

icipe's experience and contribution in such fora is vital, especially in shaping biological control options to manage destructive invasive pests, including the fall armyworm, and in insights on the worldwide scale-up of the strategies.

Some components of the *icipe* agroecological, climate-smart package for the control of the fall armyworm.



Achieve OD (ICIPE 78) biopesticide



Natural enemies (top-bottom): *Telenomus remus*, *Trichogramma chilonis* and *Cotesia icipe*



Push-pull technology

Green-veined charaxes: *Charaxes candiope*
(Nymphalidae: Lepidoptera)

Location: Karura Forest, Nairobi

This caterpillar belongs to the tribe Charaxini, commonly and aptly referred to as dragon-headed caterpillars. They are endemic to Africa and they feed on *Croton* tree species.

Adults of green-veined charaxes are beautiful butterflies with a unique blend of brown, orange and green colours.





Fruit Pests IPM

In Africa, the production of fruit offers one of the most important opportunities for income generation, employment creation, as well as food and nutritional security especially for women and the youth. However, this potential is constrained by a variety of factors including insect pests, some of which have quarantine status, resulting in the rejection of produce from Africa in export.

To control the pests and diseases they transmit, growers often rely on synthetic insecticides, which are often ineffective, eliminate natural enemies of the pests, exceed the maximum residue level (MRL) legislation set by the European Union, and are detrimental to the health of people, animals and the environment. For more than two decades, *icipe* and partners have developed integrated pest management (IPM) packages for exotic and indigenous fruit pests.

Spotted wing fruit fly

In 2020, *icipe* and partners detected and reported for the first time in Kenya, the presence of *Drosophila suzukii*, a spotted wing fruit fly that is originally from southeast Asia. The insect attacks berries and stone fruits at the ripening stage, rendering them unsuitable for human consumption. *icipe* researchers undertook surveys to establish the pest's spread. We also commenced basic and applied research on the pest.

PROGRESS IN 2023

Through research in the aboriginal home of the pest, we have identified a wasp, *Ganaspis brasiliensis*, which has co-evolved with the pest, and is therefore an effective natural enemy.

INNOVATION

icipe has presented dossier for the introduction of the natural enemy into Kenya, to the Kenya Plant Health Inspectorate Service (KEPHIS). Based on approval by the Kenya Standing Technical Committee on Imports and Exports (KSTCIE), an import permit has been granted by KEPHIS. We will import the natural enemy into Kenya from CABI's Swiss Centre. We hope to introduce it to other African countries, subsequently.

Fruit tree mealy bug

The fruit tree mealy bug, *Rastrococcus invadens*, an invasive and destructive pest of fruit trees, especially mango, was detected for the first time in West Africa in the 1980s. In eastern Africa, the pest was discovered in Rwanda in 2019, and in Burundi and Uganda in 2022. This trend suggests that the mealy bug is expanding its geographical range due to climate change.

PROGRESS IN 2023

Using machine learning predictive models, *icipe* has predicted that under current and future climatic scenarios, *R. invadens* will expand to new areas in East and Southern Africa.

INNOVATION

We have developed risk maps to help national plant protection and regulatory agencies, especially in uninvaded regions, to monitor, conduct surveillance and the pest risk analysis, to prevent the invasion of *R. invadens*.

Postharvest cold treatment of roses

The false codling moth is a devastating quarantine pest of key horticultural crops such as citrus, avocado and roses. Recently, The Netherlands has expressed interest in developing a postharvest treatment that kills all stages of the pest in imported roses. To reduce carbon emissions associated with air freight, the country has proposed development of a cold treatment suitable for sea freight.

PROGRESS IN 2023

In partnership with Wageningen University, The Netherlands, *icipe* has conducted cold treatment trials, which show that temperatures below 1°C are effective in killing the larvae and pupae of the false codling moth over 4 weeks. This falls within the shipment period of 4-5 weeks, to The Netherlands. The protocol is also applicable across Europe.

INNOVATION

Our studies provide a basis for phytosanitary measures to manage the false codling moth, while preserving exported roses. We will conduct large-scale validation trials and develop an international standards protocol.

Fruit Pests IPM

Beneficial bacteria in fruit fly natural enemies

Since it was reported in Africa in 2003, the invasive fruit fly, *Bactrocera dorsalis*, has caused horticultural produce loss amounting to USD 5.8 billion annually, by conservative estimates in sub-Saharan Africa. *icipe* has developed an integrated package for the management of the pest, which includes the release across Africa, of two effective natural enemies (both wasps): *Fopius arisanus* and *Diachasmimorpha longicaudata*, which were imported from USA in 2008.

PROGRESS IN 2023

We have conducted studies to understand how to improve the effectiveness of the natural enemies. Our results show that there are complementary and opposing relationships between the wasps and the bacteria in the gut of the fruit flies. The beneficial bacteria in *B. dorsalis* influence the development and fitness of the natural enemies. In particular, *Lactococcus lactis* bacteria favour the wasps, leading to high emergence rates of their adults. In contrast, *Providencia alcalifaciens* hinder the development and fitness of the wasps.

INNOVATION

We will incorporate *L. lactis* bacteria as a probiotic in the mass rearing of the wasps, thus increasing their use and effectiveness in the management of *B. dorsalis*.

Integrated agroecological mango production

Since 2021, *icipe* has been introducing innovative agroecological approaches to improve the mango production system in the South Ethiopia. Our aim is to control fruit pests including the fruit fly *B. dorsalis* and the white mango scale, *Aulacaspis tubercularis*. We are introducing the *icipe* IPM packages, improved mango varieties through tree grafting to replace the indigenous old mango trees as well as improved production options, including pruning, mulching and composting. We are also initiating intercropping of mangoes with compatible crops including maize, cassava, taro, beans and ginger, as well as beekeeping.

PROGRESS IN 2023

We reached close to **4000** mango farmers, including young people.

Over **1500** indigenous mango trees have been replaced with improved varieties through grafting, and close to **2700** bait traps have been installed on mango trees to control fruit flies.

Youth partners engaged in beekeeping integrated into mango production harvested over 2000 kilogrammes of honey.

Youth partners are supplying improved mango varieties and other seedlings to the local community.

One youth enterprise nurtured 217,610 pest-free mango seedlings, earning about **USD 20,000** from the sales.

icipe youth partners have been awarded a certificate for contributing to the Green Legacy Initiative, by the Job Creation and Enterprise Development Bureau, South Ethiopia Regional State.

WAY FORWARD

The success so far makes a case for scaling-up the agroecological approach to mango production, involving all farmers, with a special focus on young people.



Fruit Pests IPM

Supporting mango value chain in Kenya

Through this initiative, our aim is to demonstrate the *icipe* fruit fly IPM packages, promote the access by mango farmers to input suppliers, and link the farmers to local markets.

PROGRESS IN 2023

1602 farmers trained, provided with *icipe* IPM starter pack and linked to 12 input suppliers, who have representatives within the communities and readily deliver inputs.

40 youths (38% women) trained by *icipe* and CABI as community extension service providers, who provide backstopping services to farmers at a fee.

46,380 parasitoid wasps released to control fruit flies. As a result, 7 out of 10 mangoes were saved from fruit fly infestation.

Approximately **USD 236,000** generated through sale of mangoes by participating farmers, in one and a half years.

INNOVATIONS

The high-quality mangoes are more marketable. Moreover, farmers now have access to a fruit processing plant and a local entrepreneur who buys the mangoes at better prices compared to brokers. Thus, household incomes have increased. The model of linking farmers to input suppliers and markets helps to solve the perennial problem of availability, accessibility and affordability of IPM inputs.

Upscaling fruit fly IPM in Southern Africa

From 2019 – 2023, *icipe* implemented an initiative in Malawi, Mozambique, Zambia and Zimbabwe. The initiative had three pillars: food security, nutrition and income-generating opportunities for mango farmers, with a special focus on women and the youth, along the mango value chain.

PROGRESS IN 2023

4,075 mango farmers trained as trainers of trainers, on various aspects of fruit fly IPM (62% women)

10,369 secondary school students trained as future champions of fruit fly IPM (49% women)

52 learning sites established on mango farms (38% headed by women)

17,578 mango growers (53% women) are consistently using fruit fly IPM

Excess mangoes were dried mostly by women, using simple basket dries made of polyethylene nets.



Pictured: Yemisrach Chenchu, a member of the *icipe*-supported, youth-owned Nigat Mango Seedling Production and Grafting enterprise, South Ethiopia Regional State, posing with a grafted apple mango seedling.

Vegetable IPM

icipe is undertaking an initiative to address production constraints in traditional African vegetables and crucifers (kale and cabbage). The project, which is being implemented in Kenya and Tanzania, is scaling-up *icipe* strategies for the control of arthropod and nematode pests of vegetables. These approaches include biopesticides, parasitoids, predators and resistant vegetable varieties. Significantly, a novel agroecological-based vegetable push-pull (food-food) cropping system will be developed. Partnerships, linkages and capacity will be strengthened among vegetable value chain stakeholders.

PROGRESS IN 2023

Among the pests that we are tackling are leaf webbers (*Crociodolomia binotalis*), which can cause up to 100% yield loss. The insects wrap and roll the plant leaves to form shelters, chew between leaf veins, thus skeletonising them, leaving behind brown frass deposits. We are also addressing the challenge of leafworms, *Spodoptera littoralis*, moth larva that devours leaves, leaving large clusters. These two pests are extremely detrimental to amaranth, an important indigenous vegetable.

We are also helping to tackle the Alternaria leaf spot disease, which is common in brassica (cabbage and mustard) crops caused by the fungal pathogen *Alternaria brassicicola*; and *Spoladea recurvalis*, a major pest moth of amaranth.

Our studies have shown that coriander and mint herbs have properties that attract the natural enemy of cabbage aphids, a parasitic wasp known as *Aphidius colemani*, while the rosemary herb (*Salvia rosmarinus*), molasses (*Saccharum officinarum*) and *Desmodium* repel the pest. In addition, Ethiopian mustard (*Brassica carinata*) attracts the pest.

We have characterised farmers' perception, attitudes and practices, as well as the major factors influencing the use of agroecological-based production to manage pests in vegetables, in Kenya and Tanzania. Our findings underscore the need to increase farmers' awareness of the benefits of agroecological farming.

INNOVATIONS/ RECOMMENDATIONS

We have found that *Cotesia icipe*, a tiny beneficial wasp that was discovered by the Centre in Kenya in 2016, can control these two insects. Thus, we have released it in farmers' fields in parts of Kenya.

We have found a dual tool to control both constraints. Our studies show that strains of endophytic fungi *Trichoderma asperellum* M2RT4 and *Hypocrea lixii* F3ST1 are effective in controlling the Alternaria leaf spot disease, by inhibiting the growth of its pathogen; as well as *S. recurvalis* by limiting the insect's reproduction.

Thus, we are developing a push-pull for vegetables, which consists of Ethiopian mustard as a border trap crop for aphids, and rosemary, molasses, mint, coriander and desmodium as intercrops that repel the aphids, and attract the natural enemy. There is a possibility to integrate findings with the use of insect composted organic fertilisers.

We recommend: development of policies for agroecological farming approaches such as regulations that restrict the use of harmful chemicals and pesticides; gender-sensitive policies and interventions; targeted awareness campaigns and training programmes, farmer-to-farmer knowledge sharing, and farmer cooperatives and market linkages to empower smallholder farmers.



Farmers harvesting healthy kale produced using a push-pull strategy for vegetables, incorporating rosemary herb (*Salvia Rosmarinus*).

Tomato Leafminer Management

In 2008, *Phthorimaea (Tuta) absoluta*, a tomato leafminer was detected for the first time in Africa and it has since spread rapidly across the continent. While tomato farming in Africa is constrained by a plethora of pests and diseases, the arrival of *P. absoluta* has been particularly devastating. The tiny *P. absoluta* caterpillars damage tomatoes by tunnelling into leaves and eating the green parts, causing the leaves to dry out; and by burrowing into the fruits, they cause them to deform and rot. In the absence of effective control measures, the leafminer can cause 100% tomato yield loss.

Between 2018 and 2022, *icipe* and partners assembled, validated and implemented an eco-friendly management toolbox for *P. absoluta*. Through explorations in the native home of *P. absoluta*, we identified a natural enemy, a wasp known scientifically as *Doligochenidea gelichiidivoris*, which controls the leafminer by laying its eggs inside the pest's caterpillars. The eggs eventually emerge as adult wasps thereby killing the larvae of the pest. We have released the wasp in several parts of Africa.

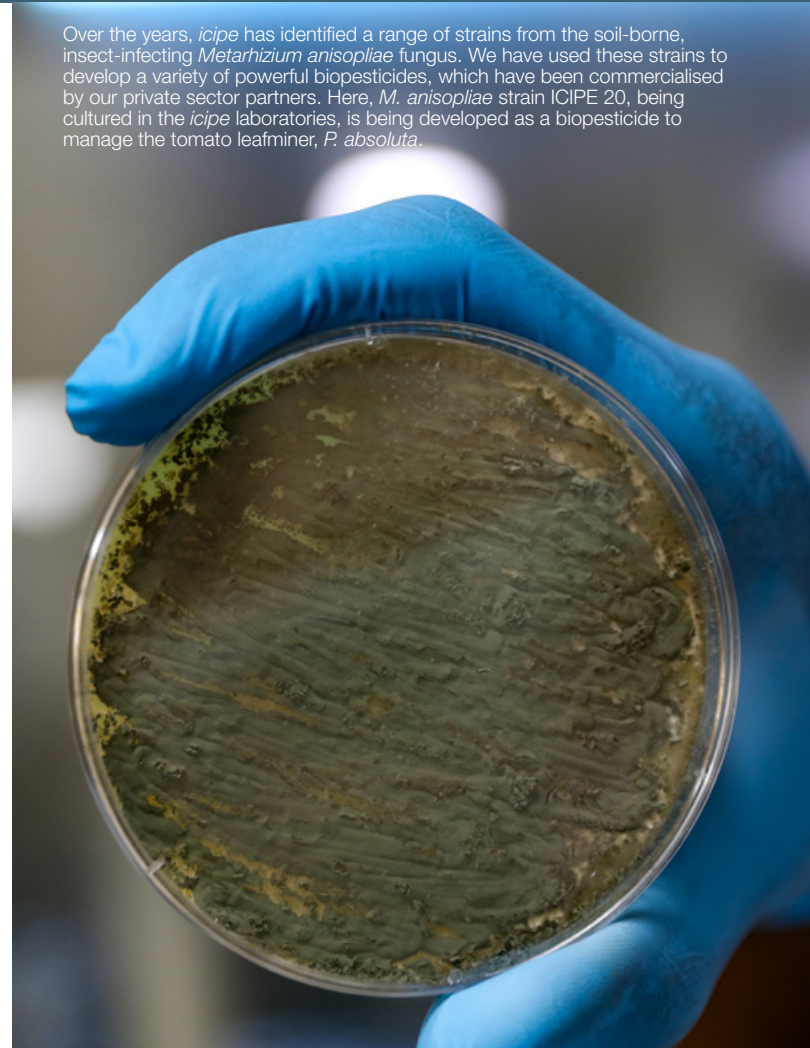
PROGRESS IN 2023

icipe has published the first report of the effectiveness of strains of *M. anisopliae* (ICIPE 20), against *P. absoluta*. The results showed significantly lower fruit yield loss, improved fruit yield and marketability, and a high cost-benefit ratio. Our findings also revealed the potential of ICIPE 18 strain in managing the pest.

INNOVATION

We have signed an agreement with Russell Bio Solutions, UK, towards the development, registration and commercialisation of biopesticides developed from ICIPE 20, in East Africa and beyond.

Over the years, *icipe* has identified a range of strains from the soil-borne, insect-infecting *Metarhizium anisopliae* fungus. We have used these strains to develop a variety of powerful biopesticides, which have been commercialised by our private sector partners. Here, *M. anisopliae* strain ICIPE 20, being cultured in the *icipe* laboratories, is being developed as a biopesticide to manage the tomato leafminer, *P. absoluta*.





Tomato Leafminer Management

PROGRESS IN 2023

Our studies have also shown that *Trichoderma asperellum* M2RT4, endophyte fungus, increases tomato plant defences and also affects the behaviour of *P. absoluta*. The endophyte triggers compounds that make the pest avoid the plants, thus limiting egg laying on the plant. In case any eggs are laid on the plant, the endophyte limits their development into adults. Some of the compounds stimulated in the plant due to the endophyte attract the natural enemy of *P. absoluta*, *D. gelechiidivoris*.

Previous *icipe* research has shown the below-ground crop protection properties of certain Asteraceae plants, like blackjack (*Bidens pilosa*) and marigold (*Tagetes minuta*), which suppress the root-knot nematode, *Meloidogyne incognita*, a pest of tomato and other Solanaceae plants. The Asteraceae plants also have above-ground pest control capacity, as they prevent the greenhouse whitefly (*Trialeurodes vaporariorum*), and green peach aphid (*Myzus persicae*), from feeding on Solanaceae plants. Our recent research shows that certain compounds in these Asteraceae plants can influence the host finding behaviour of above-ground pests, such as *P. absoluta* and its associated mirid predator, *Nesidiocoris tenuis*.

Although tomatoes and other plants in the Solanaceae family are attacked by a variety of pests, in the recent past management has shifted significantly towards *P. absoluta*. However, recent research by *icipe* shows the need to rethink such prioritisation, based on the complexity between diverse insect pests and plants. We found that plants that are infested by the greenhouse whitefly, *Trialeurodes vaporariorum*, produce chemicals, known as green leaf volatiles, which attract *P. absoluta* to lay eggs on them, thus increasing the pest's populations. Also, the chemicals repel the indigenous *Bracon Nigricans*, an indigenous wasp that is, to a certain level, a natural enemy of *P. absoluta*.

WAY FORWARD

We aim to develop a push-pull management strategy for *P. absoluta* using *Trichoderma asperellum* M2RT4.

These findings lay the foundation for intercropping either wild tomato, marigold or blackjack with cultivated tomato plants, to manage *P. absoluta*, without negative impact on the mirid predator.

Our findings indicate that, in the context of invasive species, it is important to balance pest control focus. For example, sustained attention on whiteflies will impact on the control of the invasive *P. absoluta*.

Moreover, the green leaf volatiles that we have identified may be exploited in a lure and kill strategy for *P. absoluta*.



Research on Nematodes

Banana fibre technology

In 2015, the devastating and highly destructive potato cyst nematode (PCN), was reported in eastern Africa, greatly threatening production of potato, one of the region's most important staple crops. Studies by IITA, *icipe* and partners, have shown that a simple, biodegradable paper technology made from the waste material of banana plant, can protect potato plants and other root tubers, against damage by PCN and other nematode pests. The banana fibre technology involves enclosing potato seed before planting, in a protective sheet of paper that is made from the fibre of banana plants. When treated with ultra-low dosages of nematicide, the paper releases the chemicals to the target root zone in a slow and sustained manner, in very low but effective concentrations; thus preventing contamination to non-target areas and organisms.

PROGRESS IN 2023

We have started the process of translating the banana fibre technology into a commercially viable product that is easy-to-use and accessible to farmers across the region and beyond.

In 2023, we entered the verification, assessment and scale-up phase. Through a participatory process with farmers, we completed over 100 field and on-farm demonstration trials, and 20 experimental controlled trials, under diverse agroecological zones, conditions, and crops, using nematicides and other biocontrol products.

We have evaluated different formulations of the banana fibre technology to identify the most viable product in terms of manufacturing, ease-of-use and effectiveness. We also made progress in obtaining the raw material, banana fibre, locally, and created a business plan for local production, development and distribution of the product.

In Kenya, we forged ahead towards registering the banana fibre technology, through the Pest Control Products Board (PCPB).

INNOVATION

The banana fibre technology is a nature-based solution for climate-smart agricultural technology, and it is also a model for circular economy innovations. The technology controls nematodes, increases crop yield, improves the impact of biologically-based crop protection products and, overall, contributes towards a more resilient and eco-conscious farming future. We are also assessing the impact of the technology on soil health and on the microbial environment.

Insect frass fertiliser to control nematodes

We have tested the potential of chitin-fortified black soldier fly-composted organic fertiliser in suppressing PCN.

PROGRESS IN 2023

Our results show that the fertiliser, fortified with 5% insect chitin, effectively manages PCN and increases potato yield, while also enhancing soil health. Similarly, we found that the fertiliser is more effective than a commercial nematicide, in managing the root knot nematode, *Meloidogyne incognita*, and its impacts on spinach growth.

INNOVATIONS

Chitin-fortified insect frass fertiliser is a promising multipurpose, regenerative tool for the sustainable management of plant-parasitic nematodes and better crop yield. We are conducting field trials to evaluate the fertiliser in combination with current and new nematode management practices, such as trap crops and the banana fibre paper technology. We are also testing PCN resistant potato varieties, which resemble popular local varieties, in terms of taste and acceptability by consumers. The varieties are undergoing national performance trials in Kenya, to facilitate registration.



(L-r): Sweetpotato grown on a farmer's plot, which shows nematode damage; in contrast to the harvest from an IITA/*icipe* experimental plot, on the same farm, using banana fibre technology.



Research on Nematodes

Capacity building

In 2017, *icipe* and IITA commenced a five-year partnership with Ghent University (Ugent), Belgium. *icipe* serves as a Satellite Hub for Ugent's Master of Science in Agro- and Environmental Nematology Programme. Students enrolled on the programme participate in the Kenya Track Option coordinated by *icipe* and IITA, which includes industrial training in Kenya and a Tropical Pest and Disease Course. The students also act as trainers of the annual Basic Crash Course in Nematology (BCCN).

PROGRESS IN 2023

In 2023, six students from India, Indonesia, South Africa, The Philippines and Uganda, participated in the Kenya Track, while the BCCN had a total of 17 participants from Benin, Burundi, Ethiopia, Kenya, Nigeria, Rwanda, South Africa and Tanzania.

As partners in the Nematology Education in sub-Saharan Africa (NEMEDUSSA) network, we are mainstreaming nematology training and teaching in university curricula in Africa. We have contributed to the establishment of a pan-African nematology network (PANEMA), the premier gathering of nematologists in the region.

In 2023, in partnership with KEPHIS, we held a multinational training course, in Kenya, on PCN detection and diagnostics for representatives for National Plant Protection organisations.

We coordinated the Horticultural Association of Kenya (HAK) annual workshop under the theme: 'More, healthier and safer food', where we raised awareness on nematodes through farmer and student training, and presentations. The three-day forum brought together young scholars, researchers, farmers and, for the first time, industry partners.

In 2023, we welcomed numerous visit to discuss ongoing or potential collaboration opportunities including representatives of Sida, Rwanda Agricultural Board and 2Blades company.

Nematology networks and platforms

Over the past several years, *icipe* jointly with IITA, has been pivotal in increasing awareness and expertise in nematology across Africa. Our goal is to establish a critical mass in nematological research; create public understanding across the agricultural landscape; form networks and platforms for capacity building and research; and help to integrate knowledge on nematode management within agriculture, academia and policy.

PROGRESS IN 2023

icipe is a key partner in a new initiative by the Food and Agriculture Organization of the United Nations (FAO), which aims to strengthen the eastern Africa regional capacity to diagnose and manage PCN and other key emerging potato pests.

The initiative will:

Improve stakeholder understanding, awareness and capacity to deal with PCN and other emerging pests of potato.

Strengthen diagnostic capacity and adherence to measures for phytosanitary controls of the target pests.

Help develop protocols and guidelines on phytosanitary controls for PCN and other key emerging potato pests and seed potato quality assurance systems, and their domestication at national, regional and continental levels.

Provide technical support to countries for stronger capacity to employ risk-based controls that promote regional potato trade.

Map the incidence and distribution of the target pests in project countries.



Pineapple root infested with root knot nematodes. Through the Tropical Pest and Disease Course, coordinated by *icipe* and IITA, we are partnering with commercial growers in identifying and tackling the nematode menace in the crop.

ENVIRONMENTAL HEALTH THEME

The focus of the Environmental Health 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.

Donors: Bayer Crop Science, Germany; BioInnovate Africa Programme; Biovision Foundation for Ecological Development, Switzerland; European Union; Federal Ministry for Economic Cooperation and Development (BMZ), Germany, through the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ); Global Affairs Canada; Swiss National Science Foundation (SNSF); Norwegian Agency for Development Cooperation (Norad); Fund for Scientific Research (FNRS), Belgium; German Science Foundation (DFG); IKEA Foundation; International Center for Agricultural Research in the Dry Areas (ICARDA); International Fund for Agricultural Development (IFAD); JRS Biodiversity Foundation, USA; Kenya Agriculture and Livestock Research Organisation (KALRO); Mastercard Foundation; Nature Kenya; The Rockefeller Foundation; and World Trade Organization (WTO) – Enhanced Integrated Framework (EIF).

A comprehensive list of partners is included in the annexes.

2023 IN BRIEF



New knowledge

Insights for sustainable and modern beekeeping for: ecological protection of mangrove forests on Zanzibar island; diversified livelihoods and incomes of pastoral and agropastoral communities in Kenya and Ethiopia, in the arid and semi-arid lands in Kenya and in degraded natural habitats in Ethiopia, especially for women; and dignified and fulfilling jobs for youth and women along honey and silk value chains in Ethiopia.

Generating novel knowledge on geographical indication of honey and on conservation of pollinators; insect biodiversity database that includes ca. 72,000 unique insect specimen records.



Inclusive innovations

Robust, resilient, inclusive bee and silk value chains; a range of products commercialised, leading to increased household incomes, and economic growth.

Creation of various novel tools, for example the Beekeepers' Companion app, which has high potential in private sector driven outgrower beekeeping model.

Promising leads to develop novel powerful, environmentally friendly mosquito repellents; attract and kill fruit fly traps, using plant extracts; and boosting of traditional approaches to increase bee swarms.



Policy contributions / Recommendations

Process to demonstrate the value of geographical indication (GI) of African honeys.

Support for pollinator conservation policies in Cameroon; baseline information on insect biodiversity as a basis for conservation amidst threats from factors such as climate change and human activities.

Contribution to the reorganisation of apiculture sector stakeholder platforms in Ethiopia, to form one coherent association known as the Ethiopian Apiculture Development Association (EADA).



One Health / Circular economy

Safe high-quality beehive products, including table and medicinal honeys, propolis health supplements and body care items impact human health.

Integrated sustainable beekeeping and sericulture contributes to environmental rehabilitation and protection of vulnerable landscapes and biodiversity; and a profitable business model that empowers communities and value chain actors, especially women, marginalised communities and the youth.

Bee Research

Zanbee

Mangroves, the only species of trees in the world that can tolerate saltwater, are highly beneficial. They are carbon-rich and home to unique and endemic terrestrial and marine biodiversity. Specifically, mangroves have a reciprocal relationship with bees. The diversity of flowering plants within mangroves are rich sources of nectar and pollen for wild and managed bees. In turn, bees provide pollination services thus boosting productivity of mangrove trees. Globally, mangrove forests are declining, with the trend even more rapid in eastern Africa.

icipe and partners are implementing an ecological beekeeping initiative to protect mangrove forests in Zanzibar island. This project will help to create awareness on the important functions of mangrove forests; contribute to the reduction of over-exploitation and deforestation of these critical ecosystems; and support climate change resilience. We are linking beekeeping with the cultivation of multifunctional trees that provide bee forage, firewood, high-quality animal fodder while also improving soil quality through nitrogen fixation, and carbon sequestration.

PROGRESS IN 2023

Through participatory research, we:

Selected *Moringa oleifera* (drumstick tree) and *Calliandra calothyrsus*, as the best multipurpose trees to be planted by communities. We have also identified the most essential bee forage plants in Zanzibar island, as well as the suitable mangrove zones for honey production.

Trained farmers on the use of bee hive products and multipurpose trees, and supported communities to establish healthy tree nurseries, producing close to 6,500 seedlings of the two trees.

Established 15 community apiaries and trained farmer groups in modern beekeeping, bee health, beehive products quality and value addition; and provide them with beekeeping and value addition starter kit.



A range of products have been produced and commercialised, including (l-r): honey, propolis health supplements, body care items, candles and shoe polish



Bee Research

Pastoral and agro-pastoral regions

The arid and semi-arid lands (ASALs) in Africa suffer from extreme drought, shortage of arable land and water, human conflicts and rising population. These factors have had an adverse impact on the predominant livelihood options of livestock herding and pastoralism. *icipe* is partnering with University of Helsinki, Finland, in a project that is using Earth observation and environmental sensing for climate-smart beekeeping in these areas.

PROGRESS IN 2023

We are strengthening honey beekeeping, a traditional practice in these areas by:

Generating new knowledge on optimum hive orientation, hive colonisation and honey bee growth.

Introducing meliponiculture through training of agro-pastoralist, and establishment of meliponaries to promote production of honey from *Liotrigona* sp, *Plebeina armata* and *Meliponula beccarii* for income generation.

Increasing hive colonisation rate for honey bee and stingless bees using improved plant-based lures, based on traditional beekeeping knowledge.

Conducting training and providing beekeepers with starter kits composed of modern hives and accessories.

Sequencing pollen DNA to determine plants preferred by honeybees, stingless bees and studies on suitable beekeeping habitats.

Analysing of honey produced by stingless bees to establish standards.

Arid and semi-arid lands

Generally, the arid and semi-arid lands (ASALs) are well-suited for beekeeping. Although these areas are key producers of honey, overall productivity is low. *icipe*, Kenya Agricultural & Livestock Research Organization and partners aim to contribute to improving honey production in two arid and semi-arid areas in Kenya: Baringo County, in the Rift Valley; and Kitui County, eastern Kenya.

PROGRESS IN 2023

We have trained representatives of partnering institutions on modern beekeeping, pollen sampling and analysis, honeybee breeding and postharvest processing and built the capacity of beekeepers and extension agents in advanced beekeeping and honey processing techniques.

Through participatory research, we are conducting analysis of optimal hive types suited for these areas; developing floral calendars; and designing models for determining the optimal times for honey harvesting.

INNOVATIONS

We have identified highly medicinal honeys that can be used against highly resistant bacteria, which are undergoing further tests. Moreover, our activities are contributing to the reforestation of the ASALs.

Bee Research

Geographic indication of Ogiek honey

Ogiek honey is unique. It is traditionally produced in the Mau rain forest complex, a globally recognised key biodiversity area and largest remaining indigenous montane forest in East Africa, which is also considered one of the five water towers of Kenya. The honey derives its name from the Ogiek community involved in its production, and which has a symbiotic relationship with the Mau forest ecosystem.

PRODUCT

The small black African honeybees kept by the Ogiek community prefer the nectar in the flowers of the Malvaceae (mallow or hibiscus) plant, *Dombeya goetzenii* which give the honey collected in August a characteristic whitish-grey color and unique flavour.

Our analysis shows that Ogiek honey contains cineole, a compound with anti-inflammatory, anti-microbial and anticancer activities; pinene, a potent anti-inflammatory agent; and camphene, which has cholesterol-lowering properties. Also, it has high polyphenolic content, which boosts digestion and brain health. It is also a good source of natural antioxidants due to the radical scavenging activity of the bees. The honey also has superior antibacterial activities. For example, it is active against *Pseudomonas aeruginosa*, germs whose infections are difficult to treat.

PROCESS

With their traditional right to access forest resources, the Ogiek community through support from *icipe* has formed 12 groups, amalgamated into Mariashoni Community Development Cooperative (MACODEV), which buys, refines, packs and sells honey through retail outlets in nearby towns.

icipe and partners, primarily cooperatives and producers in France, aim to demonstrate the potential of geographic Indications (GI) in adding value to a traditional practice of a marginalised community. The designation of “geographical indication” identifies products that possess the qualities, characteristics or reputation associated with a particular region. This certification protects the efforts of producers and the reputations of products, preserves species and establishes a relationship of trust between producers and consumers.

We will build capacity on GI skills and foster an active community of GI practitioners. We will also demonstrate the value of GI by piloting and establishing a case for support to unique honey from Mau Forest in close collaboration with the native Ogiek community. Other activities include: categorisation of beekeepers, mapping of households, traditional and modern beekeeping practices; characterising foraging plants and their relationship to honey type over season and landscape; strengthening quality analysis of Ogiek honey products based on seasons and landscape; and market research on consumers’ perceptions and interests for traditional honey from Kenya.



The uniqueness of the Ogiek honey results from the natural forest and the traditional harvesting practice of the Ogiek community. The traditional hives are made of large red cedar cylinders, resistant to parasites and other elements, and are hang from tall trees.



Bee Research

Conservation of pollinators in Cameroon

In Cameroon, there is limited awareness of the role of insect pollinators in increasing crop yield and in the restoration of degraded ecosystems, among key stakeholders, for example, farmers, policymakers and the general public. Additionally, data on the diversity of insect pollinators and their forage plant species is lacking. Moreover some available records on the plant-bee interactions are not digitised and they are also not freely accessible. We aim to contribute to mainstreaming data on bee and fly pollinators, and their forage plant species to increase knowledge, awareness, and to help design policies that abide primarily to the Cameroon in the conservation of this useful resource.

PROGRESS IN 2023

To address data deficit on insect pollinators and forage plant species and biodiversity conservation in Cameroon, we conducted an on-site baseline workshop for stakeholders. The participants included leaders of farmer cooperatives, heads of schools and researchers.

We also organised a high-level policy workshop in Yaounde, Cameroon, to assess the opportunities and challenges for designing policies to conserve pollinators, and enhance their interactions with plants, in the country. The forum brought together 17 participants from various institutions in agriculture, livestock, environment, forestry and research, which are responsible for the formulation, implementation and evaluation of the country's forest, natural resource, ecosystem services and wildlife policies.

WAY FORWARD

We are developing knowledge products and policy sensitisation materials on the diversity of plant-pollinators in diverse landscape types; addressing the complex challenges related to the use of pollinator-friendly pesticides; creating public awareness on the conservation of pollinators and their habitats, through good farming practices and landscape management; and training stakeholders on biodiversity research involving insect pollinators.



More Young Entrepreneurs in Silk and Honey (MOYESH) Project

In October 2019, *icipe* in partnership with the Mastercard Foundation and Ethiopia Jobs Creation Commission (JCC), launched the MOYESH project. The five-year initiative aims to see 100,000 young people (60% of them women), in Ethiopia, secure dignified and fulfilling jobs along honey and silk value chains.

Direct jobs created

156,014 for young people (61% women) in the apiculture and sericulture businesses

11,877 youth-led beekeeping enterprises and

1,117 youth-led sericulture enterprises, established.

Revenue created

ETB **918** million (approximately USD 16 million) from hive products, silk products, and integrated farming businesses.

Reached

92 districts across Ethiopia

Supplied to the market

2,379 tonnes of packed table honey

Generated

ETB **51.46** million (approximately USD 935,636) in loans, which were disbursed to 503 youth enterprises, to expand core and complementary income generating businesses.

Elevation of beekeeping and sericulture as appealing business ventures for small and medium-sized enterprises that supply inputs, deliver services and engage in trading. They have created at least **30,000** additional direct jobs.

90% of the women youth partners and **92%** of the men reported improved entrepreneurship, business, and life skills (soft skills scores).



Through the MOYESH project, we have helped to re-introduce sericulture farming in Ethiopia, using the Eri silkworm (*Samia Cynthia*), that feeds on the leaves of castor plants, due to its suitability to the country's weather conditions, its hardiness, disease tolerance and year-round production cycles, among other factors. Eri silk is unique; it is a staple fibre, which, unlike other silks has a continuous filament. It is very strong, durable and elastic and hardy for processing. It is also darker and heavier than other silks and blends well with wools and cotton. We are taking advantage of Ethiopia's comparative advantage in traditional craftsmanship in weaving and design, use of natural dyes on cotton, to create distinct, globally appealing fabrics, such as the one worn in this picture by Workite Kurse, a youth partner from Adami Tulu, Oromia Region, while posing with raw silk yarn.

More Young Entrepreneurs in Silk and Honey (MOYESH) Project

In 2023, we:

Initiated a mobile money agency pilot programme in collaboration with Ethio-Telecom and Highlight Trading PLC, as part of the effort to expand business opportunities for youth partners. A total of 26 youth-owned enterprises and 12 cooperatives have been registered as mobile money agents, and they now undertake sales of mobile vouchers and other associated electronic money transactions.

Introduced pilot scheme for Village Savings and Loans Associations, to provide youth partners, primarily women, access to more affordable and uncollateralised saving and lending services, while also nurturing their social capital through sharing of resources, ideas, and values.

Expanded market linkages through participation in local, national, and international exhibitions, trade fairs and festivals, including the USAID-organised Youth Festival, the 8th African Livestock Exhibition and Conference, the 2023 World Bee Day, and the National Agricultural Sciences Exhibition.

At the request of the Ministry of Agriculture, we assisted in the status assessment and reorganisation of three separate overlapping stakeholder platforms of the apiculture sector, namely the Ethiopian Apiculture Board, the Ethiopian Honey and Beeswax Producers, Processors and Exporters Association, and the Ethiopian Society of Apiculture Science, into one coherent sectoral association known as the Ethiopian Apiculture Development Association (EADA).

The rapid expansion of the MOYESH project in the Oromia Region, and its contribution to youth job creation was endorsed through a certificate of recognition from the Zonal Administrations (East Wollega, Jimma and Illu Ababor).



A significant aspect of the MOYESH project is the commitment by government agencies to allocate land for beekeeping or sericulture to the youth enterprises. This is either land that is degraded or adjacent to natural resource-rich ecosystems that are in need of conservation. Previously, such land was out of bounds for communities. Thus, community members had little motivation to contribute to its preservation or regeneration. Through the MOYESH project, a more compelling and sustainable way to safeguard natural resources has been introduced. For example, this apiary has been set up through the MOYESH project close to the Yayu Coffee Forest Biosphere Reserve, in the southwestern Ethiopia.

More Young Entrepreneurs in Silk and Honey (MOYESH) Project

Women beekeeping enterprises

In several parts of Ethiopia, *icipe* and partners are implementing beekeeping enterprises to improve livelihoods and resilience, especially for women, in degraded natural habitats. Our goal is to benefit women beekeepers, organised in common interests groups (CIGs), to establish improved beekeeping and complementary farming, that are socially inclusive and environmentally sound.

PROGRESS IN 2023

300

experienced and young women beekeepers have established improved beekeeping and associated complementary farming practices.

A commercial digital application known as Beekeepers' Companion, which captures and transfers bee health data, for example colony status and activity in real time, has been customised, localised and piloted by 25 women beekeepers.

3,139

honeybee occupied hives. On average holdings of honeybee colonies increased from 8.7 to 10.5, per CIG member.

43.5

tonnes of honey harvested by all the beekeepers over a 3-year period, which is 45% of the set target of 30 tonnes by the end of the initiative.

LESSONS LEARNT

The integrated apiculture business model can lead to profitable enterprise in vulnerable landscapes.

Multipurpose bee forage crops, shrubs and trees contribute to environmental rehabilitation.

Women can become technically competent and successful beekeepers.

The Beekeepers' Companion app has high potential in private sector driven outgrower beekeeping model.



Endegena Getie, a beekeeper from East Gojjam Zone, Amhara Region, Ethiopia, with wheels of beeswax, an emerging commercial product.



Bioprospecting

Bee swarm attractant

One of the challenges beekeepers face in Africa is the low hive occupation rate as they majorly depend on bee swarm attraction to the hives. The synthetic swarm lures are expensive and not accessible to local farmers. Meanwhile, many traditional plants are used to attract bee swarms, although they have not been tested.

PROGRESS IN 2023

We are researching the use of natural plants in Kenya, including practices and beliefs, to obtain insights on traditional approaches for attracting bee swarms. We tested compounds from two commonly used traditional plants, local basil and citronella plant.

INNOVATION

We have harnessed the extracts from the plants, which in combination with beeswax, will increase honey bee swarm catches.

Fruit fly attractant

Fruit flies are a major constraint to fruit cultivation in Africa. The 'attract and kill' strategy for male flies using a chemical compound known as methyl eugenol is one of the most effective techniques in fruit fly management. However, synthetic forms of the compound are often unavailable to most fruit growers.

PROGRESS IN 2023

Our studies show that several basil of the genus *Ocimum* produce methyl eugenol. Thus, we tested extracts from *Ocimum tenuiflorum* and found methyl eugenol to be the most abundant compound. Therefore, extracts from the plant can be used as fruit fly lures.

INNOVATION

We are now in the process of designing an attract to kill fruit fly trap using methyl eugenol from basil.



Insect oil mosquito repellent

Designing smart mosquito repellent system remains a major challenge in malaria control. Obstacles including limited knowledge on the mechanisms of mosquito repellents and increasing insecticide resistance in mosquitoes. Additionally, chemical repellents can have adverse effects on the environment, and on people. There are several known natural mosquito repellents, for example oils from plants like citronella grass (*Cymbopogon nardus*), camphor basil (*Ocimum kilimandscharicum*) and lemon-scented gum (*Eucalyptus citrodora*).

PROGRESS IN 2023

Our studies have established that combining essentials oils from citronella with termite oil (*Macrotermes spp*) increases repellency against mosquitoes by 2-fold. These findings open a promising path to create novel powerful, environmentally friendly mosquito repellents.

PRODUCTS

This study provides insights into the field of mosquito repellents development, and opens a promising path for the creation of powerful, environmentally friendly products in different formulations, which could help lower the incidence of mosquito-borne illnesses.

Biosystematics

Insect biodiversity and conservation

Current data suggests an overall pattern of decline in the diversity and abundance of insects, with more than 40% of species diminishing, and a third endangered. Indeed, the rate of insect and arthropods extinction is eight times faster than that of mammals, birds and reptiles. The main drivers of this trend include: agriculture, particularly the heavy use of pesticides; habitat destruction, fragmentation and quality loss; as well as urbanisation. Moreover, climate change will have a profound impact on insects. *icipe* is contributing to global efforts to overcome insect decline in several ways. Indeed, the Centre has longstanding mandate to conserve insect and arthropod biodiversity. Our efforts have led to the discovery of many interesting new species and provided insights into the geographical distribution of various insect groups, primarily Hymenoptera and Diptera.

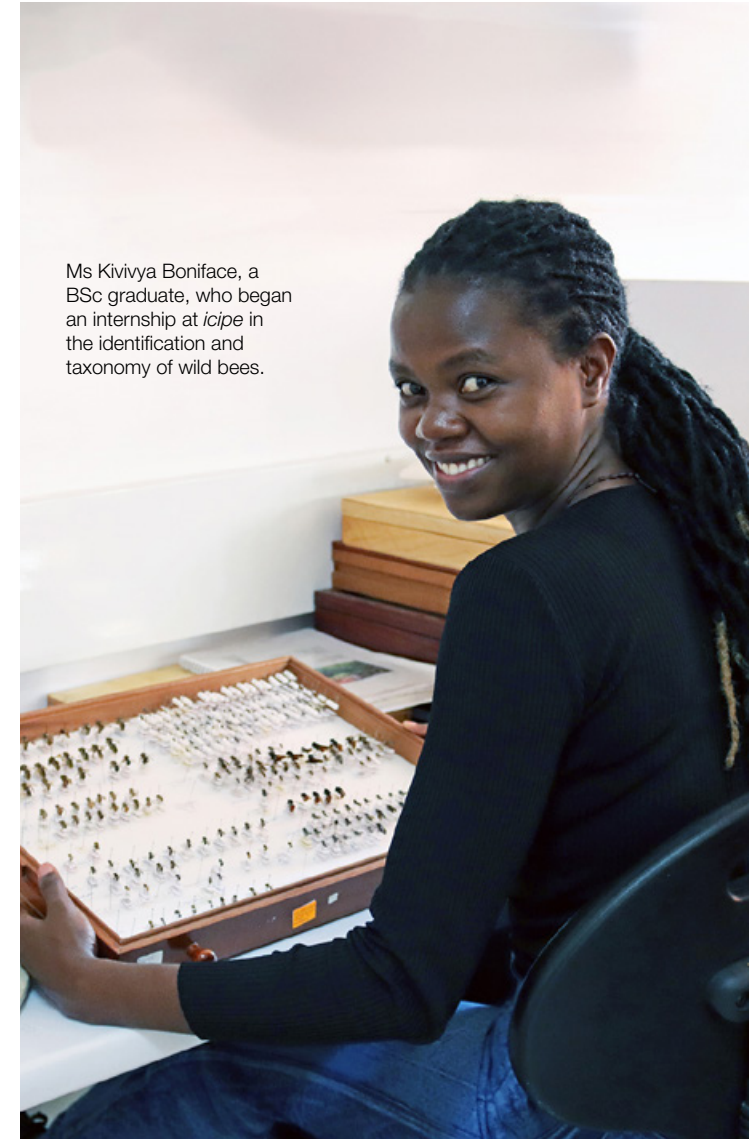
PROGRESS IN 2023

We have created a digital database of insects that we have collected. Each unique specimen record includes the specimen's geographical and temporal data as well as the specimen's identification, if known. In 2023, we increased the database collections to 72,000 unique specimens. These data provide insights on potential changes in the insect fauna over time in specific habitat types in the face of global warming and habitat loss. Our collections have led to the publication of 230 previously unknown species.

Groups of insects are sent to experts for identification and description of new species. Holotypes of new species are repatriated to Kenya and deposited in the National Museums of Kenya department of invertebrate zoology. We have also collected 21 genera of insects that were previously unreported from the Afrotropical region. Two taxonomic experts from the USA and Israel visited *icipe* and curated the groups in which they have expertise.

In 2023, we began a project to increase appreciation of the smaller species in the natural world. We believe that exposure to the wide range of forms and colours that abound in the insect world is the best place to start in building interest in the insect world.

We are running a social media campaign, dubbed 'Insect of the Week', which features a high-resolution image and accompanying narrative of a species. The response has been gratifying and we are planning to enlarge the dissemination, possibly through a wide format book.



Ms Kivivya Boniface, a BSc graduate, who began an internship at *icipe* in the identification and taxonomy of wild bees.



True bug belonging to, *Tessaratomidae: Hemiptera*

Location: *icipe*, Nairobi, Kenya

This interestingly shaped and coloured insect is a nymphal stage of the true bug belonging to the family, (*Tessaratomidae: Hemiptera*). Adults of these bugs are large shield shaped bugs and some of them are considered edible in southern Africa.

INSECTS FOR FOOD, FEED AND OTHER USES PROGRAMME

The *icipe* Insects for Food, Feed and Other Uses (INSEFF) programme aims to translate the latent benefits of insects in transforming agriculture and food systems into a more sustainable and vibrant circular economy. Currently, much of our food system is wasteful, polluting or toxic; thus, impacting air, land and water. It contributes to about a quarter of global greenhouse gas emissions. The world uses about half of available land on Earth for food production and about 70 percent of the freshwater consumption is directed to agriculture. Insects have a better ecological footprint and lower greenhouse gas emissions. They are also an alternative, more affordable and nutritious source of food for people and livestock; are efficient in bioconverting waste; and are a basis of organic fertiliser and pest control products.

Donors: Australian Centre for International Agricultural Research (ACIAR); Bill & Melinda Gates Foundation; Bioinnovate Africa Programme; Biotechnology and Biological Sciences Research Council, UK Research and Innovation (UKRI); Curt Bergfors Foundation Food Planet Prize Award; Danish International Development Agency (Danida); East African Science and Technology Commission (EASTECO); Environment for Development (EFD); Federal Agency for Food and Agriculture (BLE), Germany; Federal Ministry for Economic Cooperation and Development (BMZ), Germany, through the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ); Global Affairs Canada; Food and Agriculture Organization of the United Nations (FAO); Horizon Europe; IKEA Foundation; International Development Research Centre (IDRC); National Postcode Lottery, Netherlands; Netherlands Organization for Scientific Research (NWO); National Research Fund; Norwegian Agency for Development Cooperation (Norad); Norwegian Refugee Council; Novo Nordisk Foundation (NNF); Scientific Cooperation Grant Initiative for Eastern Africa; Swiss Agency for Cooperation and Development (SDC); The Rockefeller Foundation; UK's Foreign, Commonwealth and Development Office (FCDO); and World Bank.

2023 IN BRIEF



New knowledge

Insights to expand the pool of insect species used as food in Africa; best preparation methods to safeguard nutritional value and microbial safety of popularly consumed insects in Africa. Reversing negative impact of insects like desert locusts, while harnessing their benefits. Advantage of supplementing soybean meal, sunflower seed cake and cotton seed cake with black soldier fly larvae meal in animal feed. Insect frass fertiliser enhances biological nitrogen fixation of beans; beetles suppress manure-borne pathogens to harmless thresholds and reduce antibiotic residual effects. Discovery of sterols in insects, which are effective in suppressing drug resistant pathogens; and peptides extracts from fungal symbionts with inhibitory activity against prominent antimicrobial resistance.



Inclusive innovations

Low-cost, artificial diets using locally available residue waste streams to increase insect mass rearing. Use of desert locust powder to fortify wheat bread, increasing nutrition of consumers in countries where the insect is both a delicacy and a threat.

Low-cost easily operatable, portable suction backpack trap for large-scale collection of locusts during outbreaks.

Insect frass fertiliser to restore soil health and stimulate indigenous rhizobia populations. Transfer of knowledge to numerous stakeholders through many pathways including media, events, demonstration farms and many training initiatives, partnerships initiatives for scaling, for example in collaboration with MaMa Doing Good, a programme by the First Lady of Kenya.



Policy contributions

In partnership with the African Organisation for Standardisation (ARSO), we will contribute to harmonisation of standards on edible insects in Africa.

In partnership with Institute of Ethiopian Standards, standards and guidelines on production and commercialisation of dried insects for animal feed developed and validated; pending approval.

Studies on antimicrobial peptides insect-derived sterols have opened new frontiers in Africa and globally in the ongoing search for novel antimicrobial agents.



One Health / Circular economy

The insects for food, feed and other uses activities are an excellent example of a One Health framework. The initiatives are impacting on all aspects of the agriculture and food systems including farming, waste management and inputs, while also interacting with other key systems like energy, trade and the health of people, animals and the environment.

Insects for Food

In Africa, insects have traditionally been consumed by numerous communities. *icipe* has built on ethno-knowledge, through scientific research to mainstream edible insects and their products into agriculture and food systems. Our studies show that edible insects have a rich profile of proteins, carbohydrates, fats, minerals, vitamins, and bioactive compounds that are essential for human health and nutrition. *icipe* has also created a blueprint for using insects in food-to-food biofortification. For example, in 2022, we have used high-quality nutrients from an edible African cricket known as *Scapsipedus icipe*, to transform African porridge from a basic, often low-nutrient meal, into a super-food that meets and exceeds micronutrient requirements. These innovations are especially useful for children and undernourished individuals.

PROGRESS IN 2023

To expand the pool of insect species being used as food in Africa, we have developed low-cost, artificial diets using locally available residue waste streams. Our studies show that such diets improve growth performance and nutritional quality, in terms of crude protein, fat, energy, and amino acids, of insects.

The highly nutritious larvae of rhinoceros beetle (*Oryctes rhinoceros*) are popularly consumed in Africa. We have investigated the best preparation methods to safeguard their nutritional value and microbial safety. Roasting and toasting significantly increase the crude protein and ash contents of the beetles. All the cooking methods eliminated highly pathogenic microbes (Enterobacteriaceae, *Shigella* sp. and *Campylobacter* sp.) in the beetles.

We are researching ways to reverse negative impact of certain insects, while harnessing their benefits, to reduce their damage to crops and exploit their potential use as food. Such insects include palm weevils (*Rhynchophorus phoenicis*), which cause significant damage in palm plantations. Palm weevils are highly nutritious and they are believed to have medicinal value and skin benefits.

INNOVATIONS

Validated low-cost sensors developed by partners to establish precision black soldier fly farming, and decision-support systems for mass production automation, thus reducing operational costs, while attracting more private sector investments. The knowledge generated will be transferred to farmers and private sector partners for commercial mass production of the insects.

We have introduced easy-to-apply heat and chemical pretreatment methods to preserve the colour of processed beetles, reduce protein oxidation and inhibit most harmful microbes.

We have developed a pheromone trapping system to harvest adult palm weevils.

PROGRESS IN 2023

Desert locust outbreaks, such as the one that affected eastern African countries from 2019, cause untold damage. As *icipe* continues research to mitigate such disasters, we are also working with communities to harness the positive aspects of desert locusts. For example, our research has shown that the consumption of the desert locust could be good for people's hearts. We have shown that the insect contains a rich composition of compounds known as phytosterols which have cholesterol-lowering properties, thereby reducing the risk of heart disease.

INNOVATIONS

We are incorporating desert locust powder to fortify wheat bread, resulting in a product that is nutritious, acceptable, appealing and accessible to consumers in over 25 African countries where the insect is a delicacy. The fortified bread has significantly higher calcium, iron and zinc levels.

We have developed a low-cost cordless and portable suction backpack trap that can be used in large-scale daytime collection of locusts during outbreaks. This tool can be easily operated by community members who understand the terrain and are able to identify and harvest roasted adults (at night) or moving hopper bands.



Desert locusts (*Schistocerca gregaria*) being reared at *icipe* for experimental purposes.

Insects for Feed

While poultry, fish and piggery industries are among the fastest growing agribusinesses in Africa, their full potential is hindered by the shortage and high cost of feed protein additives, which include soybeans, fish oil, fishmeal, seed cakes and various grains. In addition, it is unsustainable to solely rely on such products for feed, as they are also food for people. *icipe* is leading the way to incorporate insects as an alternative, more affordable and nutritious source of protein in animal feeds. Our studies show that insect-based feeds promote growth, health, performance and quality of products, in poultry, fish and pigs.

PROGRESS IN 2023

We conducted a major commercial trial in Kenya, which confirmed the benefits of supplementing soybean meal and sunflower seed cake with black soldier fly larvae meal. In layer hens, growth performance increased (with a rise of 3 – 10% in egg production), and higher nutrient quality in protein, fat, energy, amino acids, fatty acid, vitamin and minerals. Profit margins are boosted when the birds are fed with diets that contain about 75% insect products.

We trained 1465 (60% women) farmers and 27 feed millers in Kenya, Uganda and Rwanda, on insect-based feed formulation.

In 2022, *icipe* launched the Scaling-Up Insect-Based Protein Feed Technologies and Practices for Enhanced Poultry Production in Ethiopia (SIPFEED). Through SIPFEED, *icipe* and partners are demonstrating the numerous benefits of insect-based feeds and insect-composted organic fertiliser. A black soldier fly training hub has been established at Hawassa University, Sidama Region. Several postgraduate students are in progress at Hawassa University and Haramaya University, Oromia Region, to generate locally tested scientific evidence for feed regulators and policy and decision makers.

PROGRESS IN 2023

A range of activities were held including: familiarisation and validation workshops, field visits, exhibitions, training on: black soldier fly production and management; awareness creation to the public and feed millers on black soldier fly products; evaluation of local organic waste substrates on black soldier fly growth and performances; and assessments of poultry farmers perception and willingness to pay for black soldier fly-based feed.

Over 70 people received training on the fundamentals of black soldier fly mass production and rearing. They include youth groups, researchers, feed companies and food processors. In collaboration with private sector partners, we established three demonstration sites in Adama and Holeta, Oromia Region and, Bahir Dar, Amhara Region. The Ethiopian Institute of Agricultural Research (EIAR) has commenced black soldier fly rearing in Bishoftu, Oromia Region. Youth partners from Adama, Oromia region, participated commendably in the second AYuTe Ethiopia Challenge Competition co-organised by the government, and development partners including Heifer International. Two MSc students have identified the best substrates for rearing black soldier flies, which are being piloted at Hawassa University.

POLICY

icipe in partnership with Institute of Ethiopian Standards (IES), and key stakeholders have developed and validated product quality standards and guidelines on production and commercialisation of dried insects for animal feed. The dossier has been submitted to the Council of Ministers, Ethiopia, for approval.



(l-r): Eyob Kefeni (PhD student, Hawassa university, Ethiopia) and Abyalew Moges (Research Assistant, *icjpe*), pictured with branded black soldier fly products (dried larvae and frass fertiliser), during a recent stakeholders visit to the insect farming pilot and demonstration site at Hawassa University, Ethiopia.

Insects for Soil Health

Insect frass fertiliser

In Africa there is massive soil degradation due to climate change, farming practices and over-reliance on synthetic fertilisers. *icipe* has developed and validated 10 multipurpose, cost-effective, organic and environmentally friendly insect frass fertilisers, including chitin-enriched versions. The products have significant impact on soil health and crop productivity, as well as crop pests and disease management. These products are packaged in various forms such as powdered, liquid and granular.

PROGRESS IN 2023

Beans supply their own nitrogen through biological nitrogen fixation. However, this capacity is hampered by low populations of rhizobia in the soil, as well as the depletion of key nutrients that are required for biological nitrogen fixation. Our studies show that insect frass fertiliser can enhance biological nitrogen fixation of beans, leading to increased yield (43 – 72%), net income (73 – 239%) and gross margin (118 – 184%), compared to commercial fertilisers.

Our studies show that insect frass fertiliser fortified with insect chitin suppresses potato cyst nematodes by up to 98% under screenhouse conditions leading to 69 – 362% increase in potato yields. The liquid chitin fortified frass fertiliser causes 95% mortality of root knot nematodes which is comparable to commercial nematicides (96%). In spinach, this intervention increased yield by 39 – 58%.

INNOVATIONS

Insect frass fertiliser is a novel strategy to restore soil health and stimulate indigenous rhizobia populations. We have commenced training of farmers to use the product to boost biological nitrogen fixation in beans.

We have established demonstration farms for the testing and training on insect frass fertilisers specifically, as well as other insect-based technologies, through a participatory process that involves producers, educators and agency personnel.

We are transferring our wealth of knowledge on insect frass fertiliser to private sector partners in East Africa. Several of them are mobilising farmers to incorporate the products in staple and commercial crop farming. As an example, efforts by two private sector partners in Kenya has led to the use of insect frass fertilisers by more than 18,000 farmers, who have rejuvenated about 7000 acres of land, creating around 3000 job opportunities, directly and indirectly along the value chain.

Animal manure management using insects

In Africa, animal manure is an organic, accessible source of crop nutrients and soil enrichment. However, the overuse of antibiotics in livestock production for disease control and growth promotion has led to persistence of residues in animal manure, which poses significant risk to the environment and people.

PROGRESS IN 2023

icipe research has demonstrated the potential of insects like the garden fruit chafer, a species of beetles, to suppress manure-borne pathogens within 14-days to levels below harmful thresholds. The recycling process by the insects also reduces the antibiotic residual effects of cattle manure.

INNOVATION

Dung composting using insects is a good strategy to reduce pathogens in manure, and increase concentrations of nutrients (nitrogen, phosphorus, copper, sulphur, potassium, zinc and boron). Such products boost crop productivity and associated nutritional quality (particularly energy and minerals) than in crops grown using soil amended with commercial fertiliser.



Garden fruit chafer larvae
burrowing into fresh dung.

Insects for Other Uses

Edible insects as novel and alternative source of sterols

Sterols comprise a huge class of compounds that occur in plants, animals and microorganisms, that are known to have diverse biological activities, for example lowering cholesterol and heart disease.

Misuse and overuse of antibiotics has contributed to a phenomenon known as antibiotic resistance, which is currently considered one of the principal threats to global public health by the World Health Organization. Existing commercial antimicrobial agents are losing their effectiveness against life-threatening conditions especially in the presence of antibiotic-resistant pathogens. In the quest for alternative drugs, insects represent one of the largest sources of antimicrobial peptides/proteins (AMPs), and a novel therapeutic option to combat antimicrobial resistance.

PROGRESS IN 2023

icipe research is focused on establishing the contribution of steroids as anti-cancer, anti-inflammatory, immunomodulatory and anti-viral agents. Through studies on nine edible insect species, we have identified 19 important sterols, particularly in garden fruit chafer and crickets. We found that the sterol extracts from crickets are the most effective in suppressing many drugs resistant pathogens like *Escherichia coli*, *Bacillus subtilis* and *Staphylococcus aureus* 25923.

We have isolated fungal symbionts from the gut of black soldier fly, wood-boring beetle larvae, cattle dung beetle larvae and desert locust. Some of these peptides extracts have robust inhibitory activity against prominent antimicrobial resistant pathogens such as *S. aureus*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Escherichia coli*.

INNOVATIONS

Our studies on antimicrobial peptides derived from insects have opened new frontiers in Africa in the continuous search for novel antimicrobial agents.

We are using advanced tools to purify the bioactive compounds that we have identified. We will provide recommendations for further basic and clinical research. We are also investigating various scientific tools and analyses methods, to accelerate the peptide-based drug discovery in insects.

Policies, standards and regulations

In 2023:

icipe in partnership with Ethiopian regulatory authorities established the Ethiopian Standards: ES 7015:2023 - Dried insect products in animal feeds-Specifications and ES 7016:2023 - Dried insect products as proteins in animal feeds – Guidelines/code of practice.

icipe signed an engagement partnership with the African Organisation for Standardisation (ARSO), an intergovernmental standardisation body established by the African Union (AU)-formerly the Organisation of African Unity (OAU), and the United Nations Economic Commission for Africa (ECA).

This agreement led to:

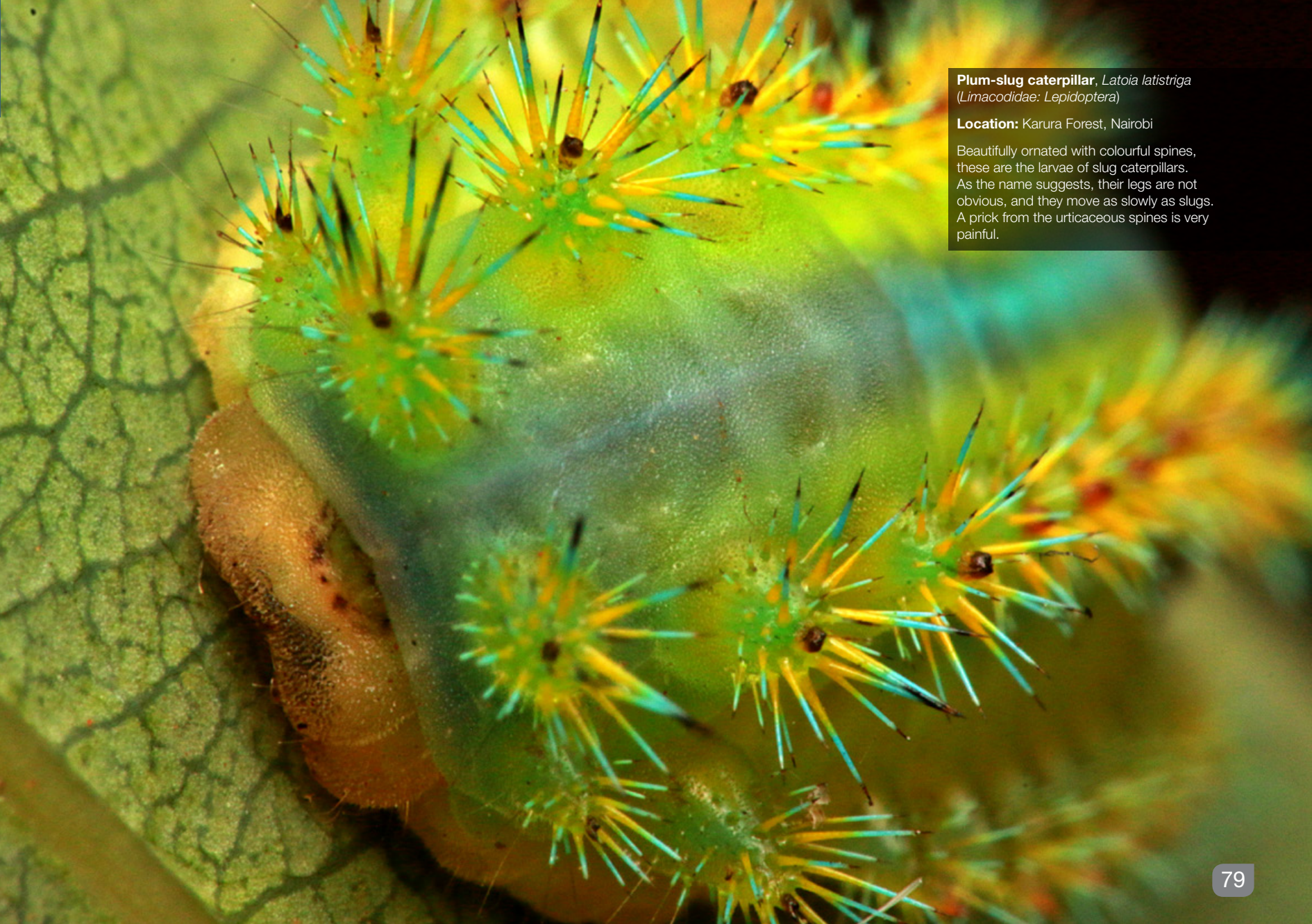
Development of 12 draft harmonised standards on Edible Insects in Africa, which are currently under open review.

Inventory of edible insects for human consumption and insects for animal feeds in Africa.

Insect value-added products – procedures, hygiene, quality, safety, environmental concerns, and standards for commercialization.

Training on African Standards and Certification Schemes for Insects for Food, Feeds and Derived Products, held in Kenya in 2023, and attended by 31 participants from Botswana, Burkina Faso, Cameroon, Congo Brazzaville, Kenya, Madagascar, Niger, Nigeria, Tanzania, Uganda, Zambia and Zimbabwe.

Training of 100 women from 31 counties in Kenya on black soldier fly farming in collaboration with MaMa Doing Good, a programme by the country's First Lady.



Plum-slug caterpillar, *Latoia latistriga*
(*Limacodidae*: *Lepidoptera*)

Location: Karura Forest, Nairobi

Beautifully ornated with colourful spines, these are the larvae of slug caterpillars. As the name suggests, their legs are not obvious, and they move as slowly as slugs. A prick from the urticaceous spines is very painful.

SOCIAL SCIENCE AND IMPACT ASSESSMENT UNIT

The *icipe* Social Sciences and Impact Assessment (SSIA) Unit focuses on generating evidence on the drivers of technology adoption, impact assessment, gender analysis, and scaling-up of strategies. The Unit also has the responsibility for implementing the *icipe* monitoring and evaluation, and gender strategies.

Donors: Donors: Australian Centre for International Agricultural Research (ACIAR); Bill & Melinda Gates Foundation (BMGF); BioInnovate Africa Programme; Biovision Foundation for Ecological Development, Switzerland; European Union; Federal Ministry for Economic Cooperation and Development (BMZ), Germany, through the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ); Swiss Agency for Development and Cooperation (SDC); German Research Foundation (DFG); IKEA Foundation; Impaxio GmbH, Switzerland; International Development Research Centre (IDRC), Canada; Mastercard Foundation (MCF); National Research Fund (NRF), Kenya; Norwegian Agency for Development Cooperation (Norad); One CGIAR through the Plant Health Initiative; The Rockefeller Foundation; Tel Aviv University, Israel; United States Agency for International Development (USAID); The GI Support Fund; International Fund for Agricultural Development (IFAD); University of Bern, Switzerland; and Wageningen University and Research Centre, The Netherlands.

2023 IN BRIEF



New knowledge

Increasing cultivation of pollinator-dependent crops could reduce nutrient deficiencies and boost agricultural income without compromising macronutrients production, and with no need for additional resources.

Machine learning-based evidence on the profitability of the *icipe* IPM packages across production scales, and to identify novel approaches and innovations for their use. Economic, health and environmental impacts of the tomato leafminer in Kenya and Uganda. Impact of the *icipe* tsetse repellent collar technology, with increases in livestock market value and reduction of household poverty levels and food insecurity; effects of trypanosomosis in Ethiopia. Confirmation that health education and public knowledge is vital in control measures of arboviral diseases. Factors, including psychological, cultural and experience, which influence insect-eating (entomophagy).



Inclusive innovations/ Policy contributions

Evidence for empowering women to increase ability to adopt agricultural technologies, through insights obtained using the Project-Level Women's Empowerment in Agriculture Index (pro-WEAI).

Proof of impact and opportunity cost of IPM packages and impact on national poverty levels, healthy crop production, and mitigation of the health and environmental risks associated with the misuse and overuse of chemical pesticides.

Evidence to scale-up *icipe* arsenal of tsetse fly control.

Recommendations for health education campaigns to enhance awareness and knowledge about arboviral diseases.

Recommendations strategies to encourage the adoption of entomophagy and mainstream insect consumption, and integration in dietary practices on a broad scale.



One Health

The critical analysis and insights on the dissemination, adoption, economic benefits, environmental and health impacts, and gender inclusiveness of the *icipe* technologies and strategies, enables us to constantly evolve our initiatives within a One Health framework.

Social Science and Impact Assessment Unit

Pollinator-dependent crops, which include perennial fruit and vegetable crop cultivars, oilseeds, nuts and legumes can help to address micronutrient deficiency in Africa. However, agricultural policies often favour pollinator-independent crops, such as roots and tubers and self- or wind-pollinated cereals, in resource allocation, including land, fertiliser and extension services, thereby impacting farm agrobiodiversity.

PROGRESS IN 2023

Recent research by *icipe* has assessed the potential benefits of reallocating resources from pollinator-independent crops to pollinator-dependent crops in addressing nutrient deficiencies in Africa.

Using data from four countries in Africa, we found that pollinator-dependent crops have higher micronutrient content per unit, albeit with lower macronutrient content compared to pollinator-independent crops. Our results demonstrate that increasing the cultivation of pollinator-dependent crops could reduce nutrient deficiencies and increase agricultural income without compromising macronutrients production and without requiring additional resources.

RECOMMENDATION

Our studies place the optimal land reallocation to pollinator-dependent crops at **50%** for most nutrients.

Integrated pest management (IPM) packages introduced by *icipe* have been successful in the control of fruit flies, thus helping to improve mango production. We used machine learning to estimate the economic benefits of the IPM strategies (parasitoids, orchard sanitation, food bait, biopesticides, male annihilation technique, and their combinations) in small-, medium- and large-scale mango production systems in Kenya.

PROGRESS IN 2023

The results showed that the impact of the IPM strategies varies based on factors like household wealth, distance to the market, age of the household head, labour availability and experience in mango farming. We have also generated knowledge on the profitability of the IPM practices across various production scales, as well as the most profitable techniques, cost effectiveness of individual practices and strategies to mitigate challenges in access to the technologies.

RECOMMENDATIONS

Our study has contributed towards mainstreaming machine learning in agriculture, to enhance analyses on the adoption and impact of technologies. The insights will enable us to improve profitability of the *icipe* IPM packages across production scales, and to identify novel approaches and innovations, for example, mechanised large-scale application of biopesticides.

Prior research indicates that the technology adoption rates among women farmers are generally lower than that of their male counterparts. A recent study by *icipe* has contributed to evolving discussions on the integration of women's empowerment in agricultural interventions. We applied the Project-Level Women's Empowerment in Agriculture Index (pro-WEAI), a standardised tool for monitoring and measuring a project's impact on women's empowerment.

PROGRESS IN 2023

We assessed the influence of women's empowerment on their willingness to pay for *icipe* fruit fly IPM packages, in Zambia. We found that the pro-WEAI individual indicators: autonomy in income, self-efficacy, attitudes about domestic violence, work balance, ability to visit important locations, and group membership, all have a positive and significant effect on women's willingness to pay for the IPM packages.

RECOMMENDATIONS

Our study provides evidence for empowering women through: intentional inclusion in training, efforts to lower women's domestic workloads, boost their finances, promotion of women's freedom of movement, encouragement to join groups, and awareness creation to change gender norms, at intra-household and community relationships, equal decision-making of men and women, participation of women in agricultural production and marketing groups, to boost agricultural technology uptake. Also, integration of gender experts and gender analysis to inform training on agricultural technologies.



A carpenter bee (Xylocopidae) pollinating cowpea.

Social Science and Impact Assessment Unit

Over the years, *icipe* has developed an arsenal of tools to control tsetse flies, which transmit the deadly Animal African Trypanosomiasis (AAT), and are among the most important constraints to livestock development in Africa. The tools include: the tsetse repellent collar, which contains a blend of chemicals identified from waterbuck, and the NGU trap, which exploits the sight and smell senses in the tsetse flies. We are deploying these two technologies either individually, or through a 'push-pull' strategy that uses the tsetse repellent collars to 'push' away tsetse flies from the animals, and attractants to 'pull' them to the NGU traps. Through a public, private partnerships approach, we have piloted, tested and commercialised the two technologies across Africa. Our studies show that the tsetse repellent collars and NGU traps are highly impactful. We continue to conduct detailed analyses on developmental and environmental impact of the technologies. In addition, we are generating insights to guide policies for the management of trypanosomiasis.

PROGRESS IN 2023

Our study shows that the adoption of the tsetse repellent collar technology increases the market value of cattle by approximately 36%.

Also, it contributes to reduction in household poverty levels, with the headcount ratio declining by 8.5 percentage points. Additionally, it reduces the household food insecurity coping strategy index and hunger scale among adopting farmers by 36% and 24%, respectively.

POLICY/ADVOCACY

We intended to leverage on these findings to raise awareness and advocate for policies to boost the scaling-up of the *icipe* tsetse repellent collar technology, and our other tools to manage trypanosomiasis.

In Ethiopia, we analysed the impact of trypanosomiasis livestock deaths, production costs, crop production and overall economic loss. We noted a significant increase in livestock deaths by 33% and production costs by 63% due to the disease. When trypanosomiasis coincides with oxen death, crop production decreases by 14%. The direct economic loss amounts to USD 58,300 annually in the study areas, with a countrywide economic loss estimated at about USD 94 million per annum.

Had this loss been prevented, approximately 9,000 people in the study districts and about 200,000 people in the country could have been lifted above the national poverty line.

Arboviral diseases present a significant global health and socio-economic burden, causing profound human and animal casualties. Inadequate awareness of the diseases and limited understanding of the infection pathways are some of the factors that hinder the effectiveness of control and management strategies.

PROGRESS IN 2023

We assessed the impact of health education on rural households, in knowledge and management of Rift Valley fever, chikungunya and dengue fever. Our results confirm that health education is vital in designing evidence-based control measures and policies for human and animal health. Thus, effective mitigation and control of arboviral diseases in sub-Saharan Africa depends on public knowledge.

RECOMMENDATION

We recommend health education campaigns to enhance awareness and knowledge about arboviral diseases. Such efforts could be directed towards school-going children, peer-learning on arboviral diseases management and a well-coordinated community outreach programmes.



A cow wearing an *icipe* tsetse repellent collar, which contains a blend of chemicals that essentially make cattle unattractive to the flies.

Social Science and Impact Assessment Unit

Having invaded Africa less than a decade ago, the tomato leafminer, *P. absoluta*, has quickly emerged as one of the most significant constraints to tomato production across the continent. *icipe* and partners have assembled and implemented an IPM package for *P. absoluta*, which includes a natural enemy imported from the original home of the leafminer, and biopesticides.

PROGRESS IN 2023

We investigated the economic, health and environmental impacts of the leafminer, the control strategies being used by smallholder farmers in Kenya and Uganda.

Our study shows that on average, tomato farmers in Kenya earn gross incomes of USD 38,123, while those in Uganda obtain USD 11,627.

A substantial portion of these earnings, ranging from 66% to 78%, is allocated to synthetic chemicals for pest control.

RECOMMENDATIONS

The opportunity cost of adopting an IPM approach for the tomato leafminer, instead of pesticides, is between USD 8 and USD 646 in Kenya and USD 895 in Uganda. The benefit-cost ratio for the IPM strategy was estimated at USD 1 in Kenya and USD 5 in Uganda.

Our findings underscore the importance of scaling-up the *icipe* IPM for tomato leafminers, to promote healthy tomato production, and mitigate the health and environmental risks associated with the misuse and overuse of chemical pesticides.

Due to its potential as an alternative and sustainable source of protein, the consumption of insects, or entomophagy, has received substantial attention, globally. Across Africa, many communities have traditionally consumed insects. Thus, a targeted promotion of insects as a nutrition source should be grounded in the understanding of the norms and attitudes of communities towards different types of insects.

PROGRESS IN 2023

We conducted a study in western Kenya, to analyse consumption patterns and determinants of insect-eating behaviour. Termites, grasshoppers, locusts, dung beetles, crickets and black ants are examples of insects eaten in the region, with the former being the most known and consumed. Most households prefer to eat the insects whole and unprocessed. In addition, to psychological factors, culture and insect-eating experience significantly influences entomophagy.

RECOMMENDATIONS

To encourage the adoption of entomophagy and mainstream insect consumption, we recommend awareness campaigns and training to change attitudes, overcome barriers to acceptance and facilitate the integration of entomophagy in dietary practices on a broader scale. A potential entry point is to begin with the most consumed insects in different communities.

Witch's Hat Bagworm Moth, *Pagodiella* sp. (Psychidae: Lepidoptera)

Location: Karura Forest, Nairobi

Bagworm larvae are known to carry and arrange the plant debris on which they feed, into interesting shapes as a protection against predators. The common and the scientific name of this insect is accurate in describing its behaviour of carrying leaf bits, and arranging them as a witch's hat or a Pagoda, a tower in eastern Asia; several stories erected as a temple or memorial with multiple eaves.



TECHNOLOGY TRANSFER UNIT

The *icipe* Technology Transfer Unit (TTU) has the mission of identifying methods, approaches, processes and technologies, and communicating them to a broad community of scientists, donors, private sector partners and end-users, to stimulate uptake. The TTU strategy encompasses five work streams: database and knowledge management; packaging and innovation; communication, capacity building, delivery and impact assessment; strategic partnerships; and backstopping and legal framework development.

Donors: One CGIAR through the Plant Health Initiative; Danish International Development Agency (DANIDA); European Union; Federal Ministry for Economic Cooperation and Development (BMZ), Germany, through the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ); IKEA Foundation; International Development Research Centre (IDRC), Canada; Norwegian Agency for Development Cooperation (Norad); Norwegian Institute of Bioeconomy Research (NIBIO), and Office of U.S. Foreign Disaster Assistance (USAID/OFDA) under United States Agency for International Development (USAID).

2023 IN BRIEF



Pathways

Viable technology dissemination strategies and pathways to scale up and out *icipe* technologies and innovations including: partnerships, demonstration field trials, field days, farmer field schools, training of trainers, training of farmers and entrepreneurs, use of lead farmers through the cascade model, participation in numerous events including national agricultural shows, targeted training and information materials, and media campaigns, including newspaper articles, TV shows, radio programmes and social media drives.



Inclusive innovations

Expansion of the climate-smart push-pull technology across Africa. Dissemination of the fall armyworm IPM package, which comprises six proven best bet innovations, in Kenya, Uganda, Tanzania, Rwanda and Ethiopia. Establishment of an insect value chain to process desert locusts into animal feed and promotion of the use of biopesticides during outbreaks.

Scaling-out of the fruit fly IPM, tomato leafminer IPM, beekeeping technologies and black soldier fly farming. Pivoting One Health through initiative combining malaria and emerging infectious diseases, climate change and ecosystem services, focusing on invasive species, and climate-smart push-pull technology. Promotion of organic agriculture and agroecology.



Policy contributions / Recommendations

Analytical report on the impact of the fall armyworm, since its arrival in Africa in 2016 (in progress). Support to government agencies in Kenya, Rwanda, and Uganda to lobby and advocate for regulatory reforms to nurture and support environmentally friendly pest control measures. Evidence to help diversify the incomes of communities affected by desert locust invasions, while also advocating for sustainable control of the outbreaks.

Evidence to accelerate insect farming and insect consumption in Africa. Promotion of insect science and its application in Africa by coordinating the African Association of Insect Scientists (AAIS) as a platform for information sharing among scientists, practitioners and policymakers, and to introduce new technologies or approaches for networking.



One Health / Circular economy

The *icipe* technology transfer activities are underpinned by developing, validating and deploying inclusive innovations, and by leveraging and building viable networks across an array of national, regional and global institutions.

Technology Transfer Unit

Through the CGIAR Plant Health Initiative, *icipe* has contributed to the development, testing and scaling-up of maize and vegetable IPM in eastern Africa. The aim is to protect agriculture-based economies of low- and middle-income countries in Africa, from fall armyworm incursions and aflatoxin outbreaks by developing, validating and deploying inclusive innovations, and by leveraging and building viable networks across an array of national, regional and global institutions.

PROGRESS IN 2023

We have:

Tested several technology dissemination strategies, enabling the expansion of the climate-smart push-pull in Kenya.

Developed mass rearing protocols and released natural enemies of the fall armyworm and the tomato leafminer in Kenya and Uganda.

Trialed biopesticides against the fall armyworm in Uganda.

Through an initiative being implemented in Malawi, Uganda and Zambia, we aim to close the knowledge gap and enhance human and institutional capacity for research, development and sustainability related to the fall armyworm IPM.

PROGRESS IN 2023

1,629 farmer demonstration field trials were established, to test 4 innovations for fall armyworm management including pheromone traps, parasitic wasps, biopesticides and the push-pull technology.

18,969 smallholder farmers trained through these demonstration fields.

225 agricultural advisors were trained.

Natural enemies of the fall armyworm were released in Kenya, Zambia and Uganda.

WAY FORWARD

We will monitor and establish new farmer demonstration field trials; train women entrepreneurs; and roll-out mass media campaigns on the fall armyworm innovations.

One of *icipe*'s earliest initiatives on fall armyworm management aims to conduct adaptive research to generate Africa-specific solutions for the pest. A key thrust is scaling-out of available fall armyworm IPM innovations targeting sub-Saharan Africa.

PROGRESS IN 2023

We deployed multiple dissemination pathways to scale up and out the fall armyworm IPM package, which comprises six proven best bet innovations, in Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia.

More than **3,500** small-scale maize growers (70% female) and about **500** (45% female) technology disseminators were trained on fall armyworm monitoring and management.

Approximately, **3** million people in Kenya, Ethiopia, Rwanda, Tanzania and Uganda, were reached through the media and other outreach and diffusion efforts.

2 private companies in Tanzania trained and engaged on the production and marketing of *Desmodium* seeds, to address the seed shortage problem.

We conducted district level awareness campaigns in Tanzania and Rwanda, on the biological control of fall armyworm. These efforts stimulated fall armyworm campaigns by the government of Rwanda.

We established 3 trial sites to test and validate two biopesticides; ICIPE 78 (Achieve) and ICIPE 7 (Detain) in Rwanda.

More than **5000** new farmers adopted the push-pull technology for fall armyworm management.

Technology Transfer Unit

icipe is a partner in the Community-based Fall Armyworm Monitoring, Forecasting, and Early Warning System (CBFAMFEW II), which commenced in 2020, focusing on Ethiopia, Uganda, Rwanda, Malawi and Zambia.

PROGRESS IN 2023

We:

Produced the bi-annual fall armyworm monitoring newsletter, which provides pre-invasion and near-real-time predicted density of the pest and the areas at risk of attack at the country level in different months. The series also propose country-specific actionable solutions, and adaptation mechanisms to manage the fall armyworm invasion for each period in which it is produced.

Scaled-out and promoted 4 best-bet technologies for fall armyworm management in the target countries.

Reached **3,527,572** people directly and indirectly through various dissemination pathways such as training of trainers, national agricultural shows, field days, farmer field schools, radio programmes, lead farmers through the cascade model and social media platforms.

WAY FORWARD

Collate data for improved fall armyworm predictions.

Boost outreach by partnering with more private sector actors to disseminate fall armyworm management tools.

Produce an analytical report on the impact of the fall armyworm, since its arrival in Africa in 2016.

2,333
people (45%
women)
attended 14
training sessions
of trainers
and technical
backstopping
events.

In 2023, *icipe* commenced an initiative to harness black soldier fly farming innovations with vegetable integrated push-pull cropping systems for One Health in Kenya, Rwanda and Uganda.

PROGRESS IN 2023

We:

Conducted stakeholder mapping in Rwanda and Kenya, created awareness on the initiative and identified potential areas of collaboration.

Mobilised and sensitised more than **150** farmers in Kenya, on black soldier fly farming and push-pull vegetable integration.

WAY FORWARD

We will conduct awareness, sensitisation and training; set up practical demonstrations and establish technology learning sites.

icipe is boosting the large-scale adoption of proven and piloted climate-smart pest management technologies and practices by smallholder farmers, for key insect pests of maize and tomato, in eastern Africa.

PROGRESS IN 2023

We:

Developed and distributed three manuals on the biology and management of the fall armyworm, *P. absoluta*, and maize IPM.

Produced a video documentary on the management of the tomato leafminer and maize IPM technologies.

Technology Transfer Unit

In 2023, we concluded an *icipe* initiative that unified global health, malaria and emerging infectious diseases, in Ethiopia and Kenya; climate change ecosystem services focusing on invasive species, in Kenya, and climate smart push-pull technology, in Kenya, Uganda and Tanzania.

PROGRESS IN 2023

We:

Trained 39 public and private sector companies and institutions including the media, as partners in technology dissemination and product development.

Conducted five training workshops in Kenya, Uganda, Tanzania and Ethiopia involving extension officers, policymakers and officers from private sectors.

Trained representatives from 15 institutions, among them government, non-governmental and private sector partners, to expand dissemination of various *icipe* innovations including the integrated pest management and integrated vector management (IVM) approaches.

Established nine technology learning sites in Kenya and Uganda, enabling us to conduct six field days, and to train more than 1,200 small holder farmers on fall armyworm management.

Scaled-out 12 *icipe* technologies targeting various value chains: Push-pull IPM, fall armyworm IPM, fruit fly IPM, tomato leafminer IPM, integrated pest and pollinators management, beekeeping technologies, desert locust management, black soldier fly rearing and IVM for malaria and mosquitoes.

343
people (65% women)
in Ethiopia, Kenya,
Uganda and Tanzania
were directly trained
on transdisciplinary
knowledge integration
and learning.

icipe aims to establish an insect value chain that can be scaled-up to process desert locusts into animal feed and promote the use of biopesticides during outbreaks. The goal is to diversify the incomes of communities that are affected by desert locust invasions, while also advocating for environmentally friendly ways to control outbreaks.

PROGRESS IN 2023

We:

Launched the initiative in four desert locust prone counties in Kenya (Isiolo, Marsabit, Laikipia and Samburu).

Developed and disseminated various materials including posters and fliers, for awareness campaigns, lobbying and advocacy on biopesticide use, as well as desert locust training manuals for extension workers.

Conducted two training courses for 30 lead entrepreneurs, and 25 training of trainers on desert locust and cricket rearing, and business opportunities in the insect value chain.

WAY FORWARD

Train communities on desert locust harvesting and processing, cricket rearing to build entrepreneurs along the value chains.

Support County governments to lobby and advocate for regulatory reforms to nurture and support environment friendly pest control measures.

Technology Transfer Unit

Management of invasive pests, with a focus on tomato leafminer in Malawi, through continuous situation monitoring, data gathering and reporting.

PROGRESS IN 2023

We are strengthening the institutional capacity at the national level, and conducting technical backstopping missions, to promote awareness at district and village levels in tomato growing areas through monitoring, data gathering and reporting.

Conduct technical backstopping missions to promote awareness both at district and village level among the tomato growing areas of the country on effective management of this invasive pest.

Coordinating the African Association of Insect Scientists (AAIS)

PROGRESS IN 2023

Our role is to promote AAIS as a platform for information sharing among scientists and practitioners, and to introduce new technologies or approaches for networking. We organised six lecture series, which promoted *icipe's* place as a centre of excellence; as well as the importance of insect science and its application in Africa.

Promotion of organic agriculture and agroecology, in collaboration with the Knowledge Centre for Organic Agriculture in Africa (KCOA)

PROGRESS IN 2023

Supporting the development, and validation of products to expand access to knowledge on organic agriculture and agroecology.

Collecting, validating and converting the information into suitable formats and languages, and making it available on a centralised database.

Developing training manuals on biological control of stemborers and fall armyworm, and on maize IPM, which were disseminated to country implementing partners.

INNOVATION

Develop method guide for lead farmers and community focal persons.

Generating new knowledge to accelerate insect farming and insect consumption in Africa for improved nutrition, health and livelihoods.

PROGRESS IN 2023

We are developing various dissemination materials based on identified training needs. Moving forward, we aim to strengthen collaboration with partners in Kenya, Ghana and Uganda, to promote healthy insect farming.

DATA MANAGEMENT MODELLING AND GEO-INFORMATION UNIT (DMMG)

The *icipe* Data Management, Modelling and Geo-Information Unit was launched in 2019 as part of the Centre's efforts to boost capacity for the development of the next generation of decision-making tools, models, software and mobile phone applications for crop, pest and disease management. The goal is to integrate advanced data analytics and approaches (such as data and model fusion), to strengthen all *icipe*'s R&D activities.

Donors: Alliance of Bioversity International and the International Center for Tropical Agriculture (ABC and CIAT); Bill & Melinda Gates Foundation; BioInnovate Africa Programme; Centre De Suivi Ecologique (CSE), Senegal; Cornell University, USA; Desert Locust Control Organization for Eastern Africa; European Space Agency; European Union; Federal Ministry for Economic Cooperation and Development (BMZ), Germany, through the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ); German Aerospace Center; Government of Canada; IKEA Foundation; International Development Research Centre (IDRC), Canada; Lacuna Fund, through MERIDIAN Institute. Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF), Germany; Norwegian Agency for Development Cooperation (Norad); One CG Initiative; Remote Sensing Solutions (RSS), Germany; Swedish University of Agricultural Sciences (SLU); United States Agency for International Development (USAID).

A comprehensive list of partners is included in the annexes.

2023 IN BRIEF



New knowledge/ Inclusive innovations

Internet of Things (IoT)-based smart irrigation system with a cloud-based data logging system, and raspberry-based AI 2-class disease detection system, for Nsukka yellow pepper; crop monitoring and prediction system using machine learning and IoT devices; smartphone applications for crop disease diagnosis and real-time advisory information; AI-enabled mobile and web applications to help farmers detect crop diseases and pests in cashew nuts, maize, cassava and tomatoes; farmer-friendly digital support systems, and early-warning systems for key pests and diseases of major crops; and index to assess suitable sites to deploy the *icipe* fall armyworm IPM using artificial intelligence and machine learning algorithms.

Validation of low-cost sensors developed by partners to establish precision black soldier fly farming; and decision-support systems for mass production and automation of insect rearing, thus reducing operational costs, while attracting more private sector investments.

Machine learning approaches to infer the relationships of insect songs, behaviour and weather variables to improve productivity of cricket farms.



Policy contributions / Recommendations

Capitalising on *icipe*'s uniqueness in Africa in data science advancement to support national and human resource capacity, awareness, application and policy in the sector, in Africa, through partnerships with research organisations, government institutions, international organisations and development agencies.



One Health

Development of a research niche to conceptualise and establish next generation of decision-making tools, models, analytics and approaches for the management of crop pests and disease vectors, and the sustainable use and conservation of beneficial insects is central to *icipe*'s One Health vision.

The Centre is contributing intelligence for strategic decision-making, agenda-setting and resilience measures, against surging risks of indigenous and invasive crop pests and disease vectors, emerging and reemerging viruses, and threats to insect biodiversity; the interdependencies with aspects such as climate change, human activities and landscape changes; and the consequences for food and livelihood security.

Data Management Modelling and Geo-information Unit

icipe is part of the Artificial Intelligence for Agriculture & Food Systems (AI4AFS), an innovation research network set up and managed by the Centre, the African Technology Policy Studies Network (ATPS) and Kumasi Hive, Ghana. The network aims to develop, deploy, test and seek to scale responsible and African-led AI innovations that will deepen understanding of how to deploy sustainable agriculture and food systems in Africa.

INNOVATIONS

We have developed:

Internet of Things (IoT)-based smart irrigation system with a cloud-based data logging system, available at thinkspeak.com, for Nsukka yellow pepper, which is unique and distinct to the region it obtains its name from, in Nigeria.

A raspberry-based AI 2-class disease detection system, in Nsukka yellow pepper, which monitors the farm in real-time.

Crops monitoring and prediction system using machine learning and IoT devices in Tanzania.

We have:

Scaled-out smartphone applications for crop disease diagnosis and real-time advisory information to smallholder farmers in Uganda, with applicability in East Africa and beyond.

AI-enabled mobile and web applications to help farmers detect crop diseases and pests in cashew nuts, maize, cassava and tomatoes.

icipe is a partner in an initiative led by the Norwegian Institute of Bioeconomy Research (NIBIO), which will develop early-warning systems for key pests and diseases of major crops in Malawi. The role of *icipe* is to establish the backbone for farmer-friendly digital support systems, by harnessing available data and collecting new data, to devise predictive models.

INNOVATIONS

We are:

Reviewing existing models focusing on geospatial mapping, system dynamics and phenology of the tomato leafminer, fall armyworm and the parasitic *Striga* weed.

Developing ecological niche models; climate and environmental-based clusters to guide the selection of sampling sites and pest traps; and modelling of maize and tomato suitability based on current and future scenarios.

Developing and deploying a traffic light expert system artificial intelligence models to forecast the tomato leafminer, fall armyworm and the parasitic *Striga* weed.

Setting up an open data kit (ODK) platform to collect *Striga* observations.

We aim to develop an index that assesses suitable sites to deploy the *icipe* fall armyworm IPM, using artificial intelligence and machine learning algorithms.

INNOVATIONS

We have:

Developed models to assess the habitat suitability of two push-pull companion plants (*Brachiaria brizantha* and *Desmodium intanum*), and three parasitic wasps (*Trichogramma chilonis*, *Telenomus remus* and *Cotesia icipe*).

Reinforced the community-based fall armyworm monitoring, forecasting for early warning and timely management, with models to generate quarterly fall armyworm prediction profiles in Ethiopia, Kenya, Malawi, Uganda, Rwanda, Tanzania and Zambia.

Operationalised a digital advisory platform, which has been tested with farmers in Rwanda and Ghana, with alerts about pest and climate stressors. The tool is applicable across Africa

Data Management Modelling and Geo-information Unit

icipe and the French Agricultural Research Centre for International Development (CIRAD), are among eight partners involved in the ROBUST project, which is supporting Robusta coffee (*Coffea canephora*) agroforestry systems, as a way of adapting to and mitigating climate change in Uganda. The project aims to transform coffee growing on every level, from farm to strategy decision-making.

INNOVATIONS

We have:

Established a satellite-based mixture model to categorise various Robusta coffee cropping systems.

Produced tree density and cover map for coffee growing areas. This will help to implement factors for compliance with the new European Union directive of deforestation-free value chains for coffee and other export commodities.

The African armyworm is an insect pest that typically emerges during rainy seasons, following prolonged drought periods. It poses a severe threat to cereal crops, as well as sugarcane and pasture grasses. In 2022, several eastern African countries were affected by outbreaks of the African Armyworm, which signifies potential danger of the pest.

INNOVATIONS

We have developed:

System models to predict the occurrence and population dynamics of African armyworm.

Monthly models to forecast the potential outbreak of the African armyworm in the African landscape.

Artificial intelligence-powered biological data reconstruction to model African armyworm-induced crop loss.

Through the model, we projected the potential maize yield loss that could arise from the African armyworm in the continent.

icipe is the lead partner in the Malaria Vector Atlas Project, an initiative that brings together a novel collaboration of partners to build an online, open access repository to hold and share analyses-ready malaria vector occurrence, bionomics, abundance and insecticide resistance data. The project is led by *icipe*; University of Oxford, UK; and the Malaria Atlas Project initiative, Australia.

PROGRESS IN 2023

The Vector Atlas country advisory groups for Burkina Faso, Democratic Republic of the Congo, and Uganda have been formed.

A stakeholder engagement workshop was held at the National Biomedical Research Institute (INRB), Democratic Republic of the Congo.

Stakeholder data management guidance and training on Vector Atlas protocols and data sharing templates were presented to stakeholders in Burkina Faso, Democratic Republic of the Congo and Uganda.

Spatio-temporal models for predicting malaria in Africa were developed.

The Data Abstraction tool has been published. The alpha version of the new Vector Atlas platform to store and share vector datasets and analytical products released.

Data Management Modelling and Geo-information Unit

icipe is unique in Africa in terms of advancement in data science. We are receiving an increasing number of requests from across Africa and the globe, to support capacity building and share experience in data science. We are nurturing young African capacity, and we are also in the frontline in creating awareness for data science and its application. This strength is being recognised by partners, including research organisations, government institutions, international organisations and development agencies.

PROGRESS IN 2023

We facilitated:

The meeting of stakeholders from Kenya and the European Space Agency under the EO Africa National Incubators (ANIN), integrated use of multisource remote sensing data for national-scale agricultural drought monitoring in Kenya (ADM-Kenya) initiative. Crop systems monitoring techniques for Kenya were developed.

Strengthening of the National Capacity of the Directorate of Plant Protection – National Ministry of Agriculture and Food Security of South Sudan, through training on basic concepts of geographic information system (GIS), global positioning system (GPS), and remote sensing technologies.



Bonoukpoè Mawuko Sokame, Postdoctoral Research Scientist, assisting Ann Jepkemboi, a student being trained at *icipe* on the survival techniques of the aphid, *Myzus persicae*, to understand the pest's life history trait.

Picasso bug or Zulu hud bug, *Sphaerocoris annulus* - aptly named the Picasso bug.



CAPACITY BUILDING AND INSTITUTIONAL DEVELOPMENT PROGRAMME

Building the capacity of people and institutions to respond to arthropod-related developmental needs in Africa is a major commitment of *icipe*. This goal 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 public health research and extension systems.

Donors: Scholarships and fellowships are provided by: German Academic Exchange Service (DAAD); Wellcome Trust; THRIVE-2 Fellowships; Fogarty International Centre – NIH, USA, through the Eastern Africa Network of Bioinformatics Training (EANBIT) network; Norwegian Agency for Development Cooperation (Norad) through the Combating Arthropod Pests for better Health, Food and Climate Resilience (CAP-Africa) project; IKEA Foundation through the Scaling regenerative black soldier fly farming along with vegetable push-pull cropping systems in rural Kenya, Rwanda and Uganda project; United Nations Educational, Scientific, and Cultural Organization (UNESCO) – The World Academy of Sciences (TWAS) through the Climate PhD Scholarships for Climate Research for students from least developed countries programme.

Further support for scholars, through *icipe* project and programmatic funds from: African Union; Agence Nationale de la Recherche (ANR), and HORTINET CI funded by PreSed/CI; African Development Bank, through Technologies for African Agricultural Transformation (TAAT); Bill & Melinda Gates Foundation; BioInnovate Africa Programme; Biovision Foundation for Ecological Development, Switzerland; Danish International Development Agency (Danida); European Union Horizon 2020 programme; European Union; Food and Agriculture Organization of the United Nations (FAO); French Agricultural Research Centre for International Development (CIRAD); French Development Agency (AFD); German Ministry of Economic Cooperation and Development (BMZ) through Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ); German Research Foundation (DFG); International Development Research Centre (IDRC); Australian Centre for International Agricultural Research (ACIAR); IMC Worldwide Limited; Kenya Education Network (KENET); Mastercard Foundation; JRS Biodiversity Foundation; Kenya Medical Research Institute – Wellcome Trust Programme; Norwegian Agency for Development Cooperation (Norad); Open Philanthropy; The Children’s Investment Fund Foundation (CIFF); Swedish International Development Cooperation Agency (Sida); The Rockefeller Foundation; Swedish Research Council; UK’s Foreign, Commonwealth & Development Office (FCDO); United States Agency for International Development (USAID); United States Department of Agriculture – Agricultural Research Service (USDA-ARS); World Health Organization (WHO); World Health Organization/Regional Office for Africa (WHO-AFRO).

2023 IN BRIEF

Postdoctoral and postgraduate training

A total of 237 fellows and scholars were undertaking their research at *icipe* in 2023, while 33 postgraduate scholars completed their studies, impacting on activities across the Centre's four themes.

Gender equity

Of the combined number of PhD and MSc scholars and interns at *icipe*, 50% are women.

Awards, recognitions, grants and presentations

icipe scholars made 30 presentations at various fora. They received 6 external awards; 6 internal awards; and 9 grants.

Geographical representation

A total of 19 African countries and eight non-African are represented in the *icipe* capacity building programmes.

Research and development impact

Of the 290 journal articles published by *icipe* in 2023, 75 were lead-authored by postgraduate scholars, and 20 by postdoctoral fellows.

Institutional strengthening

A total of 152 training events were conducted, reaching 18,458 participants (48% women) from 29 African countries.

Capacity Building and Institutional Development Programme

Capacity building of individual researchers, institutions and communities in Africa has always been an integral part of the *icipe* research and development activities. Primarily, this goal has been achieved through the Centre's highly successful postgraduate (MSc and PhD) training programmes, which enable young researchers from across Africa and beyond to acquire world-class training and hands-on research experience in insect-science and related fields. The *icipe* African Regional Postgraduate Programme in Insect Science (ARPPIS), provides 3-4-year doctoral research fellowships; while the Dissertation Research Internship Programme (DRIP), is an umbrella for MSc and PhD scholars of any nationality, enrolled in African or non-African universities, to pursue all or part of their research at *icipe*. The *icipe* postdoctoral fellowship programme provides opportunities for doctoral graduates to undertake research at the Centre to develop their research skills and careers, and collaborative research programmes.

PROGRESS IN 2023

A total of **237** fellows and scholars were undertaking their research at *icipe*. They included: **28** postdoctoral fellows; **54** PhD; **97** MSc students; and **58** research interns.

Of the **290** peer-reviewed journal articles published by *icipe* **75** were lead-authored by postgraduate scholars; and **20** by postdoctoral fellows.

A total of **33** *icipe* postgraduate scholars completed their studies.

WAY FORWARD

icipe continues efforts to transform the capacity development efforts from functional training to high quality mentoring. In addition to technical skills in specific research areas, we also boost broader academic and professional skills, including research compliance and ethics, science paper writing, proposal writing, communications and research leadership. We are taking steps to ensure even stronger embedment of the capacity building and institutional development activities across all projects and programmes, especially towards One Health skills development.

We are conducting an updated tracer study to understand the impact of the *icipe* postgraduate capacity building activities. In addition, we are revamping and strengthening the ARPPIS alumni, in collaboration with the African Association of Insect Scientists.

The *icipe* capacity building programmes pivot the young researchers through world class training and skills, while also enabling them to access the global reward system, which includes resources, knowledge and recognition.

PROGRESS IN 2023

In 2023, *icipe* scholars made **30** presentations at various fora. They received **5** external awards; **6** internal awards; and **9** grants.

WAY FORWARD

To ensure that our scholars are globally competitive, *icipe* will continue to support and incentivize them towards academic excellence, and competition for national, regional and global opportunities.



Dr Ylva Hillbur, Vice Chair *icipe* Governing Council presenting awards to:

(l) Komi Mensah Agboka (PhD, Togo), for best scientific paper on impacts of a biological control of the fruit fly, *Bactrocera dorsalis* using a wasp, *Fopius arisanus*; and (r) Abneel Matharu (PhD, Kenya) for best poster on the efficacy of Pyriproxyfen to control off-host stages of *Tunga penetrans*.

Capacity Building and Institutional Development Programme

icipe recognises that holistic and inclusive development will not be possible without the participation of all sectors of communities. Thus, the Centre continues to mainstream engendered approaches across all its activities, including in capacity building.

PROGRESS IN 2023

Currently, **50%** of the combined number of PhD and MSc scholars, and interns at *icipe* are women as follows:

19% of ARPPIS PhD scholars

48% of DRIP PhD scholars

48% of DRIP MSc scholars and

71% of interns

Among the postdoctoral fellows, **25%** are women.

As the only institution in Africa working primarily on insects and other arthropods, *icipe* is committed to ensuring that as many as possible talented and interested young African scientists, from diverse regions of the continent, benefit from the Centre's capacity building initiatives.

PROGRESS IN 2023

Currently, a total of **19** African countries are represented in the *icipe* capacity building programmes: Benin, Cameroon, Comoros, Democratic Republic of Congo, Ethiopia, Ghana, Kenya, Liberia, Malawi, Nigeria, Rwanda, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe.

6 non-African countries are represented in *icipe* postgraduate and postdoctoral training programmes. They are Costa Rica, Germany, India, Indonesia, The Netherlands and The Philippines.

WAY FORWARD

We will build on the progressive geographical expansion of *icipe*, for example to West Africa, to increase inclusion of young scientists in our capacity building programmes. In addition, we will take advantage of new programmatic footprints to tackle entomological challenges in North and Southern Africa.

The *icipe* capacity building activities include the enhancement of capabilities of end-user stakeholders to effectively adopt our technologies. The Centre conducts a range of courses, workshops and other training events for our teams, research and development collaborators, farmers and extension workers, among others. The training covers various aspects, from basic strategic research, technology development and validation, and technology implementation and commercialisation.

PROGRESS IN 2023

In 2023, we conducted 152 training events, and reached 18,458 participants (48% women) from 29 African countries: Angola, Benin, Burkina Faso, Burundi, Cameroon, Cape Verde, Chad, Congo, Côte d'Ivoire, Democratic Republic of Congo, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe. The trainings were held in 12 countries in Africa: Burkina Faso, Côte d'Ivoire, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, South Sudan, Tanzania, Uganda, Zambia and Zimbabwe.

WAY FORWARD

icipe will continue to contribute to institutional development activities in tandem with the Centre's research for development activities at the local and regional levels.

Institutional strengthening activities also include training on financial management, project technical reporting, upgrade of laboratories, enhancing the leadership roles of partners through various services to projects and programmes, for example via participation in steering committees.



An **assassin bug** belonging to the Genus *Endochus* (*Reduviidae: Hemiptera*)

Location: Karura Forest, Nairobi

As most other reduviid bugs, *Endochus* sp is also a predator of other insects. This insect has an interesting resting posture, which it uses effectively camouflage among dried plant debris and successfully predate other insects by ambush.

BIOINNOVATE AFRICA PROGRAMME

BioInnovate Africa is a regional science and innovation-driven initiative that enables scientists in eastern African universities, research institutes, and firms to translate biologically based research outputs into practical uses in society. The framework that BioInnovate Africa provides for translating research into impact is a major contribution to the strength of the innovation ecosystem of eastern Africa. Scientists not only implement innovation projects, but they also participate in building supportive innovation ecosystems within their organisations and countries. With a focus on strengthening value chains for value added biobased goods and services, BioInnovate Africa became the largest and most active regional innovation-driven bioeconomy platform in Africa. BioInnovate Africa operates in eight eastern African countries: Burundi, Ethiopia, Democratic Republic of the Congo (DRC), Kenya, Rwanda, South Sudan, Tanzania and Uganda.

Donor: Swedish International Development Cooperation Agency (Sida).

A comprehensive list of partners is included in the annexes.

2023 IN BRIEF

Newly on-boarded projects

Seven new projects were onboarded, bringing together a consortium of 26 organisations. All the initiatives advanced to the project development phase.

Development of a bioeconomy in Africa

Various activities undertaken as part of the implementation process of the East African Regional Bioeconomy Strategy, in partnership with EASTECO and the SEI – Africa Centre.

Innovations

Innovations focus on: improving food production and food safety; reducing postharvest losses; providing alternative biodegradable packaging materials; and improving human and animal health.

Techno-economic analysis (TEA) capacity building in East Africa

Through a partnership with the Thayer School of Engineering, USA.

Gender integration

Five-year gender strategy (2023-2028) and Action Plan (2023- 2024) developed.

Carbon farming in East Africa

BioInnovate Africa and the University of Bonn, Germany, are researching the economics of carbon sequestration in African agriculture.

Bio Venture Hub

to provide professional business incubation services biologically based ideas and inventions.

BioInnovate Africa Programme

In 2022, BioInnovate Africa announced a fresh cohort of projects to be implemented until 2026, under phase III of the Programme. The initiatives focus on value addition to biological materials, including converting biological waste into useful substances, and conserving biodiversity, and a new thematic area of health. In 2023, the seven new projects (listed below) were onboarded, bringing together a consortium of 27 organisations. All the initiatives advanced to the project development phase.

PRODUCT	LEAD PARTNER	OTHER PARTNERS
Rhizobia-mycorrhizae-based biofertilizer	Evangelical University in Africa, Democratic Republic of the Congo	Hope Africa University and ITRACOM Fertilisers Ltd (Burundi); a subsidiary of FOMI Fertilisers (Burundi); and University of Nairobi (Kenya)
Banana fibre technology to control nematodes and other below-ground crop pests	International Institute of Tropical Agriculture (IITA)	<i>icipe</i> ; International Fertilizer Development Corporation (Uganda); and Bio-Corn Products EPZ Ltd (Kenya)
Nano encapsulated bromelain from pineapple and seafood waste for improved livestock production	Jomo Kenyatta University of Agriculture and Technology, Kenya	Université Evangélique en Afrique, Bukavu (Democratic Republic of the Congo); Sokoine University of Agriculture (Tanzania) and Vetcare® Africa (Kenya)
Artemisinin-based combination therapy for malaria treatment	Pharmaceutical Society of Uganda	University of Bahr El Ghazal (South Sudan); Université Officielle de Bukavu (Democratic Republic of the Congo), and Jena Herbals Ltd (Uganda)
Novel bio-rational products for controlling tungiasis (jiggers)	Masinde Muliro University of Science and Technology, Kenya	Kenya Agricultural and Livestock Research Organization Biotechnology Research Institute; Gulu University (Uganda); and AtoZ Group of Companies (Vector Health International, Africa Technical Research Centre – Tanzania)
Biofungicides for the management of the coffee wilt disease	Kaffabio Control AgroIndustry Private Limited Company, Ethiopia	Kenya Agricultural and Livestock Research Organization – Coffee Research Institute; and Tanzania Coffee Research Institute
Eco-friendly packaging products from cassava wastes and other biowastes	Kyambogo University, Uganda	Institute of Policy Analysis and Research (Rwanda); Ardhi University (Tanzania) and Oribags Innovations Ltd (Uganda)



In eastern Africa, the coffee wilt disease, caused by the fungus *Fusarium xylarioides*, is a major threat to coffee production. The symptoms of the disease include leaf discolouration, leaf loss, dieback of the infected region, swelling of trunks, cracks in mature trees and finally plant death, as shown in the two photos (left and centre). No effective control methods are available for the disease, and predominant approaches include uprooting infected plants, pruning affected branches, and applying pesticides.

BiInnovate Africa is supporting an initiative that will produce a biofungicide to manage the coffee wilt disease in East Africa. To be marketed as Triasper biofungicide, the product has been tested successfully in farmers' fields, as evidenced in the photo on the right, taken in Ethiopia. The product is at market validation and testing stages. The project is led by Kaffabio Control Agro-Industry Private Ltd Company, Ethiopia; while the partners are: Kenya Agricultural and Livestock Research Organization-Coffee Research Institute in Kenya, and National Agricultural Research Organisation, Uganda (NARO/NaCORI).

BioInnovate Africa Programme

Supporting a sustainable bioeconomy in Africa

In April 2022, the East African Community (EAC) council of ministers approved a 10-year East African Regional Bioeconomy Strategy (2022 – 2032), the first of its kind in Africa and the second in the world after the European Union. The strategy was developed through a national and regional consultative process spearheaded by the East African Science and Technology Commission (EASTECO), in partnership with the region's councils and commissions of science and technology; African Technology Policy Studies Network (ATPS); Stockholm Environment Institute (SEI) – Africa Centre; Scinnovent Centre Limited; and Bioinnovations Company Limited; with support from BioInnovate Africa Programme.

PROGRESS IN 2023

The following activities were undertaken as part of the implementation process of the East African Regional Bioeconomy Strategy:

In June 2023, BioInnovate Africa and EASTECO signed a grant agreement, to conduct a study in collaboration with SEI – Africa Centre to develop the second status report on a bioeconomy in eastern Africa for 2024.

BioInnovate Africa, SEI – Africa Centre, and EASTECO, also convened a workshop on bioeconomy themed: 'Bioeconomy in Action in East Africa, Latin America and Asia'.

BioInnovate Africa in collaboration with EASTECO, SEI–Africa Centre, and the Ministry of National Education and Scientific Research, Republic of Burundi through the National Commission for Science, Technology and Innovation (NCSTI), held a high-level, national policy dialogue on bioeconomy in Burundi, under the theme 'National bioeconomy strategies: paving the future growth path for Eastern Africa'.

WAY FORWARD AND RECOMMENDATIONS

BioInnovate Africa was selected as the Secretariat of the Global Bioeconomy Summit (GBS 2024), to be held in Nairobi from 22-24 October 2024, co-organised and co-hosted with EASTECO and SEI – Africa Centre. The status report will be launched during GBS 2024. A series of status reports on bioeconomy in eastern Africa will be published every second year, for the period of the current East African Regional Bioeconomy Strategy (2022 – 2032). These reports will monitor bioeconomy progress and highlight key pathways that contribute to the achievement of the Sustainable Development Goals (SDGs) 2030, the EAC Vision 2050, and the Africa Union Agenda 2063.

There is need to adapt institutional, policy and incentive frameworks that enable coordination across sectors. The frameworks should prioritise bioresources for the bioeconomy and facilitate procedures for the sustainable use of biodiversity, and promote sustainable business models, trade and investments along local and global networks and value chains, emphasising the need for south-south cooperation in global bioeconomy discussions.

The forum endorsed the need for Burundi to develop a national bioeconomy strategy aligned to the East African Regional Bioeconomy Strategy (2022 – 2032).

BioInnovate Africa partnered with the Roundtable on Sustainable Biomaterials (RSB) and Solidaridad, on a workshop for non-governmental organisations (NGOs) working within East Africa. The theme of the forum was 'Fostering Partnerships with NGOs in Kenya for a sustainable bioeconomy in East Africa'. The workshop discussed the role of East Africa in the mitigation of climate change towards a transition to a just and sustainable bio-circular economy.

BioInnovate Africa Programme

Techno-economic analysis capacity

BioInnovate Africa and the Thayer School of Engineering, Dartmouth College, USA, are collaborating to build capacity for technoeconomic analysis (TEA) of innovation projects in eastern Africa through a six month, fully sponsored tailor-made online course, which was established in 2019.

The aim is to provide capacity to assess potential economic feasibilities, bottlenecks and to identify further research and development requirements during early stages of biobased technologies, with real world application being in the developing country setting.

Participants are competitively selected from BioInnovate Africa participating universities in eastern Africa.

PROGRESS IN 2023

In June 2023, the third cohort, consisting of seven students, completed the TEA course, bringing the total number of trained students to 15. The students will conduct TEA on selected BioInnovate Africa projects, and they are available to support the design of bioentrepreneurial projects in their home countries and institutions.

WAY FORWARD

Expanding TEA capabilities in eastern Africa will enable BioInnovate Africa to quantify the impact of its supported initiatives. It will also boost the ability of scientists, innovators, policymakers and other partners in Africa to strengthen infrastructure, financing, policies and standards for a more conducive innovation environment.

Carbon farming in East Africa

BioInnovate Africa and the University of Bonn, Germany, are collaborating to research the economics of carbon sequestration in African agriculture. The research seeks to explore the opportunities and challenges of involving smallholder farmers in the emerging agricultural carbon markets to contribute to climate change mitigation through the adoption of sustainable land management practices, referred to as carbon farming. This type of farming requires increasing carbon sequestration in soils and plants while reducing or avoiding greenhouse gas emissions in agricultural production.

PROGRESS IN 2023

The preliminary findings of the research show that smallholder farmers in East Africa can benefit from carbon markets by participating in carbon credit projects such as activity or results-based payments linked to carbon sequestration, and access to trainings or co-benefits from the adoption of sustainable land management practices that improve yield or increased resilience to extreme weather events.

POLICY SUPPORT

Carbon farming is linked to important policy efforts such as the development and expansion of a sustainable bioeconomy. The research will contribute to addressing the pressing global challenge of achieving the net-zero carbon emissions by 2050 as aligned with the Paris Agreement on Climate Change, by unlocking the potential of natural climate solutions in the pursuit of net-zero emissions.



Monitoring soil changes in response to diverse agricultural practices, using an AgroCares F Series Scanner that instantly tests soil for a range of soil nutrients including soil organic carbon.

BioInnovate Africa Programme

Enhancing gender integration in BioInnovate Africa

Integrating gender in science and innovation initiatives is important for achieving agricultural productivity, and implementing innovations in the bioeconomy that transform food systems and alleviate poverty.

PROGRESS IN 2023

Between January and June 2023, BioInnovate Africa undertook a gender analysis exercise to enhance gender mainstreaming in the Programme's activities. The analysis provided an understanding of the needs of women and men, and their capacities to participate in any given interventions, and the different ways in which they benefit from. It informed the development of a five-year gender strategy (2023-2028) and Action Plan (2023-2024), to enable BioInnovate Africa to systematically integrate a gender responsive innovation agenda. The strategic objectives include enhancing BioInnovate Africa internal culture, capacity for design, planning, implementation, responsiveness of the Programme, and reporting on gender-responsive by the staff; and improving the ability of addressing gender issues in the supported projects.

WAY FORWARD

The gender strategy affirms BioInnovate Africa's commitment to gender equality. The strategy provides BioInnovate Africa with the necessary tools for integrating gender issues in all its activities and projects.

Bio Venture hub

In June 2023, BioInnovate Africa set up a Bio Venture hub, to provide professional business incubation services to entrepreneurial scientists who have biologically based ideas and inventions with high prospects for business. The Bio Venture hub promotes entrepreneurial thinking in research and training, serving *icipe*'s scientific network, with plans to extend it across BioInnovate Africa partnering countries in eastern Africa.

PROGRESS IN 2023

Four teams of scientists have been selected to join the hub, to receive support to package their ideas in an investable way and facilitate them to conduct fieldwork.

WAY FORWARD

The Bio Venture hub working closely with the Technology Transfer Unit (TTU) at *icipe*, will continue to nurture entrepreneurial scientists in BioInnovate Africa-supported projects and those working at *icipe*, who have a vision and drive to transform scientific breakthroughs into successful business ventures through professional business incubation.



REGIONAL SCHOLARSHIP AND INNOVATION FUND (Rsif)

The Regional Scholarship and Innovation Fund (Rsif – www.rsif-paset.org), was launched in 2015 as the flagship programme of the Partnership for Skills in Applied Sciences, Engineering and Technology (PASET), an initiative established in 2013 by African governments and partners. The mission of Rsif is to strengthen the institutional capacity for quality doctoral training, research and innovation in transformative technologies in sub-Saharan Africa. *icipe* is the Regional Coordination Unit (RCU) of Rsif since 2018.

Investors

Governments of: Benin, Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Mozambique, Nigeria, Rwanda and Senegal. Further investments have been provided by the World Bank, Government of South Korea, ACP Innovation Fund of the European Union through the Organisation of African, Caribbean and Pacific States (OACPS), Carnegie Corporation of New York, Samsung Dream Scholarship Foundation and the French Embassy in Kenya.

African Host Universities (AHUs): African University of Science and Technology, Nigeria; Bayero University Kano, Nigeria; Haramaya University, Ethiopia; Institut International d'Ingénierie de l'Eau et de l'Environnement (2iE), Burkina Faso; Kenyatta University, Kenya; Makerere University, Uganda; Sokoine University of Agriculture, Tanzania; Nelson Mandela African Institution of Science and Technology, Tanzania; Université d'Abomey-Calavi, Benin; Université Félix Houphouët-Boigny, Côte d'Ivoire; Université Gaston Berger, Senegal; University of Ghana; University of Nairobi, Kenya; University of Port Harcourt, Nigeria; and University of Rwanda.

International Partner Institutions (IPIs): Ben-Gurion University of the Negev, Israel; Ghent University, Belgium; Hanyang University, South Korea; Helmholtz Centre Hereon, Germany; IMT Mines Albi, France; Institutes of Green-bio Science & Technology (GBST), South Korea; L'Institut de recherche pour le développement (IRD), France; International Cooperation Group of Brazilian Universities (GCUB), Brazil; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India; International Livestock Research Institute (ILRI), Kenya; Karlsruhe Institute of Technology, Germany; Korea Institute of Energy Research (KIER), South Korea; Korea Institute of Science and Technology (KIST), South Korea; Korea Research Institute of Chemical Technology (KRICT), South Korea; Maastricht University, The Netherlands; Mohammed VI Polytechnic University (UM6P), Morocco; Rochester Institute of Technology, USA; Seoul National University Global Research & Development and Business Center (GRC), South Korea; Télécom SudParis, France; Université Côte d'Azur, France; University of Bristol, UK; University of Greenwich, Natural Resources Institute, UK; University of Lisbon, Portugal; University of Maryland, USA; University of Michigan, USA; University of Pretoria, South Africa; Virginia Tech College of Agriculture and Life Sciences, USA; Worcester Polytechnic Institute (WPI), USA; World Vegetable Center.

2023 IN BRIEF

Resource mobilisation

The Carnegie Corporation of New York joined as a new funder with USD 950,000 for strengthening doctoral and postdoctoral training in applied science, engineering and technology in Africa (DOCTAS).

Mentorship

The mentorship platform was rolled out to 261 Rsif scholars and alumni

Awards

Of the various awards received, two Rsif scholars were among the winners of the UNESCO-L'Oréal for Women in Science 2023 sub-Saharan Africa award.

Research and innovation

58 research and innovation projects in strategic priority sectors were under implementation in African universities and research institutions, including eight projects led by early career, Rsif alumni.

Rsif scholarships

21 cohort 5 full scholarships were awarded and 20 Rsif PhD students were selected for DOCTAS research scholarships during their international placement.

Knowledge generation

Rsif scholars published a total of 226 peer reviewed papers with 1157 citations.

Network

The Rsif network incorporates 439 researchers in the 15 African Host Universities (AHUs) in 11 countries; and 29 international partner institutions (IPIs) in Africa, Europe, America and Asia.

Transformative technologies

Prototypes and innovations from Rsif projects include: mobile app to control fall armyworm in Benin; biopesticides to protect yam in Côte d'Ivoire; biodegradable sanitary towel from banana pseudo-stems in Kenya; solar powered heat pump dryer for vegetables and fruits in Tanzania; and mini pilot processing plant for orange mesocarp residues for innovations in the energy sector in Nigeria.

Regional Scholarship and Innovation Fund

PhD Scholarships

Rsif aims to mentor and nurture scholars to not only complete their programmes, but to do so with excellent research that augments the global knowledge hub, while also impacting regional and global thinking on key developmental issues.

PROGRESS IN 2023

By 2023, the Rsif scholars had published **226** peer reviewed papers garnering **1,157** citations. We continued to conduct a series of skills strengthening trainings and events for the Rsif scholars. The monthly Rsif student seminars enable them to make presentations and obtain feedback on their projects from experienced researchers. The guest webinars have evolved into think spaces that attract distinguished speakers.

Two scholars won the 2023 L'Oréal-UNESCO For Women in Science Sub-Saharan Africa Young Talents Awards; one scholar was awarded the prestigious Global Grand Challenge Funded by the Bill & Melinda Gates Foundation.

An online mentorship platform to support Rsif PhD scholars was set up, to provide social, psychological, and academic support by means of information, guidance, empathy and insight into working the system and fitting in, thereby ensuring a greater possibility for successful adjustments to the demands of tertiary study.

WAY FORWARD

In 2023, we implemented the revised Rsif Capacity Building Strategy. We will continue to review the content of the strategy and align it to the scholars needs and emerging issues. We will review and strengthen the mentorship platform, in alignment to the evolving support needs of the scholars.

In Africa, women constitute 30% of researchers in science fields, about the same as the global average of 28%. Still, this means that only a fraction of the potential contribution of women to science, technology and innovation, is being harnessed. Therefore, the issue of gender is very central to PASET and to Rsif. Indeed, at least 40% of Rsif's support is reserved for women.

PROGRESS IN 2023

Currently, **37%** (a total of **104** scholars) of **278** active Rsif scholars are female.

In 2022, we updated the Rsif gender strategy aimed to: enhance awareness among AHU faculty and scholars on gender-specific resources and services in their respective universities; identify and recommend to AHUs best practices from other institutions for mainstreaming gender in science, technology and innovation; develop a programme to promote greater family support for female scholars; introduce a mechanism to promote greater financial and social security for scholars with children; support female scholars to present their research and to network broadly; and develop a tailor-made career counselling programme for female scholars.

In 2023, we held a webinar for female scholars; identified their unique challenges and needs; established dedicated mentorship channel for female scholars; developed information materials showing female-friendly facilities at various Rsif partner institutions; and held an inaugural mentorship workshop.

Regional Scholarship and Innovation Fund

PhD Scholarships

The goal of Rsif is to attract the best and brightest talent from across Africa, ensuring geographic, gender and thematic representation.

PROGRESS IN 2023

In 2023, 23 scholarships for Cohort 5 were awarded, bringing the total of active Rsif PhD scholars to 284. The active scholars represent 24 African nationalities. Eleven out of 15 cohort 1 scholars had completed their studies by the end 2023. One of the 61 cohort 2 scholars had completed studies by end of 2023.

Rsif has a unique approach that combines intra-Africa exchange and international training. The Fund incorporates a network of AHUs – competitively and rigorously selected universities that offer a PhD programme in any one of Rsif's thematic areas. Rsif also has a network of IPIs – globally recognised universities, research institutes, public and private companies.

PROGRESS IN 2023

As of 2023, Rsif had a network of 15 AHUs in 11 African countries and 29 IPIs, three in African countries and the rest spread across Europe, America and Asia.

Resource Mobilisation

Rsif continues to grow in momentum and impact. Indeed, stakeholders in Africa and global development partners are appreciating Rsif as a channel to elevate doctoral education, research and innovation in Africa, to achieve national developmental aspirations, as well as Agenda 2063 of the African Union, and acceleration of the United Nations Sustainable Development Goals (SDGs).

PROGRESS IN 2023

In 2023, Rsif achieved several milestones in investments.

Rsif received a grant of USD 950,000 from the Carnegie Corporation of New York, which will strengthen doctoral training and postdoctoral research in applied science, engineering and technology in Africa (DOCTAS). Part of the support will be channelled through the Rsif Junior Investigator Research Award (JIRA). It will enable up to five Rsif PhD graduates who hold positions in institutions in Africa to gain research, managerial and other complementary skills, and to access regional and international networks, towards becoming independent researchers. An additional 20 grants will be given to ongoing Rsif PhD scholars, thus boosting resources for research and outcomes. The DOCTAS initiative will also increase the ability of researchers to engage with policymakers, to link research to policy and practice.

After an initial contribution of USD 2 million to Rsif in 2018, in August 2022, the Government of Rwanda announced an additional contribution of an equal amount to PASET through Rsif.

In the context of the new joint AU-EU Innovation Agenda, leading universities and research organisations in Africa and Europe issued a Joint Call for Action – Towards an Africa-EU Science, Technology, and Innovation Programme, making the case for a bold investment instrument. *icipe* and Rsif partners were signatories to this declaration that specifically mentions PASET-Rsif.

WAY FORWARD

A new strategy for PASET (2024-2034), has been developed.

Rsif has been re-confirmed as one of the pillars of PASET.

In 2024, a series of PASET and Rsif forums and events are planned to mobilise investment commitments.

An Rsif financing plan has been prepared.



A smart robust and affordable Agricultural Internet-of-Things technology (Agri-IoT), developed by Emmanuel Effah (Ghana), an Rsif PhD alumni who was registered at University of Gaston Berger, Senegal, with research placement at the Worcester Polytechnic Institute, USA.



The Agri-IoT allows remote sampling of agronomical data of the field, crops and livestock. It processes this data and makes actionable decisions regarding resource optimisation, crop and animal condition monitoring, farm automation and soil management.

Regional Scholarship and Innovation Fund

Research and Innovation Grants

Through a competitive grants system, Rsif supports researchers and faculty in AHUs to implement collaborative research programmes with international partners, to develop novel technologies that respond to specific local challenges

PROGRESS IN 2023

23 research grants have been awarded to researchers in AHUs.

23 peer-reviewed journal articles have been published, and 30 presentations made at local and international conferences, by the grantees.

Prototypes developed:

2 by University of Rwanda: one to enhance honey production through smart bee farming; and the second to promote clean energy household practices, to mitigate indoor air pollution and its associated health risks.

3 by Nelson Mandela African Institution of Science & Technology, Tanzania on sustainable water and energy solutions, including: a prototype for water defluoridation; a solar powered vaccine cooler; and a solar-assisted heat pump dryer for fruits and vegetables, thus reducing postharvest losses.

Kenyatta University, Kenya has developed a biodegradable sanitary towel from banana pseudo-stems.

University of Port Harcourt, Nigeria has installed a mini pilot processing plant for orange mesocarp residues, contributing to innovations for the oil and gas industry.

WAY FORWARD

Rsif's experience confirms that enhancing innovation ecosystems of universities in Africa can impact economic, societal and policy advancement at institutional and national levels. Thus, Rsif is exploring partnerships to expand support to more universities, thus amplifying impact across the region.

Through its innovation grants and technical support, Rsif assists AHUs to build innovation and entrepreneurship capacity, improve technology transfer practices, and foster university-industry partnerships.

PROGRESS IN 2023

Rsif has provided innovation grants to 10 AHUs and recipients in Mozambique, to enhance their innovation ecosystems.

Examples:

Bayero University, Nigeria, through the 'Sustainable Food Security Innovations in the Drylands' (ISFoD) project, trained over 600 faculty and students in intellectual property management, industry collaboration, and research commercialisation. This initiative spurred the establishment of a Directorate for Entrepreneurship, facilitating technology transfer and research commercialisation at the University. Updated policies, guided by the National Office for Technology Acquisition and Promotion (NOTAP), help to recognise and reward excellence in research and innovation. The grant also laid the groundwork for establishing the Regional Innovation and Entrepreneurship Accelerator (RITEH) agri-business, in partnership with ICRISAT.

University of Ghana through the 'Institutional Framework to enhance the Agri-Innovation Ecosystem' project developed an Agro-Innovation Strategy.

Sokoine University of Agriculture, Tanzania, through its project on 'Innovative Biosystems for Self-sufficiency in Molecular Biology Reagents in Africa', developed guidelines to operationalise its Intellectual Property Policy. The University also designed and installed an enzyme bioreactor to produce Taq polymerase to support research.

Regional Scholarship and Innovation Fund

Innovation grants for research commercialisation

Research commercialisation is key for economic growth. The process helps to foster innovation and address societal needs by translating novel research ideas into practical solutions that benefit businesses, industries and communities. Rsif, through its innovation grants awarded to researchers and innovators in AHUs, supports collaborative research with industry to develop commercially feasible prototypes and business plans from research outcomes.

PROGRESS IN 2023

Rsif has awarded 8 innovation grants for research commercialisation to researchers and innovators across African Universities including recipients from Mozambique.

Examples:

Université Félix Houphouët-Boigny (UFHB), Côte d'Ivoire, has allocated land for an industrial research unit on biopesticides, to produce two plant-based biopesticides developed, patented and approved by the country's Ministry of Agriculture.

6 patents have been registered by the Nigeria Ministry of Commerce and Industry in oil and gas at the University of Port Harcourt, focusing on: bioethanol production from non-food starch crops; development of cashew nutshell liquid into pour point depressants for waxy crude oils; flavonoids in the formulation of gas hydrates inhibitors; corrosion inhibitor formulations from natural phenolics; natural phenolic gum inhibitors for condensates; and refined petroleum fuels and phenolic derivatives in formulation of drilling detergents as drilling mud lubricant additives.

In Tanzania, the Business Registrations and Licensing Agency (BRELA), approved a local patent for a solar powered heat pump dryer for vegetables and fruits by Nelson Mandela African Institution of Science and Technology.

WAY FORWARD

Rsif recognises the importance of partnering with private sector entities and international institutions that have experience in research commercialisation, to promote similar innovative practices in Africa. Additionally, Rsif aims to cultivate an entrepreneurial mindset among its PhD scholars, for example through pitching competitions and awareness interventions.

Through an agreement signed in 2021, the government of Mozambique, through its World Bank-funded project on 'Improvement for Skills Development in Mozambique (MozSkills)', is investing USD 6 million in Rsif. Of the amount, USD 4.2 million will fund Rsif PhD scholarships, while USD 1.8 million will be dedicated to research and innovation.

PROGRESS IN 2023

Rsif in collaboration with the Ministry of Higher Education, Science and Technology, Mozambique, has awarded 32 PhD scholarships to Mozambican students, and 14 research and innovation grants to faculty and researchers in universities and research institutions in the country.

In 2023, the two partners organised the inaugural Project Implementers' Forum in Vilankulo, Mozambique.

WAY FORWARD

The Forum underscored the importance of government and institutions reviewing and mainstreaming national and institutional policy frameworks on intellectual property management, technology transfer, and procurement practices to foster research and innovation development nationwide.

Regional Scholarship and Innovation Fund

Innovation grants for research commercialisation

Rsif focuses on strengthening doctoral training in applied sciences, engineering and technology through a virtuous cycle that will lead to increased, and more qualified PhD faculty capacity, able to undertake high-quality and impactful research and innovation; and to mentor and nurture doctoral students. We aim to assist Rsif PhD graduates in transitioning into employment and developing research, managerial, and other essential skills for becoming independent researchers. In 2022, Rsif introduced the Junior Investigator Research Award (JIRA) grants, to be awarded to PhD scholars, who have completed their studies and now hold various positions in universities in Africa.

PROGRESS IN 2023

Rsif has awarded 8 JIRA grants, each of up to USD 80,000 to Rsif PhD scholars who have completed their studies and now hold various positions in African universities and institutions. These grants will enable the graduates to broaden their research networks and generate innovative concepts in their respective fields.

WAY FORWARD

Rsif is bolstering the implementation and management framework of the JIRA grants, facilitating placement of the graduates in industry and boosting their employability.

In partnership with AHUs, Rsif is facilitating gender inclusivity in innovation, by enhancing access to research and innovation opportunities for female scientists and addressing gender imbalances.

PROGRESS IN 2023

7 female faculty members are principal investigators, while several others are contributing to teams in Rsif-supported research and innovation projects.

Various multidisciplinary project teams are employing human-centred approaches and design thinking processes to enhance key aspects of female health and economic practices. Examples include the development of biodegradable sanitary products and the improvement of safe street food vendor handling practices.

The exceptional contributions of Rsif's female researchers have garnered recognition through publications in national newspapers and invitations as keynote speakers in many fora.

WAY FORWARD

We continue to implement the recommendations of the Rsif gender strategy, leveraging the Rsif mentorship platform to provide guidance and support to female researchers and PhD students.

Regional Scholarship and Innovation Fund

Rsif-AGriDI innovation initiative

Accelerating Inclusive Green Growth through Agri-Based Digital Innovation in West Africa (AGriDI) (www.agridi.org) is one of 12 projects globally financed by the European Union through the ACP Innovation fund of the Organization of African, Caribbean and Pacific States (OACPS). It is implemented by an *icipe*-led consortium in Benin, Burkina Faso, Côte d'Ivoire, Ghana and Nigeria under the innovation grants window of the Rsif. The Euro 4.2 million contribution from the EU is used to provide financial and technical support to 12 competitively selected AGriDI grantees to: increase uptake of agri-based digital technologies by farmers' cooperatives and SMEs; strengthen collaboration between research communities, industry and policy actors in digital innovations; and improve knowledge on policymaking facilitating scaling agri-business digital innovations.

PRODUCTS AND SOLUTIONS

AGriCef mobile App by Université de Parakou, which is used to control the fall armyworm in maize in Northern Benin.

Ki@ app, also in Benin, which collects and provides relevant market updates via SMS and voice message directly to local farmers on their mobile phones.

SMARTSOIL app by the Federal University of Agriculture, Abeokuta (FUNAAB), in South-Western Nigeria is using digital soil mapping and artificial intelligence techniques to provide hyper-local soil information in a way that is easily accessible and affordable to end-users.

Driving Market Access and Managing AG value chains (DigiMakt) (Ghana), allows to profile, and disseminate climate-smart agronomic advisory, market information, weather alerts, insurance and credit scoring for smallholder farmers. Esoko Ltd, the AGriDI grantee that developed DigiMakt, won the Agri-Tech Company of the Year Award at the Ghana Agriculture and Agri-Business Awards 2023.

Contribution to policies on digital innovations.

Regional study by AGriDI consortium member and Rsif AHU, Université d'Abomey-Calavi in Benin, on Digital Agriculture Policies and Strategies for Innovations in the Agri-Food System.

An Annual Implementers Forum, which included a learning visit was launched and hosted by Université Félix Houphouët-Boigny, Centre of Excellence in Climate Change, Biodiversity and Agriculture, Côte d'Ivoire, in September 2023. Nine AGriDI grantees participated.

WAY FORWARD

For sustainable impact, a long-term perspective and investment is needed. The emerging lessons from the AGriDI initiative are feeding into the strategic dialogue with African governments, and the European Union in the implementation of the Africa-EU innovation agenda and the new PASET strategy.



Hairy darkling beetle belonging to the subfamily *Lagriinae* (*Tenebrionidae*: *Coleoptera*)

Location: Karura Forest, Nairobi

Adults of these hairy darkling beetles can feed on plant tissues, while their larvae are organic recyclers feeding on decaying plant debris or wood in wild habitats.

Annexes

Regional Scholarship and Innovation Fund

Name	Country	AHU	IPi	PhD research	Current position
Frejus Sodedji	Benin	University Felix Houphouët-Boigny, Côte d'Ivoire		Crop improvement, especially emerging approaches and technologies to develop nutrients density, with a specific focus on cowpea.	Postdoctoral Fellow, and lead researcher unde PASET-Rsif JIRA Award, at the University of Abomey-Calavi in Cotonou
Jean Nepomuscene Hakizimana	Rwanda	Sokoine University of Agriculture, (SACIDS Foundation for One) Health Tanzania	Ghent University, Belgium	Understanding the genomes and epidemiology of viral diseases, using next-generation sequencing technologies and associated bioinformatics.	Postdoctoral Research Fellow in Virology, under the OR Tambo Africa Research Chair for Viral Epidemics at SACIDS Foundation for One Health, and JIRA award.
David Oluwasegun Afolayan	Nigeria	African University of Science and Technology (AUST), Nigeria	Worcester Polytechnic Institute (WPI)	Optimization of smart beneficiation and mineral bioprocessing strategy of Nigerian barite for industrial application.	Postdoctoral Fellow and Acting Head, Mechanical Engineering Department, AUST; JIRA researcher.
Emmanuel Effah	Ghana	Gaston Berger University, Senegal		Wireless sensor networks, Agricultural-Internet-of-Things (Agri-IoT), IoT-based water monitoring system, smart systems design technology and machine learning.	Senior Lecturer, Department of Computer Science and Engineering, University of Mines and Technology, Ghana; JIRA researcher.
Jean Baptiste Habinshuti	Rwanda	African University of Science and Technology, Nigeria		Mining, minerals processing and extraction using environmentally friendly techniques; case study of columbite-tantalite ores from Rwanda and Nigeria	Postdoctoral Fellow at Katholieke Universiteit, Leuven, Belgium
Jeanne Pauline Munganyika	Rwanda	African University of Science and Technology, Nigeria		Characterising gold ores from different parts of Rwanda and Nigeria and to suggest the most suitable gold recovery method, to reduce wastage during gold processing and reap optimum benefits.	Lecturer, University of Rwanda; Geologist Coordinator, Co-founder at N.M.K. Geological and Mining Consultant Services Ltd, Rwanda
Richard Koech	Kenya	African University of Science and Technology (AUST), Abuja-Nigeria		Development of new materials for applications in solar cells, light emitting diodes and energy storage devices.	Lecturer of Physics, Moi University, Kenya; JIRA researcher.

Regional Scholarship and Innovation Fund

Name	Country	AHU	IPI	PhD research	Current position
Sylvia Wairimu Maina	Kenya	Sokoine University of Agriculture, Morogoro, Tanzania		Understanding the health benefits of bioactive compounds in Africa's orphan vegetables (African cabbage and Ethiopian kale) and strategies to improve their content in a smart farming system.	Part-time Lecturer, Mt. Kenya University, Kenya; JIRA researcher.
Humphrey Andalo Mabwi	Kenya	Sokoine University of Agriculture, Tanzania		Design of an in vitro system mimicking human gut microbiome ecosystem for rapid screening of potential functional foods, prebiotics and other materials beneficial to health.	Adjunct lecturer, Masinde Muliro University of Science and Technology, Kenya; JIRA, researcher.
Noel Gahamanyi	Rwanda	Sokoine University of Agriculture, Tanzania		Pathogens, their drug-resistance, and use of natural products as alternative antimicrobials using a One Health approach, with a specific focus on <i>Campylobacter</i> bacteria.	Director, Microbiology Unit at the National Reference Laboratory, Rwanda; Honorary Lecturer of Microbiology, University of Rwanda; Postdoctoral Fellowsh, Karolinska Institute, on the resistance of <i>Plasmodium falciparum</i> to artemisinin-based combination therapy (ACT); JIRA researcher
Emmanuel Kifaro	Kenya	Sokoine University of Agriculture, Tanzania		Simple RNA preparation methods, the design and application of field deployable genomic-based diagnostic assays, and molecular epidemiology of viral infections.	Lecturer of Molecular Biology, Sokoine University of Agriculture; JIRA researcher
Ruth Lorivi Moirana	Tanzania	Nelson Mandela African Institution of Science and Technology (NM-AIST), Tanzania	University of Greenwich Natural Resources Institute (NRI), UK	Water and wastewater treatment, climate change mitigation and adaptation and soil science, with a special focus on remediation of soils contaminated with fluoride using seaweed-derived materials.	Lecturer in Material Science and Engineering, NM-AIST; JIRA researcher.

Annex A: Awards

EXTERNAL AWARDS TO ICIZE STAFF

icize Director General, Dr Segenet Kelemu is the 2022 International Recipient of the prestigious Ellis Island Medal of Honor. The medals, which were established in 1986 by the Ellis Island Honors Society (EIHs), are among the United States most renowned awards. Enat Bank, Ethiopia, has named its 94th branch, located in Addis Ababa, after Dr Kelemu, in honour of her excellence in the world of science. Initiated by 11 distinguished Ethiopian women, Enat Bank was founded in 2011 and became operational in 2013. The Bank's vision of serving all people specially aims to bring a new dynamism to supporting women in Ethiopia, to maximise their economic capabilities, especially in business. On 7 June, Doha Debates, a media organisation based in Qatar and Washington DC, USA, announced that the latest individual honoured in their SolvingIt series is Dr Kelemu, one of Africa's leading scientists and a role model for women in science and research around the world. Dr Kelemu is one of the scientists featured in a publication titled, *Earth, Oceans and Skies: Insights from selected, outstanding African women scientists*, published by the United Nations Economic Commission for Africa (ECA). She has also been awarded the title of Officier de L'Ordre national du Mérite (Officer in the National Order of Merit), by the President of the French Republic. Dr Kelemu becomes the first Ethiopian, and one of a handful of Africans that have received this honour.

Menale Kassie, Social Science and Impact Assessment (SSIA) Unit, has been awarded the 2022 TWAS Siwei Cheng Award in Economic Sciences; for advancing understanding of the process and impacts of multiple-technology adoption in complex social and agricultural environments in sub-Saharan Africa. He has also been elected as Fellow of the African Academy of Sciences.

Tadele Tefera, Head, *icize* Ethiopia Office, has been elected Fellow of the Ethiopian Academy of Sciences.

Julius Ecuru, Manager, BioInnovate Africa Programme, has been appointed to serve on the JRS Biodiversity Foundation Board of Trustees for three years, starting in January 2022.

Baldwyn Torto, Head, Behavioural and Chemical Ecology Unit (BCEU), has been appointed member of the Jury, Life Sciences, 2022 Falling Walls Breakthroughs. He has also been appointed member, 2022 Selection Committee, UNESCO Organization for Women in Science for the Developing World-Elsevier Foundation Awards.

Beatrice Muriithi, Scientist, SSIA Unit, has been selected as an African Women in Agricultural Research and Development (AWARD) Policy Fellow, in the first cohort of the Gender Responsive Agriculture Systems Policy (GRASP) Fellowship Scheme.

Sheila Agha, former *icize* African Regional Postgraduate Programme in Insect Sciences (ARPPIS) scholar and currently Postdoctoral Fellow, Behavioural and Chemical Ecology Unit (BCEU), has been awarded the Wellcome Early Career Award, to undertake a project titled: 'An investigation of drivers of dengue virus transmission and the potential for Wolbachia-based transmission blocking in Kenya', over five years, commencing in December 2022. The research will be supported by David Tchouassi and Baldwyn Torto (BCEU); and Jeremy Herren (Human Health Theme).

EXTERNAL AWARDS TO SCHOLARS

Naomi Nyambura Riithi (MSc, Kenya), was featured in the Royal Society of Tropical Medicine and Hygiene (RSTMH) blog, during the International Women's Day (8 March 2022) titled: Gender bias is a galling word in a world where women seek to be heard and their ideas appreciated.

Andrew Abiya (MSc, Kenya), won the best presentation award in the UU-A student summit on 'Bridging young researchers with the Sustainable Development Goals (SDGs)', aimed at supporting the formation of collaborative programmes by merging African potential and Japanese scientific technology. Andrew presented the results of his study on the productivity of the wonder multistorey garden technology.

Gladys Mosomtai (PhD, Kenya) was awarded the United Nations Economic Commission for Africa (UNECA) Fellowship for Young African Professionals. She was also awarded the African Research Fellowship within the European Space Agency EO AFRICA Initiative. In addition, Gladys was selected as one of the leading women in machine learning for Earth observation (ML4EO) – having been nominated by the Radiant Earth Foundation, during International Women's Day; and she has joined ESRIN (known as the ESA Centre for Earth Observation) on a research fellowship, becoming one of the first two African researchers to join the ESRIN's activities. Her research will aim to understand the role of livestock migration patterns in the transmission of Rift Valley fever.

Ayaovi Agbessenou (Togo), PhD scholar, Plant Health Theme, received the Fungi Division Travel Award, to attend the 54th Annual Meeting of the Society for Invertebrate Pathology (SIP 2022), held in Eastern Cape, South Africa, in August 2022.

Bashiru Adams (Ghana), PhD scholar, Plant Health Theme, received a student travel award to the 36th annual joint meeting of the International

Society of Chemical Ecology (ISCE) and the Asia-Pacific Association of Chemical Ecologists (APACE), held in Kuala Lumpur, Malaysia, in August 2022.

Juliet Akoth Ochola (Kenya), former MSc scholar, BCEU, was awarded first place in the student poster competition for her research in using banana paper to disrupt chemical signalling between the potato and potato cyst nematodes, during the American Chemical Society Agro Division Hybrid Meeting and Expo held in Chicago, USA, in August 2022.

JOURNAL APPOINTMENTS

Henri Tonnang, Head, Data Management, Modelling, and Geo-Information (DMMG) Unit has been appointed as Associate Editor, *Frontiers in Tropical Diseases* (Vector Biology section); and Associate Editor, International Journal of Tropical Insect Science.

Elfatih M. Abdel-Rahman, Research Scientist, DMMG Unit, is a Guest Editor of the special issue on Improving the Remote Sensing of Phytochemicals, of the *Frontiers in Remote Sensing* journal.

Tobias Landmann, CIM/GIZ Integrated Expert in Geospatial Science, DMMG Unit, is a Guest Editor of the special issue on Remote Sensing for Land Degradation and Drought Monitoring, of the *Remote Sensing* journal published by MDPI.

Merid Getahun, Scientist, Animal Health Theme, has been appointed as an Editor, *Arthropod-Plant Interactions* (Springer-Nature).

Amanuel Tamiru, Scientist, BCEU, has been appointed as an Editor, *Arthropod-Plant Interactions* journal (Springer-Nature), especially on topics relating to the chemical ecology of insect-plant interactions.

BEST PUBLISHED SCIENCE PAPER

Winner

Rehemah Gwokyalya (PhD, Uganda)

Paper: Gwokyalya R., Herren J.K., Weldon C.W., Khamis F.M., Ndlela S. and Mohamed S.A. (2022) Differential immune responses in new and old fruit fly-parasitoid associations: Implications for their management. *Frontiers in Physiology*, 13:945370. <https://doi.org/10.3389/fphys.2022.945370>

Winner

Miano Raphael Njurai (PhD, Kenya)

Paper: Miano R. N., Ayelo P. M., Musau R., Hassanali A. and Mohamed S. A. (2022). Electroantennogram and machine learning reveal a volatile blend mediating avoidance behavior by *Tuta absoluta* females to a wild tomato plant. *Scientific Reports*, 12 (1), 1–16. <https://doi.org/10.1038/s41598-022-13125-0>

Second Runner Up

Maiyo N.C., Khamis F.M., Okoth M.W., Abong G.O., Subramanian S., Egonyu J.P., Xavier C., Ekesi S., Omuse E.R., Nakimbugwe D., Ssepuuya G., Ghemoh C.J. and Tanga C.M. Nutritional quality of four novel porridge products blended with edible cricket (*Scapsipedus icipe*) meal for food. *Foods*, 11(7):1047. <https://doi.org/10.3390/foods11071047>

Second Runner Up

Mwando N.L., Ndlela S., Meyhöfer R., Subramanian S. and Mohamed S.A. (2022) Immersion in hot water as a phytosanitary treatment for *Thaumatotibia leucotreta* (Lepidoptera: Tortricidae) in bell pepper (*Capsicum annuum* L.), *Postharvest Biology and Technology*, 192. <https://doi.org/10.1016/j.postharvbio.2022.112026>

BEST SCIENCE POSTER

Winner

Evalyne Wambui Ndotono (MSc, Kenya)

Poster title: Gut microbial shift in broiler and layer chicken fed with black soldier fly larvae-based meal as a dietary protein source
Supervisors: Fathiya Khamis and Chrysantus Tanga (*icipe*); and Joel Bargul (Jomo Kenyatta University of Agriculture and Technology, Kenya)

First Runner Up

Jacqueline Wahura Waweru (PhD, Kenya)

Poster title: Investigating symbiont-based immunity in *Anopheles* mosquitoes against *Plasmodium falciparum* infection
Supervisors: Jeremy Herren and Daniel Masiga (*icipe*); and Prof Lizette Koekemoer, University of the Witwatersrand, South Africa

Second Runner Up

Sahadatou Mama Sambo (PhD, Benin)

Poster title: Combating the tomato pest *Tuta absoluta* using an assembly of native and exotic parasitoids
Supervisors: Samira Abuelgasim Mohamed and Shepard Ndlela (*icipe*); and Hannalene du Plessis (North-West University, South Africa)

Annex B: Partners

Human Health Theme

Addis Ababa University (Aklilu Lemma Institute of Pathobiology), Ethiopia; agricultural research institutes, non-governmental organisations, private sector partners, farmers and farmer groups; Agha Khan University, Kenya; Ceva Santé Animale (CEVA), France; Centre of Research in Infectious Diseases (CRID), Yaounde, Cameroon; Dabaso Tujengane Self Help Group – Watamu Marine Association, Kenya; Duke University, USA; Durham University, UK; Egerton University, Kenya; Elimination 8 Programme (E8); Free University of Berlin and Charité–Universitätsmedizin, Berlin, Germany; Helmholtz Centre for Environmental Research (UFZ), Ifakara Health Institute, Tanzania; Institute of Endemic Diseases; International Livestock Research Institute (ILRI); Jaramogi Oginga Odinga University of Science and Technology; Johns Hopkins University, USA; Jomo Kenyatta University of Agriculture and Technology (JKUAT); Kenya Medical Research Institute (KEMRI); Kenya Medical Research Institute (KEMRI) (Wellcome Trust Research Programme, Kenya, and Centre for Virus Research); Kenya Wildlife Service (KWS); Kilimanjaro Christian Medical University College (KCMUCo), Moshi, Tanzania; KTH Royal Institute of Technology in Stockholm, Sweden; Leipzig, Germany; Liverpool School of Tropical Medicine (LSTM), UK; London School of Hygiene & Tropical Medicine (LSHTM), UK; Makerere University, Uganda; Millennium Institute, USA; Ministries of Health in Kenya and Ethiopia; Ministry of Agriculture, Livestock and Fisheries, (Directorate of Veterinary Services), Kenya; Ministry of Public Health and Sanitation (Division of Disease Surveillance and Response), Kenya; Mosquito Control in Nyabondo (MOCON) community group, Nyabondo, Kenya; national malaria control programmes of Botswana, Mozambique, Namibia, Swaziland, Zimbabwe and Zambia; National Center for Agricultural Utilization Research, USDA-ARS, Peoria, Illinois, USA; National Museums of Kenya (Institute of Primate Research); Northeastern University, Boston, USA; Ohio State University, USA; Pennsylvania State University, USA; Pwani University, Kenya; Radboud University, Nijmegen, the Netherlands; RWTH Aachen University, Germany; Sumitomo Chemical, Japan; Swedish University of Agricultural Sciences (SLU); Swiss Tropical and Public Health Institute, Switzerland; Telethon Kids Institute, Australia; Ultimate Products (Aust) Pty Ltd, Australia; Umeå University, Sweden; University of Bonn, Germany; University of Glasgow, UK; University of Nairobi, Kenya; University of Oxford, UK; University of Pretoria, South Africa; University of Sudan, Sudan; University of Warwick, UK; University of Wisconsin, US; United States Department of Agriculture (USDA), USA; US National Institute of Allergy and Infectious Diseases (NIAID); Wageningen University, the Netherlands; Wellcome Sanger Institute, UK; World Health Organization-Regional Office for Africa (WHO-AFRO); Institute of Molecular Biology & Biotechnology (Foundation for Research & Technology Hellas), Heraklion, Crete, Greece; University of Cambridge, UK; University of Canterbury, Christchurch, New Zealand; University of Georgia, USA; University of Florida, Gainesville, FL, USA.

Animal Health Theme

African Union Inter-African Bureau for Animal Resources (AU-IBAR); County governments in Kenya; Director of Veterinary Services (DVS) (Kabete Veterinary Research Laboratories), Nairobi, Kenya; French Agricultural Research Centre for International Development (CIRAD), France; International Center for Research and Development on Livestock in Subhumid Zones (CIRDES); Kenya Agriculture and Livestock Research Organization (KALRO) Nairobi, Kenya; Kenya Livestock Producers Association (KLPA); Kenya Tsetse and Trypanosomiasis Eradication Council (KENTTEC); Kenya Wildlife Service (KWS); Liverpool School of Tropical Medicine, UK; Macquarie University, Australia; Makerere University, Uganda; Max Planck Institute for Chemical Ecology, Jena, Germany; Meru University; Ministry of Agriculture, Livestock & Fisheries and Department of Veterinary Services in Kwale County; Mount Kenya University, Kenya; Egerton University, National Museums of Kenya; Save the Elephants (STE), Kenya; Smithsonian Institution, USA; Sokoine University of Agriculture, Tanzania; Swiss Center for Scientific Research (CSRS), Côte d'Ivoire; Swiss Tropical and Public Health Institute; Tanzania National Parks; Tanzania Wildlife Research Institute (TAWIRI); Tsetse control Division and DVS, Zimbabwe; University of Bern, Switzerland; University of Bristol, UK; University of Copenhagen, Denmark; University of KwaZulu-Natal (UKZN), South Africa; University of Maryland, USA; University of Nairobi; University of Naples Federico II, Italy; University of Oxford, UK; University of Pretoria, South Africa; University of Twente, The Netherlands; University of Warwick, UK; University of Würzburg, Germany; Vector Control Division, Uganda; Veterinary Medicines Directorate (VMD); Wageningen University and Research, The Netherlands; Yale School of Public Health (USA).

Plant Health Theme

A to Z Textiles Limited, Arusha, Tanzania; Academy of Sciences of the Czech Republic (Institute of Organic Chemistry and Biochemistry); African Academy of Sciences; African Conservation Tillage Network, Malawi and Zambia; Agrarian Systems Ltd, Uganda; Agricultural Research Corporation (ARC), Wad Medani, Sudan; French Agricultural Research for Development (CIRAD), France; Agroscope, Switzerland; Alliance of Bioversity & CIAT; Anglican Development Services, Kenya; Anglican Development Services Eastern (ADSE), Kenya; ARC-Tropical and Subtropical Crops Austin Investment Ltd; Avocado Growers Association, South Africa; Biocontrol Research Laboratories, India; Bioversity International, Italy; Botswana International University of Science and Technology; Busitema University, Uganda; CABI Africa; Cardiff University; Crop Health and Protection (CHAP), UK; Citrus Research International, South Africa; Conservation Farming Unit (CFU), Zambia; Dschang University, Cameroon; Division of Plant Industry, Florida Department of Agriculture and Consumer Services, USA; Dudutech Ltd, Kenya; East African Community (EAC), Tanzania; East African Seed Co. Ltd, Kenya; Éléphant Vert Kenya; University of Embu, Kenya; Ethiopian Institute of Agricultural Research (EIAR); Ethiopian Agricultural Transformation Agency; Farmer groups and mango growers; Fartrack Consulting Ltd, Kenya; Forum for Agricultural Research in Africa (FARA); French National Research Institute for Sustainable Development (IRD), France; Hawassa University, Ethiopia; Heifer International – Kenya and

Tanzania; Horticultural Research and Training Institute-Tengeru (HORTI Tengeru), Tanzania; HottiServe East Africa Limited, Kenya; Humboldt-Universität zu Berlin, Germany; Institute for Sustainable Development (ISD), Ethiopia; International Center for Tropical Agriculture (CIAT); International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); International Institute of Tropical Agriculture (IITA); International Livestock Research Institute (ILRI); International Maize and Wheat Improvement Center (CIMMYT); International Potato Center (CIP); International Water Management Institute (IWMI); Jaramogi Oginga Odinga University of Science and Technology (JOOUST), Kenya; Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya; Julius Kühn-Institut (Institute for Biological Control), Germany; Justus Liebig University Giessen; Kasisi Agricultural Training Centre, Zambia; Keele University, UK; Kenya Agricultural and Livestock Research Organisation (KALRO) (Horticulture Research Institute); Kenya Biologics Ltd; Kenya Institute of Organic Farming (KIOF); Kenya Organic Agriculture Network (KOAN); Kenya Plant Health Inspectorate Service (KEPHIS); Kenyatta University, Kenya; Kushereketa Rural Development Organization (KURDO), Zimbabwe; Kyambogo University, Uganda; Lake Zone Agricultural Research and Development Institute (LZARDI), Tanzania; Lasting Solutions Ltd, Kenya; Leibniz Universität Hannover, Germany; Lilongwe University of Agriculture and Natural Resources (LUANAR), Malawi; Makerere University, Uganda; Maseno University, Kenya; Mikochei Agricultural Research Institute, Tanzania; Ministries of Agriculture in Botswana, Namibia, Zambia and Zimbabwe; Ministry of Agriculture-Plant Health Clinic (MoA-PHC), Ethiopia; Ministry of Agriculture and Natural Resources, Ethiopia; Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Uganda; Ministry of Agriculture, Food Security and Cooperatives, Tanzania; Ministry of Agriculture, Forestry, Cooperatives and Rural Development, South Sudan; Ministry of Agriculture, Livestock and Fisheries, Kenya, and County Departments of Agriculture; Agricultural Sector Development Support Programme, Kenya; Moi University, Kenya; Mukushi Seeds, Zimbabwe; National Agricultural Research Organisation (NARO), Uganda; National Crops Resources Research Institute (NaCRRI), Uganda; National Museums of Kenya; National Potato Council, Kenya; Norwegian Institute of Bioeconomy Research (NIBIO); New Zealand Institute for Plant & Food Research Ltd, New Zealand; Nutreal Ltd, Uganda; One Acre Fund, Kenya and Uganda; Pest Control Products Board (PCPB), Kenya; Private Bag X11208, Republic of South Africa; Real IPM Ltd, Kenya; Research Institute of Organic Agriculture (FiBL), Switzerland; Ripple Effect; Rothamsted Research, United Kingdom; Royal Museum for Central Africa, Tervuren, Belgium; Rwanda Agricultural Board (RAB); Homabay County Government, Kenya; Sanergy Ltd, Kenya; Sasakawa Africa Association; Seed Co. Zimbabwe Limited; Sokoine University of Agriculture, Tanzania; Tanzanian Pesticide Research Institute, Tanzania; Tanzania Agricultural Research Institute (TARI), Tanzania; Texas A&M University, USA; Tigray Agricultural Research Institute (TARI), Ethiopia; The Poverty Alleviation Department, Office of the President, Uganda; The Seed Control and Certification Institute of Zambia; The Swedish University of Agricultural Sciences (SLU); The World Vegetable Center (WorldVeg), Tanzania; Total LandCare, Malawi and Zambia; Treasure Industries Ltd, Thika, Kenya; Tropical Soil Biology and Fertility (TSBF) Institute of CIAT; Ugachik Ltd, Uganda; Unga Feeds Ltd, Kenya; United States Department of Agriculture (USDA)-Agricultural Research Service (ARS), Center for Medical, Agricultural and Veterinary Entomology (CMAVE), USA; United Nations Food and Agriculture Organization South Sudan (FAO/South Sudan); University of Amsterdam; University of Bonn, Germany (Center for Development Research - ZEF); University of Galway; University of Hohenheim, Germany; Université de Neuchâtel; University of Nairobi, Kenya; University of Pavia, Italy; University of Tennessee, USA; University of Sousse (Higher Agronomic Institute of Chott-Mariem), Tunisia; University of Würzburg; University of Zambia; University of Zurich; Wageningen University and Research Centre (WUR) (Plant Research International), the Netherlands; WeRATE; World Agroforestry Centre (ICRAF); Zambia, Zanzibar Agricultural Research Institute (ZARI), Zambia.

Environmental Health Theme

Addis Ababa University, Ethiopia; African Union Inter-African Bureau for Animal Resources (AU-IBAR); Agricultural Sector Development Programme, Zanzibar, Tanzania; Akililu Lemma Institute of Pathobiology, Ethiopia; Bahir Dar University, Ethiopia; Biovision Africa Trust; Debre Berhan University, Ethiopia; Debre Markos University, Ethiopia; East Usambara Farmers Group; Ethiopian Ministry of Trade and Industry; Ethiopian Institute of Agricultural Research; Faculty of Agriculture, University of Kinshasa (DR Congo); Federal Ministry of Health, Ethiopia; French Agricultural Research Centre for International Development (CIRAD), France; French National Institute for Agricultural Research (INRA), France; Food and Agriculture Organization of the United Nations (FAO); German Centre for Integrative Biodiversity Research (iDiv), Germany; Holeta Bee Research Centre, Ethiopia; Iziko South African Museum, South Africa; Jimma University, Ethiopia; Kamaki Beekeepers Cooperative Society Limited, Kenya; Kenya Agricultural and Livestock Research Organization (KALRO) (National Sericulture Research Centre); Kenya Marine and Fisheries Research Institute (KEMFRI - Nyabondo); Kenya Medical Research Institute (KEMRI); Martin Luther University, Halle-Wittenberg, Germany; Milba Brands Associates Limited, Kenya; Millennium Institute, USA; Ministry of Agricultural Development and Food Security, Botswana; Ministry of Agriculture (MoA-Nyabondo); Ministry for Animal Resources and Fisheries, Burkina Faso; Ministry of Agriculture, Livestock and Fisheries (Directorate of Livestock Production), Madagascar; Ministry of Agriculture, Ethiopia; Ministry of Agriculture, Fisheries, Environment, Land Use and Urban Planning, Comoros; Ministry of Agriculture, Liberia; Ministry of Agriculture, Natural Resources, Livestock and Fisheries, Zanzibar; Ministry of Agro-industry and Food Security (Entomology Division), Mauritius; Ministry of Health, Municipal Council of Malindi, Kenya; Ministry of Livestock, Fisheries and Animal Industries, Cameroon; Ministry of Public Health and Sanitation (Nyabondo); Muliru Farmers Conservation Group (MFCG), Kenya; Museum für Naturkunde, Berlin, Germany; National Agriculture and Food Research Organization, Japan; National Beekeeping Station, Kenya; National Institute of Medical Research (NIMR), Tanzania; National Museum, Bloemfontein, South Africa; National Museums of Kenya; Pangani Basin Water Board, Tanzania; Pennsylvania State University, USA; Royal Museum for Central Africa, Tervuren, Belgium; Ruhr-Universität Bochum, Germany; Schmalhausen Institute of Zoology, Ukraine; Seychelles Agricultural Agency; Smithsonian Institution, USA; Smithsonian National Museum of Natural History, USA; Sokoine University of Agriculture, Tanzania; Stellenbosch University, Department of Conservation Ecology and Entomology, South Africa; Strand Life Sciences, India; Taita Environmental Research and Resource Arc (TERRA), Kenya; Tanzania Farmers Conservation Group (TFCG); Tropical Entomology Research Center, Viterbo, Italy;

Tuscia University, Viterbo, Italy; United States Department of Agriculture (USDA), USA; University of Bonn, Germany; University of California, Davis, USA; University of Dar es Salaam, Tanzania; University of Helsinki, Finland; University of Kansas, USA; University of Lausanne, Switzerland; Umeå University, Sweden; University of Würzburg, Germany; University of York, UK; Wageningen University and Research (Resource Ecology group), the Netherlands; Yeungnam University, South Korea; COLOSS-honey bee research association; University of Maroua, Cameroon; Institute of Agricultural Research for Development (IRAD), Cameroon; York University, Canada.

Social Science and Impact Assessment Unit

Addis Ababa University, Ethiopia; Agropolis Foundation, Montpellier, France; Bavarian Research Alliance (BayFOR), Germany; Department of Agricultural Research Services (DARS), Malawi; Departamento de Economia e Desenvolvimento Agrário, Faculdade de Agronomia e Engenharia Florestal, UEM, Mozambique; Eastern Africa Farmer's Federation (EAFF), Kenya; Egerton University, Kenya; ETH Zurich, Switzerland; Food for the Hungry, Uganda; French Agricultural Research Centre for International Development (CIRAD), France; Gearbox Pan African Network, Nairobi, Kenya; Haramaya University, Ethiopia; InoSens, Serbia; International Food Policy Research Institute (IFPRI); International Maize and Wheat Improvement Centre (CIMMYT); Jomo Kenyatta University of Agriculture and Technology, Kenya; Kenya Agricultural and Livestock Research Organisation (KALRO); Kenya Plant Health Inspectorate Service (KEPHIS); Kenyatta University, Kenya; Leibniz University of Hannover, Germany; Lund University (ULUND), Sweden; Maseno University, Kenya; Ministry of Agriculture, Ethiopia; Moi University, Kenya; National Agricultural Research Organization/National Crops Resources Research Institute (NARO), Uganda; National Crops Resources Research Institute (NaCRRI), Uganda; Norwegian University of Life Sciences, Norway; Partnership for Economic Policy (PEP); Plant Quarantine Services Institute, Zimbabwe; Rwanda Agriculture and Animal Resources Development Board (RAB), Rwanda; Swedish Agricultural University, Sweden; Send a Cow, Ethiopia; Tanzania Agricultural Research Institute (TARI), Tanzania; University of Abomey-Calavi, Abomey-Calavi, Benin; University of Bonn (Center for Development Research-ZEF), and Medical Center, Germany; University of Geneva, Switzerland; University of Gothenburg, Sweden; University of Göttingen, Germany; University of KwaZulu-Natal, South Africa; University of Nairobi, Kenya; University of Pretoria, South Africa; University of Zürich, Switzerland; Virginia Polytechnic Institute and State University, USA; Wageningen University & Research, the Netherlands; World Vegetable Center (AVRDC); Zambian Agricultural Research Institute (ZARI), Zambia.

Technology Transfer Unit

Africa Inland Church of Tanzania; Bako Maize Research Centre, Ethiopia; Beula Seed Company, Tanzania; Conservation Farming Unit, Zambia; Ethiopian Institute of Agricultural Research (EIAR); Environmental Institute for Agricultural Research (INERA), Burkina Faso; Food for the Hungry, Rwanda; Institute of Agronomic Sciences of Burundi; Kasisi Agricultural Training Institute, Zambia; Kenya Agricultural and Livestock Research Organisation (KALRO); Kenyatta Agricultural Training Centre, Kenya; Kushereketa Rural Development Organization (KURDO), Zimbabwe; National Agricultural Research Organization (NARO), Uganda; National Crops Resources Research Institute (NaCRRI), Uganda; Rwanda Agriculture and Animal Resources Board (RAB); Safi Organics, Kenya; Send a Cow, Ethiopia; Sustainable Agriculture Tanzania; Tanzania Agricultural Research Institute (TARI); Tanzania Humane Charity (TAHUCHA); Total Land Care Malawi and Zambia; Tropical Seeds (EA) Ltd, Tanzania; Zambia Agricultural Research Institute (ZARI).

Data Management, Modelling and Geo-Information Unit

Desert Locust Control Organization for Eastern Africa; Food and Agriculture Organization of the United Nations (FAO); Food for the Hungry Association, Uganda; Haramaya University, Ethiopia; International Institute of Tropical Agriculture (IITA); Kenya Agriculture and Livestock Research Organization (KALRO); Ministry of Agriculture, Livestock and Fisheries (Plant Protection Services), Kenya; National Agricultural Research Laboratories (NARL), Uganda; National Crops Resources Research Institute, Uganda; Norwegian Institute of Bioeconomy Research (NABIO); Remote Sensing Solutions (RSS), Germany; Send a Cow, UK; University of KwaZulu-Natal, South Africa; University of Stellenbosch, South Africa; University of Western Cape, South Africa; University of Würzburg, Germany.

Collaborators/Implementing Partners: Addis Ababa University (AAU), Ethiopia; Agri Seed Company Limited, Kenya; Busitema University, Uganda; East Africa Nutraceuticals Ltd (EAN), Kenya; Food and Nutrition Solutions Ltd (FONUS), Uganda; GLOBAL AGRO CONCEPT Limited, Rwanda; Green Enzyme Technologies Ltd (GETL), Kenya; Guavay Company Limited, Tanzania; Hawassa University, Ethiopia; Hottiserve East Africa Limited, Kenya; iTEC Centre, Tanzania; Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya; Kenya Biologics Limited, Kenya; Kenya Industrial Research and Development Institute (KIRDI), Kenya; Kibwezi Agro Limited, Kenya; Lasting Solutions Limited, Uganda; Makerere University, Uganda; Maseno University, Kenya; MIMEA International Kenya Limited; Ministry of Trade, Industry and Cooperatives, Uganda; National Agricultural Research Organization (NARO), Uganda; National Semi Arid Resources Research Institute (NaSARRI), Uganda; Nelson Mandela African Institution of Science and Technology (NM-AIST), Tanzania; OKOA Society, NGO, Tanzania; Pwani University (PU), Kenya; Rwanda Agricultural Board (RAB), Rwanda; SENAI Farm Supplies Limited, Uganda; Sokoine University of Agriculture (SUA), Tanzania; Sulma Foods Limited, Uganda; Tanzania Agricultural Research Institute (TARI), Mikocheni, Tanzania; Tanzania Commission for Science and Technology (COSTECH), Tanzania; Tanzania Industrial Research and Development Organization (TIRDO), Tanzania; The Real IPM Company Limited, Kenya; Tonnet Agro-engineering Company Limited, Uganda; Treasure Industries Limited (TIL), Kenya; Tursam Investment Limited (TIL), Uganda; University of Dar es Salaam (UDSM), Tanzania; University of Nairobi (UoN), Kenya; W.E. Tilley Fish Processors, Kenya.

Annex C: Abbreviations and Acronyms

ACIAR	Australian Centre for International Agricultural Research	CultiAF	Cultivate Africa's Future Fund, a 10-year (2013-23) partnership between Future Australian Centre for International Agricultural Research (ACIAR) and International Development Research Centre (IDRC)
AFD	French Development Agency	DAAD	German Academic Exchange Service
AHUs	African Host Universities	Danida	Danish International Development Agency
ANR	Agence Nationale de la Recherche / French National Research Agency	DG-DEVCO	Directorate-General for International Cooperation and Development Offices (European Union)
ARPPIS	African Regional Postgraduate Programme in Insect Science	DFG	German Research Foundation
AU	African Union	DLCO-EA	Desert Locust Control Organization of Eastern Africa
AU-IAPSC	African Union Inter-African Phytosanitary Council	EAC	East African Community
AWARD	African Women in Agricultural Research and Development	EANBiT	Eastern Africa Network for Bioinformatics Training
BBSRC	Biotechnology and Biological Sciences Research Council, UK	EASTECO	East African Science and Technology Commission
BecA-ILRI Hub	Biosciences eastern and central Africa – International Livestock Research Institute Hub	EC	European Commission
BLE	German Federal Agency for Food and Agriculture	ESA	Entomological Society of America
BMZ	Federal Ministry for Economic Cooperation and Development, Germany	EU	European Union
CAP-Africa	Combating arthropod pests for better health, food and resilience to climate change	FAO	Food and Agriculture Organization of the United Nations
CBFAMFEW II	Community-based fall armyworm monitoring, forecasting, and early warning system (phase II)	FAW-IPM	Integrated pest management strategy to counter the threat of invasive fall armyworm to food security in eastern Africa
CIAT	International Center for Tropical Agriculture	FCDO	UK Foreign, Commonwealth & Development Office
CIRAD	French Agricultural Research Centre for International Development	FIBL	Research Institute of Organic Agriculture
COMBAT	Controlling and progressively minimising the burden of animal trypanosomosis	FNIH	Foundation for the National Institutes of Health
		GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
		HAK	Horticultural Association of Kenya
		IAEA	International Atomic Energy Agency

ICARDA	International Centre for Agricultural Research in the Dry Areas
IDRC	International Development Research Centre, Canada
IFAD	International Fund for Agricultural Development
INRAE	French National Research Institute for Agriculture, Food and the Environment
IRD	French National Research Institute for Sustainable Development
KALRO	Kenya Agricultural and Livestock Research Organization
KCOA	Knowledge Centre for Organic Agriculture in Africa
KEMRI	Kenya Medical Research Institute
KEPHIS	Kenya Plant Health Inspectorate Service
MRC	Medical Research Council, UK
NEMEDUSSA	Nematology Education in Sub-Saharan Africa
NIH	National Institutes of Health, USA
Norad	Norwegian Agency for Development Cooperation
NRF	National Research Fund
NSF	National Science Foundation
NWO	Netherlands Organization for Scientific Research
OACPS	Organisation of African, Caribbean and Pacific States
PAMCA	Pan-African Mosquito Control Association
PANEMA	Pan-African nematology network
PASET	Partnership for Skills in Applied Sciences, Engineering and Technology
Rsif	Regional Scholarship and Innovation Fund of PASET
SCLAMP-EA	Scaling-up climate-smart pest management approaches for enhanced maize and tomato systems productivity in eastern Africa

SDC	Swiss Agency for Development and Cooperation
SEI	Stockholm Environment Institute Africa Centre
Sida	Swedish International Development Cooperation Agency
SNSF	Swiss National Science Foundation
SRC	Swedish Research Council
SwECCA	Swedish Development Cooperation team for Environment and Climate Change in Africa
THRiVE	Training Health Researchers into Vocational Excellence
TSARA	Transforming Food and Agricultural Systems through Research in Partnership with Africa
TWAS	The World Academy of Sciences
UKRI	Biotechnology and Biological Sciences Research Council, UK Research and Innovation
UNECA	United Nations Economic Commission for Africa
UNEP-GEF	United Nations Environment Programme / Global Environment Facility
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
USAID-PEER	United States Agency for International Development's Partnerships for Enhanced Engagement in Research
USDA-ARS	United States Department of Agriculture-Agricultural Research Service
WHO	World Health Organization
WHO-AFRO	World Health Organization/ Regional Office for Africa
WTO-EIF	World Trade Organization – Enhanced Integrated Framework

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Flower head bug or Shield bug, *Agonoscelis nubilis* (Pentatomidae: Hemiptera)

Location: Singampunari, Tamil Nadu, India

The shield bugs of genus *Agonoscelis* are native to the Afrotropical region and Australia. But they are also observed in South Asia as minor pest of flax, cotton, sorghum and millets. In some parts of Africa, where millets are grown widely, these bugs are also considered edible.



Annual Report 2023

The **International Centre of Insect Physiology and Ecology** (www.icipe.org): is globally distinct, being the only research institute working primarily on insects and other arthropods. *icipe* is also the sole institution that combines food security, human health, animal health and environmental health. Moreover, the Centre is a model of scientific eminence, uniquely blending the generation of world-class knowledge, and its translation into climate-smart, nature-based, One Health, systems-approach, inclusive innovations that transform the livelihoods of millions of people across Africa.

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