icipe

Annual Report 2022

www.icipe.org

Celyphidae (*Spaniocephalus* sp.)
Celyphidae, commonly known as beetle flies or beetle-backed flies, are a family of flies (order Diptera). They exemplify the convergent evolution between beetles and flies. Most beetles have forewings that are not used for flying; rather they have evolved into hardened sheaths. Likewise, the shell of the Celyphidae covers and protects the softbodied abdomen within which the reproductive and digestive organs are located. The flies are associated with moist or we areas. Their larvae are saprophagous, consuming rotting vegetation.

Annual Report
2022

April 2023

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icipe gratefully acknowledges the financial and technical support of our core donors: Swedish International Development Cooperation Agency (Sida); Swiss Agency for Development and Cooperation (SDC); Australian Centre for International Agricultural Research (ACIAR); Federal Democratic Republic of Ethiopia; and Government of the Republic of Kenya (Ministry of Education, State Department of University Education and Research).

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

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April 2023

Concept and text compilation: Liz Ng'ang'a
Review: Segenet Kelemu
Editorial contribution: Idupulapati Rao
Design and layout: Brian Mwashi

Cover image: A beautiful adult female of the fly genus Cladoderris, *C. convexa* (family Platystomatidae). The elaborate markings on the body and wings of this species are probably for camouflage. *icipe* researchers collected this specimen in Kakamega forest, western Kenya, the easternmost part of the Congo-Guinean rainforest.

The full-page insect photos (except those on pages 55 and 69) have been taken using a MacroSolutions Macropod photographic system acquired by *icipe* through a grant from the Swedish International Development Cooperation Agency (Sida).

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

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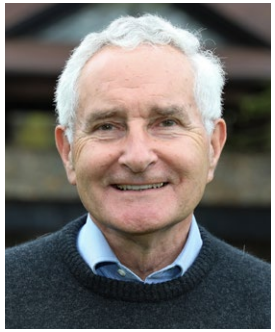


Prof. Kym Anderson
Chair,
icipe Governing Council

The year 2022 marked the middle of the implementation of the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs), through which world leaders made commitments in 2015 to end extreme poverty, inequality and climate change by 2030. In addition, the first ten-year implementation plan of the African Union's Agenda 2063 that was initiated in 2013, entitled, "the Africa We Want," closes in 2023.

Two reports, both published in 2022 against the background of the COVID-19 pandemic and the war in Ukraine, review progress towards, and challenges in achieving the SDGs and Agenda 2063.

The *United Nations Sustainable Development Goals Report 2022* calls for an urgent rescue effort for the SDGs, to deliver on their commitments to the world's most vulnerable people, communities and nations. The *2022 Africa Sustainable Development Report* identifies sub-regional policy solutions to the continent's structural weaknesses and vulnerabilities, to help African countries achieve the SDGs and Agenda 2063.

The two reports provide convergent recommendations, including the need for community-based and -owned solutions and approaches. These strategies should be coupled with public-private solidarity and partnerships, to build resilient social protection systems, and to address the root causes of inequality and poverty.

Specifically, the documents highlight the need to transform our food systems, for example by moving agriculture from a carbon contributor to a carbon sink, and by reducing food loss and wastage; transitioning to a greener, more inclusive and just economy, by rebalancing nature and climate through better conservation of natural resources; and by designing and de-risking a new generation of nature-based livelihoods that support youth-led rural entrepreneurship.

The reports also propose integrated thinking and action on health systems; countering the obstacles of rising urbanisation including the mounting problem of solid waste management; and investing in data and information infrastructure for more-targeted responses.

While these calls to action are immense, they are not unattainable. Indeed, this message of hope and optimism is at the heart of this *icipe Annual Report* for 2022. The publication provides ample evidence that with the right focus and dedication, we can simultaneously improve food and nutritional security and build cleaner, healthier and more-resilient environments. And this can be achieved while strengthening capacity for innovation and unlocking novel income generation opportunities, especially for women and the young.

icipe epitomises the power of world-class insect science as the basis for inclusive innovations. The Centre illustrates the viability of nature-based One Health approaches that have at their heart balanced and optimised benefits for people, animals and the environment. It exposes the potential of using Africa's rich biodiversity to create circular economies that have as their underlying principles the elimination of waste and pollution, of the circulation of products and raw materials through reuse or recycling, and of the regeneration of natural systems by conserving or redeploying resources.

We hope that you will find this *Annual Report* informative and reinvigorating, and we look forward to your partnership in 2023 as we collectively work towards a more prosperous Africa and better world.

Preface

Dr Segenet Kelemu
Director General, *icipe*

The year 2022 should have been one of new beginnings. However, just as the world was beginning to put the COVID-19 pandemic in the rearview mirror, ongoing and new conflicts around the world drove up global inflation, creating food and energy shortages. The headwinds blew towards Africa, coalescing with the rising impact of climate change and a myriad of interconnected, persistent developmental challenges.

So, while we thought we would go back to a relatively easy way of living and the level of comfort we knew before, we had to adjust to the fact that our lives are ever in motion, and the need to remain highly adaptable to change, to weather uncertainty, to be flexible yet firmly grounded. Thus, 2022 became the year of resilience, strength and authenticity.

In accordance, this *icipe* Annual Report for 2022 is written in the spirit of reflection, of our place as a Centre in a fast-evolving world. Its curtain-raiser is the Management and Leadership chapter, which consists of a snapshot of the events that *icipe* hosted or participated in, and the visitors we welcomed; rising investments in our Centre, as well as the increasing partnerships, visibility and recognition. Together, these aspects ratify *icipe*'s unique place as an African yet global institution; a thought leader and a worthwhile investment and partner.

Through four chapters that are dedicated to the *icipe* 4H themes: Human, Animal, Plant and Environmental Health, which work closely with the Centre's Research Support Units, we comprehensively curate our research and development (R&D) accomplishments. The highlights include our contributions to tools and strategies for malaria control and elimination; neglected tropical diseases as well as emerging and re-emerging viruses and diseases; and sustainable livestock farming. We also outline a range of nature-based solutions for the management of a plethora of agricultural pests such as tomato leafminers, nematodes, whiteflies and stemborers. Combined, these tools and strategies ensure improved crop health and yield, as well as more resilient agricultural systems.

We are tapping into our vast knowledge and experience to implement climate-smart and sustainable beekeeping in a range of ecological zones, including previously degraded landscapes or those adjacent to natural resource-rich ecosystems; pastoral and agro-pastoral regions; arid and semi-arid lands; and mangrove ecosystems. Our pioneering R&D activities on insects for food, feed and other uses, are helping to transform the food system, to provide more affordable and nutritious food for people and livestock and to create cleaner and healthier environments.

Three chapters of this report focus on: the Social Science and Impact Assessment Unit, and its insights on the dissemination, adoption, economic benefits and gender inclusiveness of our technologies and strategies; the Technology Transfer Unit, which is scaling-out *icipe* technologies across Africa; and the Data Management, Modelling and Geo-Information Unit, a hub of cutting-edge expertise in decision making tools for the prediction and modelling of pests and vectors, and developmental thinking.

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

Mindful of the urgent need to bridge between solutions and challenges, the main chapters of this report are prefixed by a compelling overview 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); Federal Democratic Republic of Ethiopia; and Government of the Republic of Kenya (Ministry of Education, State Department of University Education and Research).

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.

Communications

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

Partnerships

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

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

41 new staff recruited, bringing the total to 549.

2022 Timeline

January

icipe attended meeting to discuss the contribution of science and research to societal transformation and plans for the 2023 Nobel Forum in Kenya; participated in the Global Forum on Agricultural Research and Innovation talks themed: The United Nations Food Systems Summit (UNFSS): Where next?; and the Rockfeller Foundation's new Good Food Strategy – Africa focused Roundtable Meeting.

February

icipe participated in the Rockfeller Foundation Good Food Strategy roundtable meeting. The DG attended a meeting organised by the Swedish Embassy to discuss science and research and societal transformation, and the 2023 Nobel Forum. Visitors to *icipe* included delegates from the Swiss Agency for Development and Cooperation (SDC): Dr Daniel Valenghi (Programme Officer, Global Programme Food Security, GPFS, Swiss Cooperation Office, Ethiopia), Dr Amsalu Abate (GPFS, Ethiopia), and Dr Corinne Corradi (International Cooperation Team, Nairobi, Kenya); Dr Daniel Elger, CEO CABI-UK and Dr Dennis Rangi, DG, Development, CABI-Kenya.

March

The DG participated in: the ACIAR PAC meeting; the 'Breaking Barriers Toward Gender Equity' conference by *Nature* journal; and the launch of: '*Earth Oceans and Skies*', a book by UNECA. *icipe* took part in the annual conference of the German Centre for Integrative Biodiversity Research (iDiv) in Leipzig, Germany; the commemoration of the AU-IBAR 70th Anniversary and 10th Anniversary of rinderpest eradication in Africa; and the launch of the TSARA Initiative, by INRAE, CIRAD and African research organisations. The Emerging Insect Technologies Hub was launched by ACIAR, AgriFutures Australia and *icipe*.

April

The DG took part in the Advances in Genome Biology and Technology conference. Visitors to *icipe* included: Dr Kjersti Thorkildsen and Mrs Helga Torsknæs (Norad); and Mr Erlend Arnesen Haugen and Mr Øystein Rune Størkersenthe (Norwegian Embassy in Kenya); Dr Susanne Johansson, Senior Research Advisor, Swedish International Development Cooperation Agency (Sida). The Centre participated in the kick-off meeting of the One CGIAR Initiative Nature+; the World Bioeconomy Forum Roundtable; and the 'Africa Wide Science, Technology, and Innovation Conference' organised jointly by AUDA-NEPAD and AATF.

May

The DG received the Ellis Island Medal of Honour Award; participated in the FAO Science and Innovation Days 2022; and in the UNU Governing Council meeting in Helsinki, Finland. *icipe* participated in the 7th International Congrees of Nematology, in Antibes, France. Visitors to *icipe* included: Sida delegates working in 12 embassies in Africa, led by Dr Jan Wärnbäck, Regional Coordinator/Specialist Environment and Climate Change, Swedish Development Cooperation hub for Environment and Climate Change in Africa (SwECCA); a Canadian delegation that included: Honourable Harjit Sajjan, Minister of International Development, Canada; Mr Antoine Chevrier, Assistant Deputy Minister for sub-Saharan Africa, Global Affairs, Canada; Mr Christopher Thornley, High Commissioner of Canada to Kenya; Ms Janine Cocker, Head of Cooperation, High Commission of Canada to Kenya; and Dr Sarah M. Schmidt, International Agricultural Research, GIZ.

June

The DG met with Dr Susan Kaaria, incoming Director of the AWARD programme. *icipe* teams participated in the meetings of the conferences of the Parties to the Basel, Rotterdam and Stockholm conventions, in Geneva, Switzerland; made a keynote speech at the International Conference on Insects to Feed the World 2022*;* and attended a CIRAD Partnership Meeting, in Montpellier, France. Prof. Antoine Petit, CEO, CNRS, led a high-level delegation visit to *icipe*. The Centre, through Rsif, in partnership with Mohammed VI Polytechnic University, organised a conference themed: 'African-led science, technology, and innovation for contributing to the SDGs and boosting global development'. *icipe* participated in the National Stakeholder Validation of the Draft Phytosanitary Policy.

July

The DG participated as a plenary speaker in the XXVI International Congress of Entomology, in Helsinki, Finland. *icipe* participated in the Gordon Research Conference in California, USA, and led a discussion on 'Mechanisms and applications of natural and engineered genetic incompatibilities'; a conference on 'Inclusive digital co-creation in resilient agri-food systems – opportunities for gender-responsive digital solutions", hosted by ICARDA; and in the Kenya National Farmers Federation Farmers Forum; the 87th World library and information congress.

August

icipe participated in the meeting of the International Society of Chemical Ecology and the Asia-Pacific Association of Chemical Ecologists; the kick-off meeting of the Malawi Digital Plant Health Services; and the Annual Conference of the THRiVE consortium. Prof. Heikki Hokkanen and Dr Ingeborg Hokkanen from University of Eastern Finland visited *icipe* to discuss ongoing initiatives on suppressive soils and entomovectoring.The DG participated in the Plant Health 2022 annual meeting at the David L. Lawrence Convention Center, Pittsburgh, Pennsylvania, USA.

September

Visitors to *icipe* included: Dr Leah Ndungu, Regional Manager, and Dr Anna Okello, Research Program Manager, Livestock Systems, ACIAR; and Dr Juan Lucas Restrepo, Director General of Alliance of Bioversity International and CIAT.

October

The DG participated as a Council Member in the 7th National Council for Science and Technology meeting in Rwanda; and gave a seminar on 'Innovation and Development' at the Rwanda Institute for Conservation in Agriculture. The DG took part in a panel discussion in the FAO Science and Innovation 2022 meeting'; *icipe* hosted webinars on 'Nature-based solutions for biodiversity, food security and health', and on 'Edible insects for circular economy and inclusive development'. Visitors to *icipe* included: a delegation led by H. E. Caroline Vicini, Ambassador and Head of Mission, Embassy of Sweden, Kenya; accompanied by Dr Katrin Aidnell, Regional Environment and Climate Change Specialist, Sida, to launch the new scientific equipment funded by Sida. A delegation from the European Commission visited *icipe* to familiarise themselves with initiatives funded by the EU. They included Ms Simona Mari-Sabatini, EC Directorate General for International Cooperation and Development Offices (DEVCO); Mr Peter Koren, Programme Manager, Innovation and Connectivity, EC; Dr Bernard Rey, Immediate Former Head of Cooperation Delegation of the European Union in South Africa; and Ms Anna Hakami, Policy Analyst, EC.

November

icipe took part in the 13th commemoration of the Africa Day for Food and Nutrition Security; the 1st FAO global conference on Sustainable Plant Production, with a plenary keynote address on 'Confronting the global burden of pests and pathogens in a changing climate'; the AU–EU Innovation Agenda Stakeholder Event; the 1st general assembly of TSARA; the first meeting of the implementation committee of A14D Africa, a project funded by IDRC and Sida; in the inter-regional workshop for the development of a research plan for desert locust; in the 11th International Symposium on Fruit Flies of Economic Importance at Macquarie University in Sydney, Australia.

The DG participated in the ACIAR PAC meeting. She also participated in the TropAg conference as a panelist in the ACIAR and CGIAR plenary session on 'Food security and food systems transformation in the Indo-Pacific – the role for science'. The DG met with Dr David Priest, Chief Executive Officer of Farm Input Promotions Africa Ltd.

December

The DG met Dr Paola Sotelo-Cardona, Scientist-Entomology, World Vegetable Center, Taiwan. *icipe* participated in a consultation workshop of the 'Regional Programme in Livestock and Change Adaptation in Eastern/Horn of Africa' organised by the EU Delegation to Kenya; the Space for Agriculture (Future of Space) at the World Economic Forum; and the FAO Regional Workshop on the Implementation of the Global Action for Fall Armyworm Control in the NENA region.

Resource Mobilisation

Overview

USD 39.6 million: Total value of signed donor agreements for strategic long-term funding and restricted projects.

USD 7.98 million: Total value of contracts for restricted projects approved by donors, pending signatures.

USD 16.1 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); Federal Democratic Republic of Ethiopia; and Government of the Republic of Kenya (Ministry of Education, State Department of University Education and Research).

New donors

Australian Center for international Agricultural Research (ACIAR); Cordaid; Desert Locust Control Organization of Eastern Africa (DLCO-EA); IKEA Foundation; iMC Worldwide; Kenya Education Network; Ministry for Primary Industries, New Zealand; Novo Nordisk Foundation, Denmark, through Impact Designs; One CGIAR Secretariat through CIMMYT and ILRI; Participatory Ecological Land Use Management, Kenya; University of Bern, Switzerland, through GIZ; University of Eastern Finland.

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; and ACP Innovation Fund of the European Union through the Organisation of African, Caribbean and Pacific States (OACPS).

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; Cambridge Africa ALBORADA Research Fund; Chalmers University of Science Technology; Children's Investment Fund Foundation (CIFF); Code for Science & Society (CS&S); Canadian Executive Service Organization, CESO-SACO; 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); 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); JRS Biodiversity Foundation; Keele University, UK; 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; 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); Open Philanthropy; 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 Cambridge, UK; University of Glasgow, Scotland, UK; 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 2022

Partnerships

Project partners

Intensified agroecological-based cropping systems for crucifers and traditional African vegetables	World Vegetable Centre
Long-term farming systems comparisons in Kenya	Kenya Agricultural and Livestock Research Organization (KALRO)
Waste to value: accelerating economic viability of insect-based value chain	Eastern Africa Grain Council
AgriPath – Empowering smallholder farmers' transition to sustainable agriculture through digital pathways	Kilimo Trust, Tanzania
Malaria Vector Atlas	Geospatial Research International, Kenya
Symbiovector Project – *Microsporidia MB* symbiont as a malaria control intervention	Millenium Institute
Accelerating inclusive green growth through agri-based digital innovation in West Africa (AGriDI)	• Actions pour l'Environnement et le Développement Durable • Agrocenta Limited • Africa Green Corporation SA • Laboratoire de Recherche sur l'Innovation pour le Développement Agricole (LRIDA), Université de Parakou • Esoko Limited • Science and Technology Policy Research Institute, Council for Scientific and Industrial Research • Federal University of Agriculture • Sosai Renewable Energies Company • Association 3535 • West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) • Universite D' Abomey Calavi (UAC) • GearBox PanaAfrican Network

Memoranda of understanding (MoUs)

Developing a joint concept note to respond to a call for proposals released by FCDO	Goal Relief and Development Organisation, Uganda
Cooperation in the advancement of a sustainable bioeconomy in East Africa	East African Science and Technology Commission (EASTCO)
Collaboration in scientific research, knowledge exchange, capacity and institutional development	University of KwaZulu-Natal, South Africa; Geneva School of Engineering Architecture and Landscape – HEPIA, USA

Material transfer agreements

To operationalise a payment platform for LiMA mobile application	mHealth Kenya Limited
Designation of the biological material: Evaporated solvent extract of *Glossina palpalis gambiensis* (COMBAT project)	CIRAD
Tick cell lines to isolate cultivate and study arthropod-borne microorganisms	University of Liverpool, UK
Data sharing for volatile pyrethroids against mosquitoes	University of California San Diego, USA
Transfer of biological material, scientific and technical knowledge for commercial exploitation	Russell Bio Solutions Ltd, UK

Contractual agreements under the MOYESH project

Southern Nations, Nationalities and Peoples' Region (SNNPR)	Damascene Essential Oil Processing PLC; and K and T PLC
Oromia Region	Limmu Inara Multipurpose Farmers Cooperative Union; Green Face Trading PLC
Amhara Region	Mulat Sericulture Farm PLC

Rsif – tripartite partner agreements

Implementation of the Rsif PHD scholarships sandwich programme

icipe, Korea Institute of Energy Research and University of Nairobi, Kenya

icipe, University of Pretoria, South Africa, and University of Nairobi, Kenya

icipe, University of Greenwich Natural Resources Institute, UK, and Nelson Mandela African Institution of Science and Technology

icipe, Institute of Green Bio Science and Technology Seoul National University, South Korea, and University of Rwanda

icipe, Seoul National University Global Research and Development Business Center, and University of Ghana

icipe, Institute of Green Bio Science and Technology (GBST) in Seoul National University, South Korea, and University of Ghana

icipe, Seoul National University Global Research and Development Business Center, South Korea, and University of Rwanda

icipe, Institute of Green Bio Science and Technology in Seoul National University, South Korea, and Nelson Mandela African Institution of Science and Technology, Tanzania

icipe, Institute of Green Bio Science and Technology in Seoul National University, South Korea, and Sokoine University, Tanzania

icipe, Ghent University, Belgium, and Nelson Mandela African Institution of Science and Technology, Tanzania

icipe, Mohammed VI Polytechnic University, Morocco, and University of Nairobi, Kenya

icipe, Virginia Polytechnic Institute, USA, and Sokoine University of Agriculture, Tanzania

icipe, Korea Research Institute of Chemical Technology and University of Nairobi, Kenya

icipe, Ghent University, Belgium, and Sokoine University, Tanzania

icipe, Mohammed VI Polytechnic University, Morocco, and Sokoine University of Agriculture, Tanzania

icipe, University of Pretoria, South Africa, and University of Rwanda

icipe, Karlsruhe Institute of Technology, Germany, and University of Nairobi, Kenya

icipe, Virginia Polytechnic Institute and State University, USA, and University of Nairobi, Kenya

icipe, Mohammed VI Polytechnic, Morocco, and Université Gaston Berger of Saint-Louis, Senegal

icipe, Telecom SudParis, Paris, & Université Gaston Berger of Saint-Louis, Senegal

icipe, Seoul National University Global Research and Development Business Center, Gwanak-gu, South Korea, and Université Gaston Berger of Saint-Louis, Senegal

icipe, University of Greenwich, Faculty of Engineering and Science, Natural Resources Institute, UK, and Université Gaston Berger of Saint-Louis, Senegal

icipe, University of Greenwich, Faculty of Engineering and Science, Natural Resources Institute, UK, and Université Félix Houphouët-Boigny, Côte d'Ivoire

icipe, Institut de recherche pour le développement, France, and Université Félix Houphouët-Boigny, Côte d'Ivoire

icipe, Mohammed VI Polytechnic University, Morocco, and Université Félix Houphouët-Boigny, Côte d'Ivoire

icipe, Korea Institute of Science and Technology, and Nelson Mandela African Institution of Science and Technology, Tanzania

icipe, Korea Institute of Energy and Research, and University of Port Harcourt, Nigeria

Communications

467

media mentions

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

1.74 billion people

potential reach

of the *icipe* media coverage.

USD16.06m

advertising value

of the *icipe* media coverage.

10

top countries

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

10

top media

with the highest number of news items mentioning *icipe* were: Multidisciplinary Digital Publishing Institute (MDPI); Science Africa; The Brief; AllAfrica.com; Daily Nation, Kenya; Nature; Farmers Review Africa; Opera News; AllAfrica.com; and Standard Digital News, Kenya.

8,295

social media

mentions of *icipe*:

- Twitter (7,710)
- Facebook (171)
- Blogs (414).

79,344

website visits

and 246,920 page views registered on the *icipe* website. The top countries (ranked in order of visitor numbers) were: Kenya, United States, Ethiopia, China, Germany, United Kingdom, India, Uganda, France, South Africa.

Scientific Publications

In 2022, *icipe* published and produced:

261 peer-reviewed journal articles

211 articles in open access or open access model journals

183 articles in high impact factor journals, including niche journals (impact factor above 2)

103 articles in collaboration with national agricultural research systems

8 conference proceedings

6 book chapters

Some of the top ranked 2022 papers based on online attention:

Kelemu, S. (2022). Achieving workplace equity. *Nature Human Behaviour*, 1–1. https://doi.org/10.1038/s41562-022-01418-3
IF 24.25
ALTMETRIC 14 (16 readers on ResearchGate)
Ranked 49th of the 63 tracked articles of a similar age in the journal. The article is in the top 25 percent of all research outputs scored by Altmetric.

Agha, S. B., Tchouassi, D. P., Turell, M. J., Bastos, A. D. S. & Sang, R. (2022). Risk assessment of urban yellow fever virus transmission in Kenya: is *Aedes aegypti* an efficient vector? *Emerging Microbes & Infections*, 11(1), 1272–1280. https://doi.org/10.1080/22221751.2022.2063762
IF 19.568 (1,718 accesses)
ALTMETRIC 1 (13 readers on Mendeley, 86 readers on ResearchGate)
The article is in the 11th percentile (1,008th of 1,254 outputs from the journal).

Mokaya H. O., Nkoba K., Ndunda R. M. & Vereecken N. J. (2022). Characterization of honeys produced by sympatric species of Afrotropical stingless bees (Hymenoptera, Meliponini). *Food Chemistry*, 366, 130597. https://doi.org/10.1016/j.foodchem.2021.130597
IF 9.231 (12 citations)
ALTMETRIC (53 readers on Mendeley, 167 readers on ResearchGate).

Ochieng B.O., Anyango J.O., Nduko J.M., Cheseto X., Mudalungu C.M., Khamis F.M., Ghemoh C.J., Egonyu P.J., Subramanian S., Nakimbugwe D., Ssepuuya G., & Tanga C.M. (2022) Dynamics in nutrients, sterols and total flavonoid content during processing of the edible long-horned grasshopper (*Ruspolia differens* Serville) for food. *Food Chemistry* 383. https://doi.org/10.1016/j.foodchem.2022.132397
IF 9.231
ALTMETRIC (22 readers on Mendeley, 135 readers on ResearchGate).

Ramos Aguila, L. C., S.nchez Moreano, J. P., Akutse, K. S., Bamisile, B. S., Liu, J., Haider, F. U., Ashraf, H. J., & Wang, L. (2022). Comprehensive genome-wide identification and expression profiling of ADF gene family in Citrus sinensis, induced by endophytic colonization of *Beauveria bassiana*. *International Journal of Biological Macromolecules*. https://doi.org/10.1016/j.ijbiomac.2022.11.153.
IF 8.025
ALTMETRIC (2 readers on Mendeley, 47 readers on ResearchGate).

Awards and Recognitions

In 2022, *icipe* and several of the Centre's staff received a variety of external and internal awards and recognitions

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

5 awards given internally by *icipe* to staff and partners

9 journal appointments for *icipe* scientists

7 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, was the 2022 International Recipient of the prestigious Ellis Island Medal of Honor; and 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). Enat Bank, Ethiopia, named its 94th branch after Dr Kelemu, in honour of her excellence in the world of science; and she was awarded title of Officier de L'Ordre national du Mérite (Officer in the National Order of Merit), by the President of the French Republic.

Menale Kassie, Head, Social Science and Impact Assessment Unit (SSIAU); and Tadele Tefera, Head, *icipe* Ethiopia Office, were elected as Fellows of the African Academy of Sciences.

Menale Kassie was 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 (SSA).

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

Beatrice Muriithi, Scientist, SSIAU, was 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 *icipe* African Regional Postgraduate Programme in Insect Sciences (ARPPIS) scholar and currently Postodoctoral Fellow, BCEU, was awarded the Wellcome Early Career Award, for a five-year project titled: 'An investigation of drivers of dengue virus transmission and the potential for Wolbachia-based transmission blocking in Kenya', commencing in December 2022.

Gladys Mosomtai, a former *icipe* PhD scholar, joined ESRIN (known as the ESA Centre for Earth Observation) on a research fellowship. She is one of the first two African researchers to join ESRIN's activities. Her research will explore the role of livestock migration patterns in the transmission of Rift Valley fever.

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; 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; World Health Organization-Regional Office for Africa (WHO-AFRO).

A comprehensive list of partners is included in the annexes.

2022 IN BRIEF

New knowledge

Evidence on feasibility of *Microsporidia MB*-based interventions in malaria control; insights on the biological and ecological adaptation of mosquitoes; yellow fever outbreaks risk assessment and prevention actions; efficiency of *Aedes* mosquitoes in urban yellow fever transmission; expanding geographical distribution of leishmaniasis in Kenya; implication of *Sergentomyia* sand flies in the circulation of the Ntepes virus; first record of the Jingmen tick virus in Kenya, and in a reptilian host; and first report of Ngari virus in livestock hosts in Kenya.

Inclusive innovations

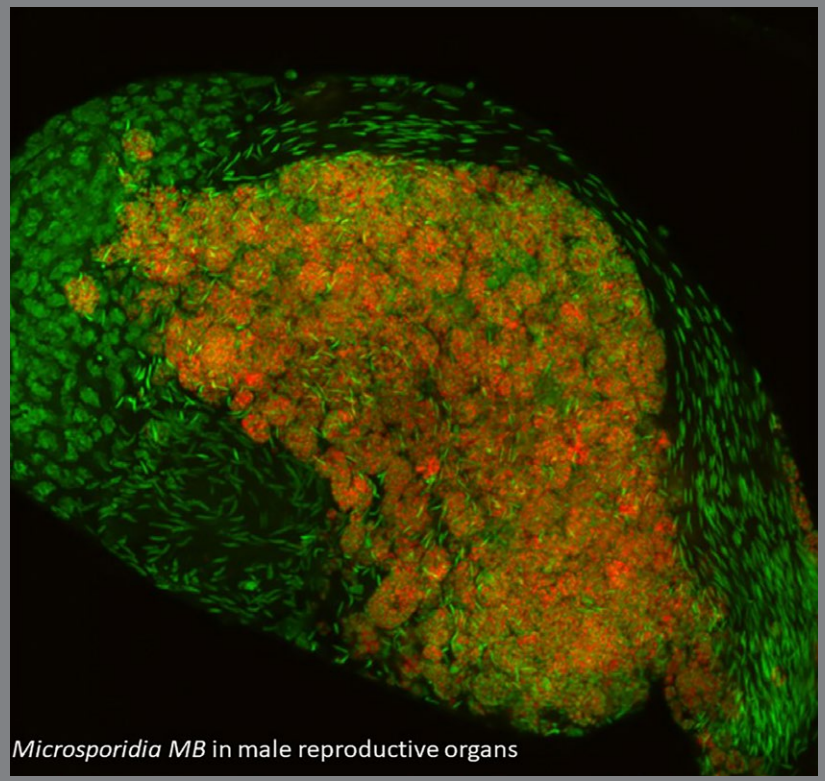
Dissemination strategy and semi-field tests for realeases of mosquitoes containing *Microsporidia MB*; cost-effective PCR-based tool for the identification of *Tunga penetrans* larvae; and simple, affordable thermography technology to detect tungiasis-associated inflammation.

Policy contributions

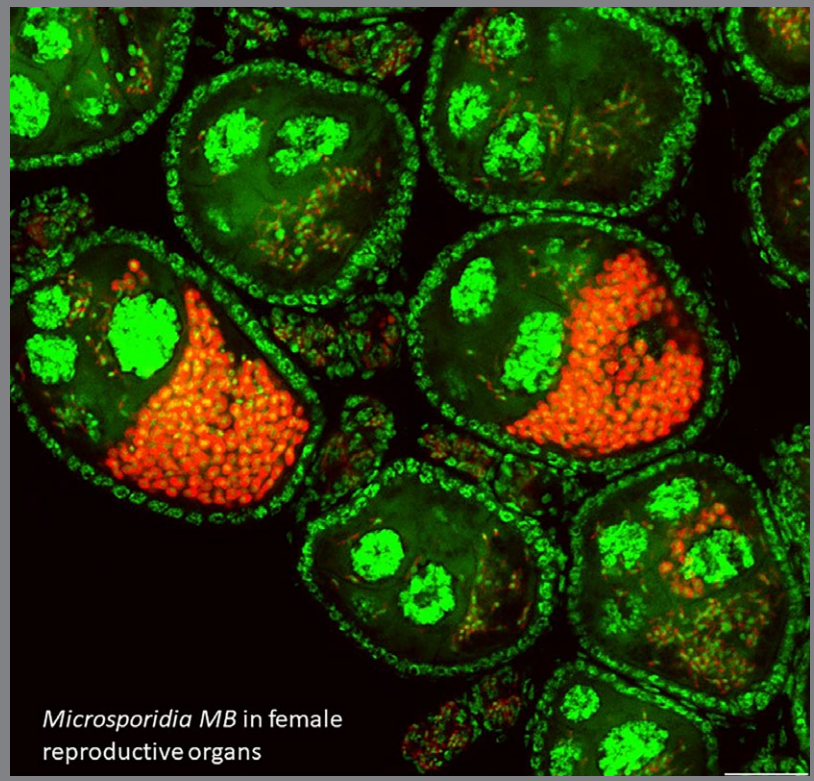
Recommendations for IVM to achieve malaria elimination; knowledge to update the risk map of key malaria vectors in Kenya; evidence for complementary outdoor malaria control interventions; evidence for tungiasis prevention measures and education that target households infrastructure and behaviour; evidence for continuous surveillance of disease vectors, infections in hosts, and zoonotic arthropod-borne viruses, for early detection and intervention measures to prevent disease outbreaks.

One Health

Model for the control of insect disease vectors of people and animals.



Microsporidia MB in male reproductive organs



Microsporidia MB in female reproductive organs

Malaria Research

Focus	Context	Progress in 2022	Way forward
Determine the potential and feasibility of *Microsporidia MB* as a malaria control intervention	**In 2020, *icipe* made the groundbreaking discovery of a microbe in *Anopheles* mosquitoes, which blocks transmission of *Plasmodium*, the malaria parasite, from the insects to people.** The scientists found that the microbe, which they named *Microsporidia MB*, is passed on from female mosquitoes to their offspring at high rates and that it does not kill or cause obvious harm to the mosquito host. Further studies showed that *Microsporidia MB* is also transmitted sexually between mosquitoes. This knowledge paved way to investigate a viable dissemination strategy to increase the spread of *Microsporidia MB* among mosquito populations, leading to a transformative malaria transmission blocking intervention.	We are exploring the key characteristics of the microbe, to obtain evidence on the feasibility of *Microsporidia MB*-based interventions in malaria control. By 2022 we had **determined the diversity of *Microsporidia MB* strains in *Anopheles* mosquito species in Kenya; the characteristics associated with high efficiency of the microbe in blocking the transmission of the malaria parasite; the effect of the genetic background of the host mosquitoes on *Microsporidia MB* infections; and the environmental factors that drive their fluctuations.**	We will investigate the role of *Microsporidia MB* density, localisation and effects on gene regulation and on *Plasmodium* protection. This will enable us to determine the protection profiles of the different *Microsporidia MB* strains.
Develop capacity for research and implementation of *Microsporidia MB*-blocking strategies.		We have developed: a cost-effective and rapid method to detect *Microsporidia MB*; tools to investigate, model and predict the microbe's levels in the field, and to provide foresight for malaria disease incidences. We have also **created a strategy and conducted semi-field test releases of mosquitoes containing the microbe; and undertaken a stakeholder analysis and mapping of the influences of *Microsporidia MB* use for malaria control in Kenya.**	This knowledge has **formed the foundation for *Microsporidia MB* field trials and the design of qualitative research.** In addition to a rapid assessment of perspectives, opportunities and barriers for malaria control in general, and *Microsporidia MB*-based control specifically, we have identified field locations for trials and we are planning stakeholder engagement.

Malaria Research

Human Health Theme

Focus	Context	Progress in 2022	Way forward
Contribute to malaria control and elimination in southern Africa	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).**	Since 2017, *icipe* has supported six southern African countries to implement IVM approaches. The Centre and partners have evaluated the incorporation of winter larviciding using *Bti* and house screening; and the impact of these IVM tactics on the health of communities, socio-economic conditions, gender and the environment.	Based on our research, we recommend: mainstreaming house screening and dry season bio-larviciding into national malaria control strategies; strengthening community and stakeholder participation in IVM programmes; a multi-sectoral approach; strategies for behaviour change; and **operational research to evaluate vector control interventions, for evidence-based decision-making on efficacy, cost-effectiveness and long-term feasibility of alternatives.**
Profiles of outdoor malaria vectors species in dryland ecosystems of Kenya	Following sustained vector control of malaria vectors, there have been changes in the composition of the malaria-transmitting *Anopheles* species and their behaviour, including resting and biting habits. As a result, **outdoor biting by *Anopheles* mosquitoes has gained attention as one of the contributing factors to residual malaria transmission;** the continued spread of malaria in a given area, despite full operational coverage with long-lasting insecticidal nets and indoor residual spray interventions.	A recent *icipe* study focussed on outdoor malaria transmission in dryland ecosystems. **We found previously unknown, and some unidentified cryptic *Anopheline* mosquito species, which were infected with the malaria parasite.** *An. longipalpis* C, belonging to the Funestus mosquito group, was the most important and prevalent malaria vector. Also, **we detected mutations in the gene that confers resistance to pyrethroid and DDT, in *An. funestus* and *An. longipalpis* C. mosquito species;** the first report of the detection of this resistance marker in a species other than *An. funestus* s.s. in the Funestus group.	These findings will be useful in **updating the risk map of key malaria vectors in Kenya,** and in evidence-based decision-making malaria intervention initiatives. The results also underscore the **need for complementary outdoor malaria control interventions; and the need to understand the biological and ecological adaptation** including breeding structure, resting and biting habits; as well as the malaria vector potential of *An. longipalpis* C.

Barrack Owino, PhD scholar, *icipe,* and Johnstone Ingonga, Research Technician, Kenya Medical Research Institute (KEMRI), setting a Lumin-8 trap for sand flies near a termite mound in Nguruman, Kajiado County, Kenya, the focus of a recent leishmaniasis outbreak.

Neglected Tropical Diseases

Focus	Context	Progress in 2022	Way forward
Cost-effective PCR-based tool for the identification of *Tunga penetrans* larvae	Tungiasis, a highly neglected, debilitating skin disease in people and animals, is caused by *Tunga penetrans*, a parasitic sand flea. 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. To understand the ecology of the sand flea, it is important to identify where the off-host development of the fleas occurs, through analysis of soil samples. Thus, there is need for a morphological key to conclusively identify juvenile stages.	***icipe* has developed an efficient and economical polymerase chain reaction (PCR)-based kit to identify *T. penetrans* larvae.** This was no mean feat, as the flea's larvae feed on organic material in the soil, which is known to be rich in PCR inhibitors. We tested six protocol combinations based on three DNA preparation methods and two PCR enzymes to determine the most optimum protocol.	Our tool reduces the costs by more than 80 percent, when compared to conventional approaches. Thus, **the kit is highly relevant for resource-poor settings.** Moreover, the protocols will enable the screening of much higher numbers of samples. Although *T. penetrans* can be detected using other protocols, ours **will enable characterisation of the sensitivity and specificity of the insect's species.** It can also be adapted for other arthropods in PCR-inhibitor-rich matrices, such as soil or faeces.
Novel two-level classification of tungiasis severity, and simple, affordable detection tool	Tungiasis has been added to the WHO list of NTDs (under scabies and other ectoparasites). As governments and organisations start to plan surveillance and intervention programmes, they will require clearly defined indicators and targets. As is the case for other NTDs, a classification of disease severity is needed, to enable prioritisation of individuals with the highest morbidity.	*icipe* and partners have characterised the tungiasis disease burden in two highly affected regions in Kenya. Along with other pathologies, we tested the use of simple thermography to detect tungiasis-associated inflammation. This approach helped to classify mild and severe disease; and to create a new two-level classification of disease severity.	**Our findings show that simple hand-held, infra-red cameras, such as the ones we used in this study, may be employed to map, target and monitor tungiasis interventions.** The survey spanned the COVID-19 pandemic instigated school closures. It demonstrated that when children spent extended periods out of school, the prevalence, intensity and morbidity of tungiasis increased significantly. Therefore, tungiasis prevention measures and awareness should target household level infrastructure and behaviour.

Neglected Tropical Diseases

Focus	Context	Progress in 2022	Way forward
Expanding geographical distribution of leishmaniasis in Kenya	Leishmaniasis is 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, and is the most lethal form; cutaneous, which affects the skin, leading to permanent scarring and disfigurement; and mucocutaneous, which produces lesions that spread to the mucous membranes of the nose, mouth and pharynx causing severe disfigurement and suffering. Eastern Africa is the most active transmission zone of kala-azar globally. Moreover, **the impacts of climate change, and the extensive movement of people and livestock, are shifting the geographical presence of kala-azar.**	In 2022, the Kenya Ministry of Health reported an apparent **outbreak of in Kajiado County in Kenya.** In partnership with the county government, ***icipe* contributed to the training of health workers; community sensitisation and comprehensive population screening for leishmaniasis; medical camps, and the establishment of new treatment facilities. We also conducted entomological surveillance and found competent vectors of both kala-azar and cutaneous leishmaniasis, and vector-parasite associations that confirm active transmission.**	We are taking a more comprehensive approach to understand the epidemiology of kala-azar and cutaneous leishmaniasis, the vectors, environmental and socio-economic drivers of transmission. This knowledge will facilitate predictions of disease hotspots; and guide potential interventions and mitigation of the risk of spread to new areas.

Josephine Osalla, an MSc scholar at *icipe*, identifying *Aedes* mosquitoes; the first step in the Centre's studies on the viruses transmitted by this species.

Emerging and Re-emerging Viruses

Focus	Context	Progress in 2022	Way forward
Response to the yellow fever outbreak in Kenya in 2022	Yellow fever is an acute viral haemorrhagic disease transmitted by infected mosquitoes of the *Aedes* species. Symptoms include fever, headache, muscle pain, nausea, vomiting and fatigue. In severe cases, patients develop jaundice and bleeding. Vaccination remains the single most important measure for preventing yellow fever. However, **knowledge on the ability of mosquito species to transmit the virus is an important component in assessing the risk of yellow fever outbreaks.**	In 2022, the Kenya Ministry of Health reported yellow fever outbreaks in two counties. In response, the government launched a vaccination campaign. ***icipe* participated in the planning of the response activities, and in conducting surveys of mosquito vectors in the response sites.** The goal was to assess disease ecology and establish the potential vectors that may have been involved in the transmission of the disease. This knowledge will guide risk assessment and prevention actions.	*icipe* continues to **expand the Centre's longstanding research on yellow fever which aims to: determine existence and locality of transmission in focal points** in Kenya and at the border with endemic countries; assess the presence of mosquito vector species and their potential to transmit the disease; evaluate the risk of yellow fever and dengue fever transmission.
Efficiency of *Aedes aegypti* in urban yellow fever virus transmission	Yellow fever has re-emerged in the past decade as a major public health challenges. In SSA about seven genotypes of the yellow fever virus are in circulation. Yellow fever has three transmission cycles: urban, intermediate/rural, and sylvatic/jungle. Urban yellow epidemics, mediated by *Aedes aegypti* mosquitoes, are dreaded due to their potential to spread rapidly. **The absence of urban yellow fever epidemics in East Africa is a mystery, considering the abundance of *Ae. aegypti* mosquitoes.**	We investigated the ability of *Ae. aegypti* mosquitoes in three major cities in Kenya, to transmit the yellow fever virus. **We found that urban *Ae. aegypti* populations in Kenya are unable to disseminate or transmit one of the yellow fever virus genotypes circulating in East Africa,** perhaps due to tissue barriers or innate immune responses, which have previously been reported to limit virus transmission within arbovirus vectors. But, ***Ae. bromeliae* mosquitoes, although currently found in low abundance in urban areas, can transmit the yellow fever virus genotype circulating in Kenya.**	We recommend: an assessment of the susceptibility of urban *Ae. aegypti* to other yellow fever virus genotypes circulating in East Africa and beyond; and additional studies to determine the abundance and host-blood meal preference of *Ae. bromeliae* in urban areas in Kenya.

Emerging and Re-emerging Viruses

Human Health Theme

Focus	Context	Progress in 2022	Way forward
Sand fly blood-feeding habits and ability to transmit Ntepes virus	In Kenya, novel sand fly-borne viruses (phleboviruses), have been reported recently. Among them is **a previously unknown phlebovirus detected by *icipe* in Kenya, which we designated Ntepes virus,** after its place of detection. Sand flies in the genus *Phlebotomus* have primarily been associated with the transmission of sand fly fever viruses.	*icipe* has conducted a study to determine the ability of *Phlebotomus duboscqi* (a sandfly that is common in the Ntepes virus isolation focus), to transmit Ntepes virus. Our findings show that *P. duboscqi* is an inefficient vector of the Ntepe virus. However, we found a high level of sand fly feeding on people in the area where the Ntepe virus was originally identified. This was especially by the ***Sergentomyia* species, thus, implicating these sand flies in the circulation of the Ntepes virus.**	Although the *Sergentomyia* sand fly species are known to feed on people, they have not been implicated in the transmission of pathogens. **Further studies on the species belonging to this genus will examine their roles in the circulation of the Ntepe virus and other novel phleboviruses.**
Circulation of Ngari virus in Kenya	Ngari virus is a virulent, mosquito-borne pathogen that causes severe febrile illness and hemorrhagic fever in people and small ruminants. The virus circulates concurrently with the Rift Valley fever virus during outbreaks, leading to clinical misdiagnoses, especially due to disease similarities. **Knowledge is needed on how the virus is maintained during inter-epidemic periods, and its geographic distribution and health impact.**	Ngari virus has been isolated from diverse tick and mosquito species including the mosquito species, *Anopheles funestus*; *Aedes mcintoshi*; and tick species *Amblyomma gemma* and *Rhipicephalus pulchellus*. In recent studies, we made the first report on the isolation, detection, and characterisation of the virus in livestock hosts in Kenya. **We established active circulation of Ngari virus in apparently healthy cattle, sheep, and goats in Kenya in two pastoralist-dominated areas in Kenya.**	It is important to investigate the potential health impact of Ngari fever on people and livestock. Our research also makes **a strong case for the continuous surveillance of disease vectors, infections in hosts, and zoonotic arthropod-borne viruses,** as a prerequisite for early detection and intervention measures to prevent outbreaks.

One Health

Focus	Context	Progress in 2022	Way forward
One Health model for the control of insect disease vectors of people and animals	In two sites: Kwale County along the Kenyan coast; and Busia County, western Kenya; *icipe* is 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, including the development of an environmentally friendly biopesticide for a range of vectors. Cattle will be used as decoys and treated with a biopesticide, thus protecting the animals as well as people.	We tested the effect of the commercially available Mazao TickOff® biopesticide, developed by *icipe* from a strain of *Metarhizium anisopliae* fungus, on ticks and mosquitoes, when applied on cattle; and an insect growth regulator, pyriproxyfen. By combining lessons from *icipe* disease vector control initiatives, as well as community participation, we conceptualised and built two healthy home demonstration sites. The structures feature simple improvements using locally available materials to prevent people and animal diseases. Community-owned resource persons, supported by community gatekeepers are leading disease vector surveillance.	We are using a **community participatory approach to raise awareness and formulate the most optimum application strategies for the biopesticide**, and to improve its effectiveness. Pyriproxyfen has high potential in the control of vectors around cattle, and around homes. Thus, we are testing the use of pyriproxyfen treated fabric around house entry points; and its commercialisation. **The healthy home concept, has been received by stakeholders with great enthusiasm and it lays the foundation for similar interventions.**

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; Wellcome Trust, UK; 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.

2022 IN BRIEF

New knowledge

Identification of ionones in the urine of cows, which are predictive biomarkers of African animal trypanosomosis; knowledge on drivers of ticks-camel interactions, and tick borne pathogens in camel; algorithm that combines a species distribution model with satellite-derived data, to identify tsetse fly breeding and foraging sites; and livestock microbiota, vector interactions and greenhouse gases emissions sinking.

Inclusive innovations

Steps to develop non-invasive, rapid, affordable, efficient and easy to use tool to diagnose African animal trypanosomosis; safe, botanical, anti-tick nostril ointment for camel; novel tick (and biting flies) biopesticide formulation.

Participatory rolling out of integrated eco-friendly tsetse control technologies in Borana zone, Ethiopia.

Policy contributions

Evidence for the design and deployment of cost-effective, large-scale tsetse control tools; model to update the maps of tsetse and animal trypanosomosis in eastern Africa; publication of first protocol in Africa, which will serve as a reference point for bioacaricide registration.

One Health

Sustainable livestock keeping improves food security, household incomes and nutrition, while addressing the challenges of climate change and environmental protection.

The head of *Hippobosca camelina*
Commonly known as camel ked or camel fly, the insect is a vector of several pathogens including African trypanosomes and Anaplasma bacteria in livestock. *icipe* is aiming to develop lures for the fly. However, our efforts to trap this highly abundant fly using camel odours have been unsuccessful. Based on our preliminary studies, we believe that this is because of the fly's reduced olfactory system including the diversity of the sensilla and the fact that the entire antenna is placed inside pits, which limit its exposure to ecological signals such as host odours. And yet, the fly can locate its blood meal, mate partners and birthing places. Thus, in collaboration with Max Planck Institute for Chemical ecology, Jena, Germany (where this image was captured), we are studying the fly's brain organisation, as well as the morphological and cellular architecture of its olfactory system, to obtain insights about its interactions with camel and the ecology in general.

Tsetse Fly Management

Focus	Context	Progress in 2022	Way forward
Developing a non-invasive, rapid, affordable, efficient and easy to use tool to diagnose African animal trypanosomosis	Every year in Africa, three million cattle succumb to African animal trypanosomosis, a debilitating disease of livestock that is caused by trypanosome parasites, which are mainly transmitted by tsetse flies, and mechanically by other biting flies. African animal trypanosomosis is difficult to diagnose. The main diagnostic strategies, which include microscopic examinations and PCR tests, are technical, costly and often inaccessible to livestock keepers. Microscopy is also not sensitive enough to detect asymptomatic trypanosomosis cases. Often, livestock keepers make speculative, symptom-based diagnosis of African animal trypanosomosis. Thus, a high proportion of the infections are either undetected or misdiagnosed. **Lack of treatment or wrong therapies lead to livestock deaths, and in the latter case, drug resistance.**	*icipe* has identified compounds known as ionones in the urine of cows, whose production is specifically stimulated by trypanosome infections. **Therefore, these compounds are predictive biomarkers of African animal trypanosomosis.** This knowledge has enabled us to **develop a much needed non-invasive, rapid, affordable, efficient and easy method to diagnose African animal trypanosomosis.** Thus, through a simple urine test, which can be administered even by livestock keepers, it is possible to confirm whether an animal has the disease. The tool: indicates with certainty the presence of trypanosomes infection, even at low levels that would not be detectable through microscopy; detects a wide spectrum of trypanosomes infections, and trypanosome species; identifies active forms of the disease; can monitor the effectiveness of therapeutic interventions; and it is specific to trypanosome infections, as it is negative on animals suffering from other ailments with symptoms similar to African animal trypanosomosis.	We are exploring ways and partnerships to **translate the biomarker-based diagnosis into a ready-to-use, inclusive innovation.** For example, the reagent and activator can be packaged into a dipstick that can be easily applied to a urine sample. This would empower livestock keepers to make evidence-based decision on the health of their animals. In addition, **we are augmenting the *icipe* biomarkers bank with knowledge on other livestock diseases that occur concurrently with trypanosomes.**

Tsetse Fly Management

Focus	Context	Progress in 2022	Way forward
Updating tsetse and animal trypanosomosis risk maps in East Africa	The sustainability of the available tsetse control tools, such as odour-baited traps and insecticide-treated targets, is hindered by the high costs of large-scale implementation. Thus, **reliable information on tsetse distribution, particularly their breeding localities, is needed to guide strategic control initiatives.**	We have developed an **algorithm that combines a species distribution model with satellite-derived data, to identify tsetse fly breeding and foraging sites.** Through studies conducted in Shimba Hills National Reserve, Kenya, between 2017 and 2019, we used the model to predict high-risk, tsetse-infested areas. Additionally, we identified pockets of potential breeding areas outside the reserve.	This knowledge will guide the design and deployment of cost-effective, large-scale tsetse control tools. Moreover, **we aim to expand the model across East Africa, to update the maps of tsetse and animal trypanosomosis in the region.**
Paticipatory tsetse fly and trypanosomosis management in Borana zone, Ethiopia	The *icipe* tsetse fly control tools, which include the tsetse repellent collar and odour-baited traps, have been successful in various sites across Africa. A key factor is the **strong partnership between the Centre and communities.** This strategy enables participatory implementation of the activities, for example the setting up and monitoring of tsetse fly traps, and electronic transmission of data.	In collaboration with local partners, pastoralist and agro-pastoralist communities, ***icipe* has demonstrated and rolled out integrated eco-friendly tsetse control technologies in Borana zone, Ethiopia.** Our activities include knowledge and skills strengthening of smallholder farmers, trainers of trainers, community-owned resource persons (CORPs) and national agricultural research officers. As a result, close to 1,180 community members including pastoralist and agro-pastoralist community members; CORPs; extension workers; and micro-enterprises have been trained on the use of biorational technologies.	We aim to consolidate the gains achieved thus far. In partnership, with the local government we will expand activities into areas that have high tsetse fly infestation.

Ticks Management

Focus	Context	Progress in 2022	Way forward
Understanding drivers of tick-camel interactions	Ticks – small, blood-sucking arachnids — are external parasites that are among the most important disease vectors of livestock including goat, cattle, sheep and camel, with the latter being the most preferred host.	*icipe* has **conducted studies to determine the diversity and prevalence of tick-borne diseases circulating among livestock** in selected regions, as well as the specific tick species transmitting them. So far, we have documented 11 hard tick species from three genera: *Hyalomma*, *Rhipicephalus* and *Amblyomma;* collected from camels, goats, cattle and sheep in northern Kenya. The most prevalent tick species infesting camel were *Hyalomma rufipes,* followed by *Hyalomma impeltatum.*	We intend to **determine the diversity and prevalence of tick borne diseases** circulating in the tick species that we have collected, to document their significance as vectors.
Tick borne pathogens in camel	*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, will develop new knowledge, detection tools and surveillance systems to improve preparedness for vector-borne diseases transmitted by mosquitoes, ticks and freshwater snails to livestock and people.	We have **made the first molecular detection of *Rickettsia africae,* the causative agent of African tick-bite fever, in the saliva and haemolymph of *Amblyomma gemma* ticks; and the first detection of the pathogen in *Rhipicephalus pulchellus* ticks.** We have also identified *Candidatus Anaplasma camelii*, *R. africae*, and *R. aeschlimannii* bacteria in various tick tissues, which indicates the ability of the pathogens to migrate from the midgut of their hosts to the saliva.	This knowledge **contributes to understanding the mechanisms of pathogen transmission and tick vectors competence.** Our findings also suggest that ***Coxiella* spp. bacteria endosymbionts play an important role in blocking the transmission of *Rickettsia* spp.** Ongoing studies will compare the microbiomes in tick tissues (saliva, haemolymph, salivary glands, and midgut), to disentangle infection status from likely vector competence.

Ticks Management

Focus	Context	Progress in 2022	Way forward
Developing safe, anti-tick nostril ointment for camel	Based on the increasing prevalence and incidence of tick-borne diseases in camel, it is vital to develop control tools. Interestingly, ***icipe* studies have shown that the camel's nostril is the tick's most preferred site for feeding and mating.** However, because the nose has very sensitive tissue, it cannot be treated with synthetic acaricides. In any case, ticks are known to be resistant to most chemical acaricides.	We tested extracts of *Tagetes minuta* (stinking Roger; khaki-weed), a locally available plant, whose essential oils are known to have acaricidal and repellent properties against ticks. Laboratory studies showed that spiking the crude extracts from the plant with selected safe organic components from the same plant increases the efficacy against ticks to 100 percent. **Furthermore, field tests of the ointment on camel nostrils reduced the tick load by 80 percent.**	We continue studies on the ointment as a safe botanical based acaricide; to improve its formulation to make it stronger and to last longer. **We are also conducting research to explore the possibility of formulating a tick attractant using odours from the body and breath of camels.**
Progress in the deployment of *icipe* novel tick biopesticide	Ticks parasitise a wide range of animals. They also transmit more pathogenic agents than any other arthropods. The use of chemical acaricides remains the primary approach to the management of tick-borne diseases. However, ticks have developed resistance to most such products. In collaboration with Real IPM Biobest, *icipe* has developed a fungus-based bioacaricide (Mazao Tickoff®) as an alternative to chemical acaricides.	Mazao Tickoff® is specific to insects and it has no safety risk to people, animals and the environment. However, a stringent evaluation and conclusive evidence of the effectiveness of the acaricide are critical for its registration and scaling-up. **For the first time in Africa, *icipe* and partners developed and published a randomised efficacy protocol for the testing and use of bioacaricides.** We have used it to conduct a large-scale efficacy trial of the biopesticide along the Kenyan coast.	The protocol is a reference point for bioacaricide registration in Kenya. Molecular analysis of samples obtained from livestock in the trial sites are ongoing, to understand the impact of the bioacaricide on tick-borne diseases incidence. **We have observed additional benefits of the bioacaricide against flies and other vectors of One Health significance. This means that the product can be used in intensive livestock systems.**

Livestock Microbiota

Focus	Context	Progress in 2022	Way forward
Livestock microbiota, vector interactions and greenhouse gases emissions	Livestock possess a unique digestive system, with a complex microbiota community that facilitates production of various odours that are significant in host-vector interaction.	We are investigating the drivers of the variations, such as microbes, diet or genetics, that manipulate the rumen environment to make livestock less susceptible to vectors by interfering with the smell pathways. Our studies show differences in the diversity and chemical composition of rumen odours in cattle, sheep, goat and camel.	Our findings will contribute to understanding vector-host preferences and help in developing mitigation strategies for vector-borne pathogens. Furthermore, **the livestock rumen is the organ of greenhouse gases production.** Thus, we are **applying metabolites and microbes networking to sink significant amounts of greenhouse gases. This will make livestock keeping environmentally sustainable.**

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; French Agricultural Research Centre for International Development (CIRAD); 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 National Research Institute for Sustainable Development (IRD); IKEA Foundation; International Atomic Energy Agency (IAEA); International Development Research Centre (IDRC), Canada; International Fund for Agricultural Development (IFAD); Norwegian Agency for Development Cooperation (Norad); OneCGIAR through CIMMYT and IFPRI; Research Institute of Organic Agriculture (FiBL), Switzerland; Royal Society, UK; United States Agency for International Development (USAID), USA, through the IPM Innovation Lab; United States Department of Agriculture (USDA).

A comprehensive list of partners is included in the annexes.

2022 IN BRIEF

New knowledge

Resilience and adaptability of climate smart push-pull technology; scientific mechanisms through which the push-pull technology conquers the fall armyworm; impact of push-pull technology soil conditioning on rhizosphere microbiome and on maize phytochemistry; immunological responses of fruit flies to parasitoid wasps.

New strains of endophytes that promote maize growth and confer resistance against the fall armyworm; and interactions of fall armyworm natural enemies in a maize-based intercropping system.

Origin of the citrus pest, *Diaphorina citri*, populations in Africa; genetic diversity and distribution of the tomato leafminer, *Phthorimaea absoluta*, and the potato tuber moth, *P. operculella.*

Inclusive innovations

Vegetable integrated push-pull technology; improved availability of intercrops seeds for expansion of the push-pull technology in Ethiopia; commercialisation of fall armyworm biopesticides in Tanzania and Uganda.

Participatory and inclusive upscaling of sustainable fruit fly IPM on Zanzibar island and in Southern Africa; integrated agroecological mango production in Ethiopia; host-marking pheromones as tools for the integrated pest management of fruit flies.

Biopesticides and potential push-pull approach for *P. absoluta*; novel vegetable push-pull cropping system for high value vegetables; biopesticides for the management of the greenhouse whitefly; commercialisation of banana fibre paper for the control of potato cyst nematodes and other pests.

One Health

Reduced crop damage and increased yield enhances household food and nutritional security, and incomes; safe food production benefits people, animals and the environment.

Circular economy

Soil conditioning by the push-pull technology enriches fungal groups that improve soil fertility and plant protection; the banana fibre paper technology is a nature based solution and a model for circular economy solutions.

Push-Pull Integrated Pest Management

Focus	Context	Progress in 2022	Way forward
Resilience and adaptability of climate smart push-pull technology	The push-pull technology was developed by *icipe,* Rothamsted Research, UK, and partners in East Africa over two decades ago, originally targeting stemborer pests. The technology involves intercropping cereal crops with plants, for example legumes of the *Desmodium* genus, which produce defence compounds that repel (push) stemborer moths from the target food crop. In addition, a fodder grass, for instance *Brachiaria*, 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. *Desmodium* also suppresses the parasitic *Striga* weed. The legume produces two sets of compounds: one that stimulates the germination of *Striga* seeds and another that inhibits their growth after germination.	Currently, a climate-smart push-pull incorporates Greenleaf desmodium (*Desmodium intortum*), as an intercrop and *Brachiaria* cv Mulato II as a border crop. Push-pull also improves soil fertility and reduces mycotoxins contamination, a major food safety hazard. In collaboration with Lund University, Sweden, and Cornell University, USA, we conducted studies to understand the resilience of the push-pull technology against climate change. **Our analysis of a long-term dataset (2005 – 2016) shows that the push-pull technology contributes to yield stability, and also buffers yield losses due to challenging climate conditions.**	We are conducting similar research on the performance of the push-pull technology in the control of the invasive fall armyworm.

A vegetable integrated push-pull field, incorporating kale (sukuma wiki), a leafy vegetable that is popular in East Africa due to its affordability and high nutrient content.

With the support of the IKEA Foundation we are harnessing 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. The initiative will also contribute to a resilient, circular, and regenerative food system, and create novel income generation and job creation opportunities especially for women and the youth, in eastern Africa.

Push-Pull Integrated Pest Management

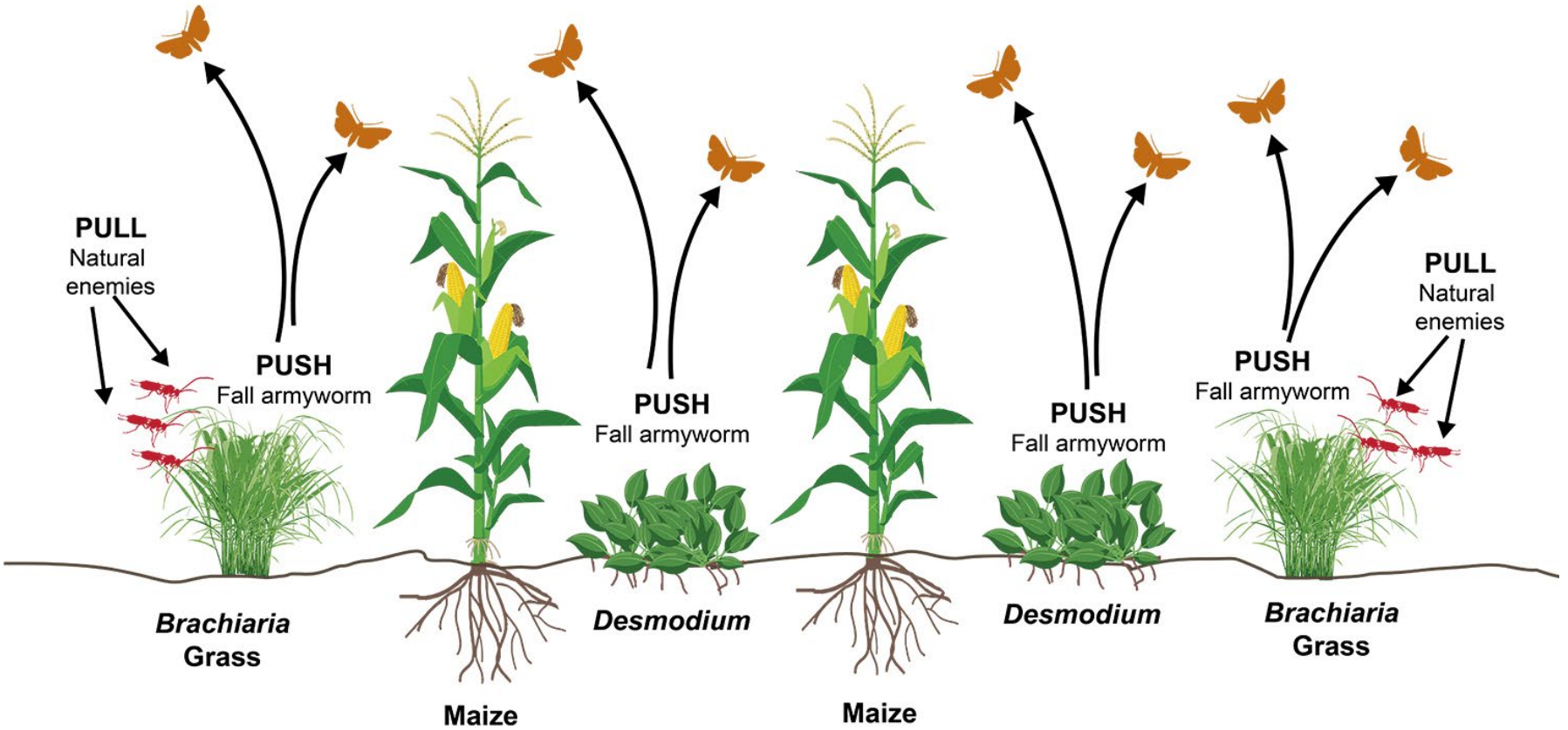
Plant Health Theme

Focus	Context	Progress in 2022	Way forward
Push-pull technology as a model for agroecology	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 by addressing one of the major constraints in its adaptation, which is the inadequate availability of *Desmodium* and *Brachiaria* seeds.**	We have improved seed availability of the push-pull intercrops through community and private sector production. Our strategies also include training, experience sharing and awareness creation. Through a participatory process with farmers, we have established close to 300 push-pull demonstration plots for locally-adapted push-pull seed production. **A functional network of community-based seed producers, as well as market linkages between them and seed companies, has been established.**	We will continue to generate knowledge on the push-pull technology as an agroecological solution. We are conducting participatory documentation of key variables of the technology, for example cereal yield, milk production, soil nutrients, pest occurrence and resilience.
Vegetable integrated push-pull technology	Our previous studies have shown that *Desmodium*, a push-pull intercrop, repels vegetable pests. The legume also attracts the natural enemies of the pests. Thus, we have begun to integrate farmer-preferred vegetables like kale, black nightshade, cabbage, cowpea, tomato and onion, into push-pull systems. The vegetables will supplement household nutrition and provide income during maize off-seasons.	Our research, conducted over three years, shows that the **vegetable integrated push-pull technology controls several vegetable pests and diseases, with substantial yield advantage.** In most cases, the effectiveness of the push-pull technology against pests improves progressively over the years. In all cases, the vegetable integrated push-pull technology **has higher total yield and the least proportion of produce that is unfit for consumption due to damage or infections.**	Ongoing trials include on the evaluation of the **role of the vegetable integrated push-pull technology on soil health, focussing on the microbiota and its potential ecosystem services or disservices.** This knowledge will help us to optimise the system for improved resilience system. The minimal damage of vegetables means lower yield losses; provides food safety and nutritional security; generates more appealing products for consumers, and thus, better marketability.

Fall Armyworm Management

Focus	Context	Progress in 2022	Way forward
Establishing the scientific mechanisms through which the push-pull technology conquers the fall armyworm	In 2017, the push-pull technology, became the first documented, readily available technology that could efficiently manage the fall armyworm in an environmentally friendly and cost-effective manner. Push-pull's capacity to control the fall armyworm was originally based on observations by farmers. These reports were confirmed through field evaluations and socio-economic assessments by *icipe* researchers, which showed fall armyworm infestation to be 80 percent lower in plots where the push-pull technology was being used, compared to monocropped maize plots.	Studies by *icipe* and Keele University, UK, show that, just like in stemborer control, *Desmodium* acts as a push plant against the fall armyworm. The legume releases chemical scents that ward off the pest's moths, preventing them from laying eggs on the cereal crop. However, **in contrast to stemborer control where the border crop, *Brachiaria*, serves as a 'pull', in the case of the fall armyworm the plant functions as a 'push' that repels the pests. Both *Desmodium* and *Brachiaria* emit chemicals that attract (pull) natural enemies of the fall armyworm.**	This knowledge will **enable *icipe* and partners to continue to implement a pest management package for the fall armyworm,** integrating: the push–pull technology; natural enemies; biopesticides; and cereal varieties that are resistant to the pest, which have been identified in previous *icipe* research. Moreover, the findings advance global knowledge on exploiting insect behaviour and stimulation and deterrent approaches in pest control.
Impact of the push-pull technology on soil microbiome and plant-soil feedbacks	We are conducting studies to understand how various factors within the push-pull technology condition soil, and the impact on rhizosphere microbiome and maize phytochemistry.	We found that **soil conditioning by the push-pull technology enriches the Ascomycota fungal groups including the order *Xylariales,*** which are linked to the decomposition of organic matter, thus improving soil fertility as well as plant protection through the production of insecticidal compounds. **Innoculating sterile soil with soil from push-pull fields enhances the diversity of volatile organic compounds emitted by maize plants.**	We continue studies on the effect of the push-pull technology on soil legacies and maize phytochemistry, and subsequent resistance to the fall armyworm by reducing larval feeding and attracting parasitoids. Further, **we are assessing maize root microbial communities in soil conditioned by push-pull technology.**

Push-pull mechanisms in controlling the fall armyworm



Fall Armyworm Management

Focus	Context	Progress in 2022	Way forward
Develop and commercialise biopesticides for the management of the fall armyworm	In 2020, *icipe* and partners in partnership embarked on a journey towards the use of biopesticides in the control of the fall armyworm. In partnership with Real IPM Biobest, we found that two isolates of the insect-infecting *Metarhizium anisopliae* fungi: ICIPE 78 and ICIPE 7, which had been commercialised as Mazao Achieve® and Mazao Tickoff® respectively, are effective against the fall armyworm, and they work in synergy with the pest's natural enemies. In 2021, we obtained approvals for the label extension of Achieve OD® in Kenya.	**In 2022, we received the final approval for the label extension and registration permits of Mazao Achieve®) (ICIPE 78); and Mazao Detain® (ICIPE 7), in Tanzania and Uganda.** We have also established that a corn oil-based formulation of *M. anisopliae* (ICIPE 41), significantly supresses the fall armyworm with no negative effects on the pest's parasitoids. A combination of Mazao Achieve®, Mazao Detain® and *M. anisopliae* ICIPE 41, and the fall armyworm indigenous parasitoids (*Cotesia icipe*, *Telenomus remus* and *Trichogramma chilonis*), provides better management of the pest.	**We are developing the next generation of fall armyworm biopesticides from endophytic fungi,** a fascinating group that lives within plant tissues in a mutually beneficial relationship, without causing disease in their host plants. We established that strains of *Trichoderma atroviride* (F5S21); *T. asperellum* (M2RT4); *T. harzianum* (F2R41); *T. harzianum* (F2L41); *Hypocrea lixii* (F3ST1); and *Fusarium proliferatum* (F2S51) are effective endophytes that promote the growth of maize seedlings and confer systemic resistance against the fall armyworm.
Interactions of the natural enemies of the fall armyworm within a maize-based intercropping system	Though the fall armyworm is an alien invasive pest, *icipe* has identified its native parasitoids in Africa, namely: *Telenomus remus*, *Trichogramma chilonis* and *Cotesia icipe*. In 2020, *we* embarked on the mass releases of the parasitoids across Africa.	Our studies on the fall armyworm-plant-natural enemy interactions show that the pest lays significantly more eggs on maize compared to other plants; and it deposits fewer eggs on maize when the crop is combined with beans, groundnut, sweet potato and *Desmodium*. **Compounds emitted by neighbouring plants reduce and disrupt the attraction of the fall armyworm to compounds released by maize plants.**	**We continue to mass produce and release the fall armyworm natural enemies across Africa. We are also improving the design of maize-based intercropping systems.**

Fruit Pests IPM

Focus	Context	Progress in 2022	Way forward
Reduce fruit fly populations in Zanzibar to an economically viable threshold	*icipe* commenced fruit fly control activities in Zanzibar in 2018. We identified the invasive fruit fly *Bactrocera dorsalis,* as the major species attacking mango, alongside several other fruit fly species in Zanzibar.	We have provided farmers with several components of the *icipe* fruit fly integrated pest management (IPM) package, including lures and traps and approaches for orchard sanitation; and involved them in field trials on fruit fly baits and biopesticides. **Our entomological surveys in five districts in Unguja, Zanzibar, show over 80 percent reduction in fruit fly populations, between 2018 and 2022, based on trap catches.**	This progress presents a **case for upscaling fruit fly IPM technologies in Zanzibar, through a multi-stakeholder approach** that will ensure their sustainability.
Use of fruit fly host-marking pheromones	In previous studies, *icipe* generated knowledge on the host-marking pheromones that enable certain fruit fly species to deposit a chemical (pheromone) to indicate fruits on which they have already laid eggs, thereby preventing repeated egg-laying on the same fruit. Knowledge on the specific chemicals, commonly known as a host-marking pheromones, is useful in the control of species that exhibit such a phenomenon. For instance, if a product containing such host-marking pheromone(s) is sprayed onto fruits, it could deter and prevent some fruit flies from laying eggs on them.	We identified glutathione and glutamic acid as the host-marking pheromones of *Ceratitis cosyra* and *Ceratitis rosa* (respectively) fruit fly species, which are both indigenous in Africa. We have advanced studies on the effectiveness of the two sets of host-marking pheromones in reducing fruit fly population infestations in mango orchards. Our results indicate that spraying mango trees with synthetic forms of the host-marking pheromones significantly reduced the infestation of *Ceratitis* fruit fly species within 14 days after the first treatment. Repeated applications of the host-marking pheromones decreases *C. cosyra* and *C. rosa* infestation in mango by eight- and six-fold, respectively.	This knowledge **confirms the potential of the host-marking pheromones as promising biorational tools for the management of *C. cosyra* and *C. rosa*.** Further studies are needed towards the **cost-effective development of the host-marking pheromones as a readily available tool for farmers.** Additional research will uncover the underlying mechanisms by which both the native, as well as the invasive *B. dorsalis* fruit fly species respond to host-marking pheromones; as well as the competitive advantage of invasive species over native fruit fly species.

Fruit Pests IPM

Focus	Context	Progress in 2022	Way forward
Integrated agroecological mango production in Ethiopia	In Ethiopia, mango production is constrained by several challenges, mainly pests including the white mango scale, *Aulacaspis tubercularis* and fruit flies; as well as diseases such as anthracnose and powdery mildew. Mango growers also lack access to improved varieties, good agronomic practices, harvesting, postharvest and market linkages. To address these issues comprehensively, *icipe* and partners have embarked on integrated agroecological approach to mango production in Ethiopia.	We have introduced **top working (pruning and grafting), to replace the indigenous mango trees. The hybrid varieties will grow faster, be easier to manage and enable effective implementation of pest control strategies.** They will also have better yield and superior quality that incorporates selected traits of both varieties. **We are deploying several *icipe* IPM packages**; supporting soil fertility enhancement and irrigation; creating awareness on proper harvesting and postharvest practices; boosting market linkages; assisting growers to cultivate early income generating crops that are compatible with the mango farming system; and integrating beekeeping as a complementary activity.	**Our goal is to support youth and women enterprises in the mango value chain.** We are partnering with lead farmers and also using success stories, to motivate others to adopt the technologies.
Immune responses of fruit flies and their natural enemies	The invasive *B. dorsalis*, and the indigenous *C. cosyra*, are the major fruit fly species across Africa. Their biological control using parasitic wasps has been widely adopted, albeit with varying levels of success.	*icipe* has conducted studies on the cellular immune responses of *B. dorsalis* and *C. cosyra* to the indigenous *Psyttalia cosyrae* and the introduced *Diachasmimorpha longicaudata* parasitoids. *B. dorsalis* has a high number of circulating blood cells, which elevate its immune defense. However, ***D. longicaudata* is able to suppress and evade the defense mechanisms of both *B. dorsalis* and *C. cosyra*.**	These results explain the high parasitism rates on fruit flies by *D. longicaudat*a, making it a formidable control agent for tephritid fruit fly pests in Africa.

Fruit Pests IPM

Focus	Context	Progress in 2022	Way forward
Tackling fruit flies in Southern Africa	Since 2019, *icipe* and partners have implemented an initiative to adapt, promote and enable wide-scale adoption of the Centre's holistic and scientifically proven IPM packages to tackle alien invasive fruit flies in Southern Africa (Malawi, Mozambique, Zambia and Zimbabwe). **The initiative has three pillars: food security, nutrition, and income-generating opportunities for mango farmers, with a special focus on women and youths along the mango value chain.**	Insect rearing facilities in the four countries have been upgraded and rearing of fruit flies is ongoing. We are strengthening the capacity of partners to mass-produce the parasitoids in their laboratories. In addition, we have provided green energy, solar fruit drying baskets, to women and youth in Zambia and Zimbabwe, to dry mango for household consumption and for sale. This approach has proven to be an important resilience response as it boosts incomes and nutrition among vulnerable women and children.	Through the project **we have built up support and interest of traditional, political leaders and government institutions and public policy agencies. This has created momentum for the return of mangoes from the region to the export markets,** and it will also help in the sustainability of the initiative.
Origin of *Diaphorina citri* populations in Africa	The invasive citrus pest *Diaphorina citri,* which transmits the destructive Huanglongbing or citrus greening disease, was reported in eastern Africa about seven years ago. In previous studies, *icipe* and partners discovered a link between the pest populations in Kenya and Tanzania; and those in China.	*icipe* has analysed the genetic diversity and the historical processes that may be responsible for the past to present geographic distributions of the lineages of the *D. citri*. We discovered two distinct population structures pointing to two separate invasion events into Africa. Furthermore, the *D. citri* population in Kenya and Tanzania were most likely introduced from southeastern Asia and the pest's population in Ethiopia was most likely introduced from the Americas.	**Our findings are of phytosanitary and quarantine regulatory importance for the management of Huanglongbing and African citrus greening disease spread in the continent.** The determination of the origin of *D. citri* populations in Africa, and population structure and diversity across a wider geographic range on the continent will strengthen the argument for stricter quarantine and regulatory policies.

James Wahome, an *icipe* Research Assistant, conducting a training on the invasive *Bactrocera dorsalis* fruit flies, during a farmers field day in eastern Kenya.

Vegetable IPM

Focus	Context	Progress in 2022	Way forward
Push-pull strategy for vegetable pests	*icipe* and partners have commenced a project to address the production constraints in traditional African vegetables and crucifers (kales and cabbage). To be implemented in Kenya and Tanzania, the initiative 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. Partnerships, linkages and capacity will be strengthened among vegetable value chain stakeholders.	We have made **progress in developing a novel agroecological-based vegetable push-pull (food-food) cropping system for high value vegetables focusing on crucifers.** As a starting point, we have assessed the response of the cabbage aphid, *Brevicoryne brassica*, and its parasitoid, *Aphidius colimani,* to odours from potential candidate plants. We have found that rosemary (*Salvia rosmarinus*); molasses (*Mellinis minutiflora*); mint (*Mentha* sp.) and *Desmodium* (*Desmodium intortum*); have repellent properties against the cabbage aphid. Coriander (*Coriandrum sativum*) and mint strongly attract the parasitoid.	We are conducting further evaluations of the companion plants that we screened to test their effect on aphids and other pests under field settings.
Biopesticides for the management of the greenhouse whitefly	Whiteflies (*Trialeurodes vaporariorum)*, are soft-bodied, winged insects that are so tiny that they are usually camouflaged on plants, forming clusters on the undersides of leaves. They feed on plant phloem by injecting enzymes and removing the sap, thus reducing the vigour and at times killing their host plant. The feeding and the pest's honeydew excreta affects crop yield and product aesthetic. The whiteflies also transmit disease-causing viruses in plants.	Previous studies by *icipe* identified three isolates of the entomopathogenic fungus *M. anisopliae:* ICIPE 18, 62 and 69 that are virulent against the greenhouse whitefly. Our tests show that *M. anisopliae* (ICIPE 69), is compatible with a known commercially available whitefly attractant, (E)-2-hexenal. We have also identified *H. lixii* (F3ST1) and *T. asperellum* (M2RT4) fungal endophytes that are effective against whiteflies on various crops.	Our findings demonstrate that spatially separated fungus–volatile compatibility provides a basis to optimise the volatile formulation to **achieve better *T. vaporariorum* suppression with an excellent autodissemination efficiency when used in the management of whiteflies** under screenhouse conditions.

Research on Nematodes

Focus	Context	Progress in 2022	Way forward
Developing revolutionary 'defence' technology against PCN and other nematode pests	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 against damage by PCN and other nematode pests. The technology involves enclosing potato seed at planting in the banana fibre paper to protect it.	Through a project known as Deployment of a Novel Biodegradable Carrier for Efficient Crop Protection (DEFENCE), the partners are **translating the banana fibre paper technology into a commercially viable product that is easy-to-use and accessible to farmers across the region.** We will: prepare a business plan towards local production and distribution of the technology; generate field data to verify proof of concept across geographical, climatic and agroecological scenarios; and identify additional crops, pests, diseases and control products, that could be used with the paper.	Our results so far show that the **banana fibre paper improves the impact of biologically-based crop protection products. Preliminary results of its use against sweet potato pests are impressive and encouraging.** The technology lends itself to nature-based solutions for climate-smart agricultural technology, and it is also a model for circular economy innovations.
Ensuring safety of banana paper technology on soil health	Our studies show that the banana fibre paper technology can improve the delivery and effectiveness of nematicides. However, we aim to **establish, with absolute certainty that the banana paper, if impregnated with nematicides, is safe to soil health and that it has no negative impact on the microbial environment.**	In partnership with James Hutton Institute, UK, we have commenced a study along three complementary thrusts: morphological identification and assessment of free-living soil nematodes in plots where the technology has been used; evaluations using with microBIOMETER®, a low cost soil test that enables quick soil health assessments; and evaluations using molecular barcoding of the soil microbial environment.	The *icipe*-IITA team are receiving training, in Kenya and in the UK, from James Hutton Institute, on DNA extraction of microbes, and the barcoding of the microbial environment. **This study creates a basis for microbiome soil health assessments.**

A prototype of the banana fibre paper technology being developed for commercialisation by IITA, *icipe* and partners, with the support of BioInnovate Africa Programme, for the control of potato cyst nematodes and other pests. The banana fibre has unique sponge-like properties. Thus, through a process known scientifically as 'hydrogen bonding', the technology soaks and physically binds the critical chemical signals released by potato crops that allow the PCN to hatch, find and infect the plant's roots. These characteristics make the paper dense, rigid and sturdy, such that it remains intact in the soil while also allowing the plant's roots to germinate and thrive. Although the paper is durable, it is also biodegradable, and it eventually decomposes.

Research on Nematodes

Focus	Context	Progress in 2022	Way forward
Supporting nematology capacity building networks and platforms in Africa	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 act as trainers of the annual Basic Crash Course in Nematology (BCCN).	In 2022, the institutions renewed their partnership, with a **five-year agreement (2022 – 2027) that strengthens the role of *icipe* jointly with IITA, as a leading nematology training hub in Africa.** As partners in the Nematology Education in sub-Saharan Africa (NEMEDUSSA), we are raising 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.	Through these networks and activities, *icipe* and IITA are **expanding their sphere of influence on the nematology landscape in Africa and globally.**
Creating awareness and understanding of nematology across the agricultural landscape	In Africa, nematology capacity is limited. In addition to creating a critical mass, together with IITA, we are increasing public awareness and understanding across the agricultural landscape. Our **efforts include enabling farmers, government agencies, private sector partners to integrate knowledge on nematode management in their practices.**	In 2022, we conducted a variety of training and awareness creation. In partnership with Bayer East Africa – training for floriculture sector in Kenya; training of farmers through the Horticultural Association of Kenya (HAK); and together with the International Potato Centre (CIP) and KEPHIS, we trained national plant protection officers from several African countries.	These activities lay the foundation for an upcoming training and development initiative to strengthen capacity in nematology at the governmental levels, in particular on the invasive PCN.

Tomato Leafminer Management

Focus	Context	Progress in 2022	Way forward
Genetic diversity and distribution of *Phthorimaea absoluta,* and *P. operculella*	Since 1910, the taxonomy of the tomato leafminer has been a point of contention. **In 2021, the pest, previously known as *Tuta absoluta*, was renamed *Phthorimaea absoluta* based on the morphological similarities with the *Phthorimaea* nominal taxa.** *P. absoluta* is now one of two invasive members of the *Phthorimaea* genus, the other being *P. operculella* (the potato tuber moth) that are key pests of tomatoes and potatoes, respectively. However, the reverse is also possible: *P. absoluta* can survive on potato, and *P. operculella* on tomato.	To understand the genetic basis for the reclassification of *T. absoluta* to *P. absoluta*, we compared the complete mitochondrial genomes of the related species *P. absoluta* and *P. operculella* and found a similarity of 92 percent across the entire mitogenome. We modelled the global habitat suitability of both pests and identified key production areas where the pests have not been reported. We also found that the ecological habitat of both species overlaps significantly. Therefore, **the environmental suitability of any one of these invasive pests will most likely support the invasion and establishment of the other species.**	Knowledge of the genetic diversity and niche distribution of these species will contribute to the development of effective control measures. Also, **the information presents a strong case for more pest surveillance and stricter phytosanitary restrictions in the countries and regions where the pests have not been reported.**
Biopesticides for P. absoluta	The invasive and highly destructive *P. absoluta*, the tomato leafminer, was detected for first time in Africa in 2008 and it has since spread rapidly across the continent. Between 2018 and 2022, *icipe* and partners assembled, validated and implemented an eco-friendly management toolbox for *P. absoluta*.	*icipe* has published the first report of the field efficacy and economic viability of Mazao Campaign®, an *icipe* biopesticide derived from strains of *M. anisopliae* (ICIPE 20), against *P. absoluta*. The results show significantly lower fruit yield loss, improved fruit yield and marketability, and a high cost–benefit ratio.	Ongoing research will establish the most optimum formulations of the biopesticide, delivery and application approaches; its effectiveness in diverse agroecological zones; and compatibility with commonly used pesticides in tomato production systems.

(Left) A tomato plant innoculated with the endophytic fungus *Trichoderma asperellum* (ICIPE 700, M2RT4). As shown in the picture, the endophyte improves tomato defenses against the tomato leafminer, *P. absoluta*. In contrast the middle control plant of the same age shows early signs of *P. absoluta* damage, which will lead to eventual withering as evident in the photo on the right.

Tomato Leafminer Management

Focus	Context	Progress in 2022	Way forward
Push-pull management of *P. absoluta*	Previous *icipe* studies have demonstrated that the endophytic fungus ***Trichoderma asperellum* (M2RT4) improves tomato defenses against the tomato leafminer, *P. absoluta,* by reducing egg laying, leafmining and disrupting the pest's lifecycle.**	*icipe* has conducted studies to understand how *T. asperellum* (M2RT4) mediates the chemical interactions between *P. absoluta* and its host plant, towards the development of an environmentally friendly management of the pest. We have established that *T. asperellum* (M2RT4), **boosts the defenses of tomato plants in two ways: by eliciting the release of organic compounds by the plant which repel *P. absoluta;* and by activating the plants natural defense mechanism.**	These findings indicate that the two sets of compounds, repellents and attractants, are candidates for a push-pull management approach for *P. absoluta*.

Hover fly, *Betasyrphus* sp. (Syrphidae: Diptera) foraging on *Ocimum kilimandscharicum* (Lamiaceae: Lamiales). Adult syrphid flies are efficient pollinators, while their maggots are excellent predators of small insects and their eggs.

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 Bee Care, Germany; 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 National Science Foundation (SNSF); Fund for Scientific Research (FNRS), Belgium; German Science Foundation (DFG); IKEA Foundation; International Fund for Agricultural Development (IFAD); JRS Biodiversity Foundation, USA; Kenya Agriculture and Livestock Research Organisation (KALRO); Mastercard Foundation; Nature Kenya; The Rockefeller Foundation; World Trade Organization (WTO) – Enhanced Integrated Framework (EIF); and Norwegian Agency for Development Cooperation (Norad).

A comprehensive list of partners is included in the annexes.

2022 IN BRIEF

New knowledge

Insights for sustainable and modern beekeeping for: ecological protection of mangrove forests on Zanzibar island; alternative livelihoods for food and income security, in the Indian Ocean island nations and in Zanzibar; diversified livelihoods and incomes of pastoral and agro-pastoral communities in Kenya and Ethiopia; and in the arid and semi-arid lands in Kenya.

Ethnobotanical knowledge, diversity and geographical distribution of plant species for malaria control; database that includes ca. 65,000 unique insect specimen records, and their positional and temporal data, and preliminary identifications; first inventory of insects in a peri-urban landscape.

Inclusive innovations

Participatory processes and capacity strengthening for robust, resilient beekeeping; inclusive recruitment of youth; gender equity and inclusive value chains for bee and silk products; finance, digital literacy and financial inclusion in beekeeping and silk farming; model to integrate beekeeping and other agricultural products, drive formal trade and export and maximise economic benefits across the value chain and economy in Ethiopia.

Development, commercialisation and inclusive enterprises for botanical mosquito repellent production. Awareness creation of insect diversity through a social media campaign and targeted events.

Policy contributions

Draft National Honey Standard in Mauritius; support for regulations on organic honey certification in Ethiopia; quality production and fair trade of honey; support for the preparation of a directive by the Ministry of Agriculture, Ethiopia, on honey bee resources development and protection; MOYESH project as a model for holistic and inclusive job creation for youth in Africa.

One Health / Circular economy

Safe and high quality bee products and sustainable beekeeping impacts human and environmental health.

MOYESH project sites emerging as potential hubs for One Health and circular economies.

Baseline information on insect biodiversity will enable conservation amidst climate change and human activities.

Protection of mangrove ecosystems and link between beekeeping and multifunctional trees for bee forage, high-quality animal fodder, firewood, improved soil quality, carbon sequestration; beekeeping pivots resilient livelihoods in the island nations; regeneration of landscapes through beekeeping.

Bee Research

Focus	Context	Progress in 2022	Way forward
Beekeeping and ecological protection of mangrove forests on Zanzibar island	Mangroves, the only species of trees in the world that can tolerate saltwater, are highly beneficial, 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. We are linking beekeeping with the cultivation of multifunctional trees that provide bee forage, firewood, improve soil quality through nitrogen fixation, sequester carbon and provide high-quality animal fodder. We have trained farmers on the use of bee hive products and multipurpose trees.	We are conducting research to determine the most essential bee forage plants in Zanzibar island, as well as the suitable mangrove zones for honey production. **This knowledge 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 in Zanzibar; and support climate change resilience.**
Beekeeping in Indian Ocean Island Nations and in Zanzibar island	In 2015, *icipe* commenced activities on beekeeping as a source of alternative livelihoods for food and income security, in four Indian Ocean island nations (Mauritius, Seychelles, Comoros and Madagascar); and on Zanzibar island (United Republic of Tanzania). We have conducted technology transfer in beekeeping, capacity building, development of honey marketplaces, honey quality control facilities and bee health research.	In the second phase (2017-2022), we trained lead trainers; set up new apiary sites; introduced stingless beekeeping; strengthened good beekeeping practices; and supported regulatory bodies on quality control and organic certification of honey. Resource centres have been established in Mauritius, Seychelles and Zanzibar, with materials domiciled in relevant government departments. Beekeeping associations and marketplaces have been set up in Zanzibar and Madagascar. *icipe* contributed to the draft National Honey Standard in Mauritius.	**Beekeeping has proven to be a worthwhile occupation in the Indian Ocean Nations and on Zanzibar island. Indeed, the activity became a lifeline during the COVID-19 pandemic, when the tourism sector, the mainstay in the islands, was negatively impacted.**

Bee Research

Focus	Context	Progress in 2022	Way forward
Beekeeping for pastoral and agro-pastoral communities in Kenya and Ethiopia	The arid and semi-arid lands in Kenya and Ethiopia 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 will use Earth observation and environmental sensing for climate-smart beekeeping in these areas.	We are introducing honey bees and stingless bees keeping in Taita Taveta County, Southeastern Kenya, and in Yabelo area, Southeastern Ethiopia. Using geospatial and remote sensing, we have identified suitable sites for apiaries and meliponiaries. We are mapping the vegetation structure and evaluating its impact on colony growth, viral prevalence and honey production. We are also assessing the impact of hive orientation and the efficiency of local baits on swarm attractiveness and colony dynamics.	Using this knowledge, we will build the capacity for sustainable environmental management and contribute to the rearing of bee colonies that are resilient to changing climatic conditions.
Improving beekeeping in the arid and semi-arid lands in Kenya	Generally, the arid and semi-arid lands are well-suited for beekeeping. However, although these areas are key producers of honey, overall productivity is low. *icipe*, KALRO 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.	We are analysing optimum hive types; developing floral calendars and bee swarming seasons; a model for best honey harvesting times; and the capacity of beekepers and agricultural research officers to conduct participatory on-farm research. We have also recorded major bee pests; the honey badger, *Varroa* mites and ants. We have compiled a list of plants visited by bees; recorded indigenous knowledge on honey bees; completed studies on the effects of beehive material on the phytochemical and bio-functional properties of propolis; and collected various honeys from beekepers for analysis of their chemical components.	Our studies show that beekeeping is being affected by landscape changes due to agricultural expansion and practices, and loss of natural vegetation. Thus, bees are absconding colonies because of lack of forage, in addition to climate change, drought and pests. We will tap into our vast knowledge and experience in: best management practices for apiculture; queen rearing and breeding; identification of bee pests and diseases; testing of honey quality parameters; advanced tools to detect pesticide contaminants in honey; and build the capacity of beekeepers and value chain stakeholders.

More Young Entrepreneurs in Silk and Honey (MOYESH) project

Focus	Context	Progress in 2022	Way forward
Strategic and inclusive youth recruitment	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 percent of them women), in Ethiopia, secure dignified and fulfilling jobs along honey and silk value chains.	*icipe* and partners are taking a diverse approach in the recruitment of partnering youth. For example, we seek to engage not just unemployed youth, but those who are either underpaid or working as unpaid labour. **By end of 2022, the MOYESH project had created direct jobs for 67,191 young people in beekeeping and sericulture, which is 67 percent of the 100,000 target and 12 percent above the threshold set for this point of implementation.** In addition, an additional 25,066 direct jobs were created through partner organisations providing inputs and service delivery. The youth partners have been aggregated into 6,818 cooperative enterprises (6,057 beekeeping; and 761 sericulture).	Across Ethiopia and indeed Africa, youth unemployment remains a massive challenge that requires innovative approaches backed by strong, effective partnerships. We will continue to work with private and public sector actors to create employment opportunities for interested and deserving youth.
Enable more women to enter and thrive in the MOYESH project	*icipe* and partners have set a target where 60 percent of the youth partners in the MOYESH project will be women. **We have achieved our gender target through several adjustments in beekeeping;** for example more female-friendly apiary designs; convenient apiary sites; all-female enterprises; and childcare facilities; and model female beekeepers to serve as an inspiration for others.	In 2022, we started to pilot the use of a Transformative Household Methodology, a tool that aims to create awareness of intra-household gender relations. This tool has enabled us to identify gaps and corrective measures in the project. **We have conducted a rapid gender capacity gap and needs assessment enabling us to develop a tailor-made gender capacity development training course.**	We are preparing case stories and video documentaries of women-only youth enterprises to systematically document lessons learnt and exemplary practices. These tools will support empowerment of female youth partners, as well as training and targeted communication.

This photo of honey produced by the Jijiremo Enterprise, in Yirgacheffe District, Gedio Zone, Southern Nations, Nationality and People's Region (SNNPR), is emblematic of the beautiful unison being created by *icipe* and the Mastercard Foundation, through the MOYESH project, in using beekeeping as an entry point for holistic and inclusive development, as well as the creation of circular economies. The apiculture site is based in a previously degraded and unproductive land that has now been rehabilitated to its flourishing state by the youth partners. The bees benefit from the abundant flora, for example the Mexican sage plant in the foreground, and from coffee plants in the adjacent forest. In turn, the bees provide pollination services for the plants. Through sale of the high quality honey, as well as complementary income activities, the youth generate much needed income, leading to better livelihoods.

More Young Entrepreneurs in Silk and Honey (MOYESH) project

Environmental Health Theme

Focus	Context	Progress in 2022	Way forward
Increased bee products and silk production	*icipe* is introducing modern and improved beekeeping technologies and processes including bee breeding; colony multiplication; inspection and control of honey bee diseases, pests and predators; postharvest training; as well as quality control in processing and packaging of honey and beeswax. Also, we have introduced the rearing of Eri silkworm (*Samia Cynthia*), a saturniid moth that feeds on the leaves of castor plants.	The beekeeping enterprises are rearing a total of 80,224 bee colonies; they have produced over 1,093 tonnes and 59 tonnes of beeswax, generating the equivalent of USD 5.38 million. We have enabled the enterprises to domesticate castor plants, establish high quality silkworm egg grainages, rear them and produce silk cocoons, and grade and process the cocoons into yarn. About 1,800 kg of silkworm cocoons have been produced, out of which 450 kilogrammes of yarn has been reeled and sold. Indirectly, through the MOYESH project, opportunities have been created for 548,512 people cummulatively, including input suppliers, trainers and agricultural professionals.	We foresee more opportunities to establish small and medium enterprises that produce inputs like honeybee colonies and beeswax, and services such as product aggregation, value addition and practical training. In sericulture, we are harnessing Ethiopia's comparative advantage in traditional craftmanship in weaving and design and use of natural dyes on cotton, to create distinct, globally appealing silk fabrics. We note the potential of vibrant, inclusive value chains across all silk farming stages.
Bolster finance, digital literacy and financial inclusion of partnering youth, and market development	*icipe* and partners aim to increase access of finance by the youth partners from the private sector; and to create platforms for business to business (B2B) linkages, and marketing information delivery services. We are also supporting construction of marketplaces that will serve as trading points and knowledge transfer hubs.	We have leveraged the capacity of partnering private banks to deliver loanable funds to collaborating micro-finance institutions, to be accessed by youth enterprises at village level. There is a growing savings culture in the youth enterprises. By end of 2022, through various strategies, the youth enterprises had saved and deposited in banks the ≈ of USD 1.28 million. These savings enabled them to obtain loans amounting to ≈ USD 0.8 million, from microfinance partners.	Together with partners, we will tap into emerging opportunities for uncollaterilised loans through the micro-finance institutions.

More Young Entrepreneurs in Silk and Honey (MOYESH) project

Focus	Context	Progress in 2022	Way forward
Create One Health hubs	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 the community and at best, it was only used for grazing livestock.	Through the MOYESH project, 7,343 hectares of previously degraded land have been rehabilitated. The availability of land enables the youth partners to diversify their income sources with numerous complementary activities.	The enterprises created by *icipe* and partners have evolved into **One Health hubs that amalgamate knowledge and technologies from the Centre's 4H themes while also embracing novel, transformative elements.**

Commercial and Beneficial Insects

Focus	Context	Progress in 2022	Way forward
Quality production and fair trade of honey in Ethiopia	Since 2018, *icipe* has been implementing a project in Amhara Region, Ethiopia, to increase production and organic certification of the production and processing of honey and other bee products, for example beeswax. The project aims to increase the income of beekeepers, as well as investments along the value chain, and to generate thousands jobs for unemployed young women and men in Ethiopia. **The business model involves product aggregation and processing marketplaces.**	A total of 314 youth beekeeping enterprises (bringing together 3,050 members), which were established under the Young Entrepreneurs in Silk and Honey (YESH) project that was implemented by *icipe* and the Mastercard Foundation between 2015 and 2021, were supported to strengthen their trade and business integration. Eight marketing cooperatives for table honey and beeswax have been registered. About 153.1 tonnes of honey and 17.3 tonnes of beeswax have been produced, generating a total of USD 1,364,020. About USD 414,513 has been earned from complementary businesses and USD 78,312 from the sale of bee forage seedlings. Organic certification of two cooperatives: Guangua Honey Production, Processing and Marketing Share Company; and Achayita Honey Production, Processing and Marketing Cooperative, have been completed. Awareness creation campaigns, and training on the basics and requirements of organic certification have been conducted.	Our progress shows that **the business model is effective, and it can be replicated to integrate beekeeping with other agricultural practices, drive formal trade and export and maximize economic benefits across the beekeeping value chain and the economy.** We are scaling up, building collaborations, diversifying products and identifying niche export markets, to meet requirements on volume, timely delivery, and consistency in quality. Through the project, *icipe* has supported the Ministry of Agriculture, Ethiopia, to prepare a directive that is in the final steps of enactment, on the national honeybee resources development and protection.

Commercial and Beneficial Insects

Focus	Context	Progress in 2022	Way forward
Beekeeping enterprises to improve livelihoods and resilience, especially for women, in degraded natural habitats, in Wag Himra Zone, Amhara Region, Ethiopia	This initiative aims to benefit women beekeepers, organised in common interests groups (CIGs), to establish improved beekeeping and complementary farming, that are socially inclusive and environmentally sound.	By 2022, about 200 women beekeepers had been recruited into the initiative. They were rearing a total of 4,020 honeybee colonies. They had harvested honey amounting to 22,700 kilogrammes. In addition, they supplied to the market 745 kg of refined beeswax. The total revenue from honey, beeswax, vegetables, bee forages seedlings and feedlots, and small animal rearing, was about USD 175,500. One honey processing marketplace and several honey collection centres have been established.	The women beekeepers showed resilience by continuing with their beekeeping activities during a period of disruptions in the region. Their participation in honey festivals has raised the profile of honey from Wag Himra Zone, and in promoting market linkages. **Moreover, the extensive bee forage development through the project sites has proven to be an effective livelihood diversification and farm integration tool. We will build up on this momentum.**

Biosystematics

Focus	Context	Progress in 2022	Way forward
Insect biodiversity and conservation	*icipe* has a mandate of conserving insect and arthropod biodiversity. This has led to the discovery of many interesting new species and provided insights into the geographical distribution of various insect groups, primarily Hymenoptera and Diptera. We have established a pioneering, well curated and long-term collection of insects in East Africa. The physical collection is supported by a comprehensive database with complete geographic and temporal data and images for each specimen.	In 2022, our survey and inventory project in Kenya resulted in over 200 newly described species. Our collection database now includes about 65,000 unique specimen records, each of which has complete positional and temporal data as well as preliminary identifications. We conducted a first inventory of the insects of a peri-urban landscape. An illustrated report and checklist were produced and used to promote awareness of insect diversity among high school students at a “bioblitz” event.	The *icipe* insect species database will provide important baseline information on the distributions of species for comparison with future censuses in assessing the effects of climate change and human disturbances on insect biodiversity.

Catnip, a plant of the mint family that has anti-mosquito compounds.

Bioprospecting

Focus	Context	Progress in 2022	Way forward
Production, processing and marketing of anti-mosquito products from catnip	The use of selected plant extracts as mosquito repellents is one of the ways of preventing people-mosquito contact, thus limiting the chances of malaria transmission. One of the most effective species is catnip (*Nepeta cataria*), a plant in the mint family, which contains products that are known to be effective repellents against mosquitoes.	Through a project supported by BioInnovate Africa Programme, led by University of Burundi, *icipe* and partners have **developed and tested mosquito repellent products (lotion and soap) using essential oils extracted from catnip.** We have also compiled ethnobotanical knowledge, diversity and geographical distribution of plant species of interest in malaria control in Burundi.	Private sector partners in Burundi in liaison with the Burundi Bureau of Standards will commence manufacturing of catnip-based mosquito repellent products. A processing facility equipped with modern hydrodistillation equipment has been established in the country. And we have supported communities, especially around Bubanza region in Burundi, to domesticate catnip plants and build thriving enterprises.

Bocande's Stingless Bee, *Meliponula bocandei* (Apidae: Hymenoptera) foraging on *Ocimum suave* (Lamiaceae: Lamiales). The species is an effective pollinator of strawberry, cucurbits grown in protected culture. It is also an efficient honey collector.

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 the food system 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); 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); 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); 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); World Bank.

2022 IN BRIEF

New knowledge

New evidence on the superiority of insect-based animal feeds.

Amendment of soil with black soldier fly frass fertiliser reduces the incidence of common pests, produces higher vegetable yields and leaf dry matter; black soldier fly-composted fertiliser, fortified with chitin suppresses potato cyst nematodes (PCN).

Nutritional benefits of winged termites and rhinoceros beetle.

Inclusive innovations

Seven chitin-fortified products for pest and plant disease control, which also have high concentrations of macronutrients, secondary nutrients and micronutrients required for optimal crop growth.

Contribution to the establishment of the country's first commercial insect-based animal feed plant.

Sustainable harvesting; and rearing and optimal preparation methods for rhinoceros beetles.

Policy contribution

Support for the launch of the Rwanda national standards for the edible insects sector, which include: a code of practice for production and handling of insects for food and feed; specifications for dried insect products for animal feeds and edible insect products and those for whole insect and insect flour.

Insights on the willingness to adopt edible insects farming and insect-based feed among poultry farmers and feed millers in Rwanda and Uganda.

One Health

Black soldier fly based meals increase beneficial bacteria in the gut of poultry, thus promoting health and growth of poultry, and pre-empting over-reliance on antibiotics, which are harmful to the health of people and animals.

Increased production of crops, poultry and fish using insect-based products; and consumption of edible-insects; will boost food and nutritional security.

Circular economy

Insect-based farming contributes to the transformation of the food system into a more sustainable and vibrant circular economy. Insects have a better ecological footprint and significantly lower greenhouse gas emissions; they are efficient in bio-converting organic waste; are a basis of organic fertiliser and pest control products. It also provides innovation and entrepreneurial opportunities, thus impacting household incomes and national economies.

Insects for Food

Focus	Context	Progress in 2022	Way forward
Health benefits of winged termites	Termites are widely distributed globally. In Africa, the insects are consumed as a delicacy in several parts, with the winged termites (*Macrotermes* spp.) being the most eaten species. The insects are harvested from the wild during the rainy seasons.	*icipe* has **evaluated the phytochemicals, fatty acids, amino acids, minerals, vitamins and proximate composition in the *Macrotermes* spp.** in Kenya. The study revealed nine flavonoids, five alkaloids and a cytokinin. The oil content was high as were the levels of beneficial omega 3 fatty acids. We also identified eight essential amino acids. In addition, the termites have a rich mineral profile with eight elements ranging from 0.2 to 118 mg/100 g dry matter, as well as high levels of fat- and water-soluble vitamins and proximate composition.	These findings **support the use of termites as food.** They will also **contribute to environmental conservation,** through recommendation for better harvesting, thus pre-empting the negative aspects of termites on agriculture and ecosystems.
Rhinoceros beetle	Rhinoceros beetles (*Oryctes* sp.), so named because of their horn-like projections, are a delicacy in parts of Kenya.	Our studies show that the **larvae of rhinoceros beetles have high amounts of crude protein, fibre, fat and carbohydrates.** Nine minerals namely magnesium, iron, zinc, calcium, copper, aluminum, cobalt, manganese and sodium were detected in the larvae. Furthermore, a level of flavonoids and vitamins A, E, nicotinic acid, nicotinamide, B2, B5, B6 and B9, were recorded in the larvae.	*icipe* has **commenced the rearing of rhinoceros beetle larvae** and identified the right substrates (organic waste) and their formulations. The development period is around 35 days. We have also established **preparation methods that will retain nutritional integrity and safety** of the grubs for human consumption.

A bowl full of goodness
Judy Gitonga, a research assistant at *icipe,* with a bowl of fried termites, a delicacy in many parts of Africa. Our studies show that the insects are highly nutritious.

Insects for Feed

Focus	Context	Progress in 2022	Way forward
New evidence on the superiority of insect-based animal feeds	Since 2014, *icipe* has led the way in incorporating insects as alternative, more affordable, nutritious and sustainable protein options in animal feed. In particular, the Centre has demonstrated that black soldier fly larvae or the proteins derived from them, can be used safely as components in feeds for poultry, pigs and fish. In poultry, such feeds have been proven to improve growth performance, the quality and quantity of meat and eggs, and overall profitability for farmers.	*Recent icipe* studies show that the incorporation of **black soldier fly larvae in poultry feeds also increases the wealth of beneficial bacteria in the gut of poultry, thus promoting the overall health and growth of the birds.** We found that three lactic acid bacteria predominate the enhanced beneficial bacteria community. These bacteria enable the fermentation of carbohydrates to produce two lactic and acetic acids, which help to create balance in the gut and stimulate the growth of beneficial microbes. They also produce bacteriocins, compounds that prevent the development of disease causing agents in poultry.	These findings by *icipe* are **significant against the ongoing quest, in Africa and globally, to re-evaluate and reduce the use of antibiotics in poultry farming.** While the use of antibiotics to enhance growth or manage diseases in poultry has largely been beneficial, there are concerns about the rising resistance to antibiotics by harmful bacteria in poultry.
Knowledge to advance the edible insect-based feed sector in Rwanda	Rwanda aims to mainstream the use of edible insects, to achieve food security and economic growth. Insect-based feeds will unlock the potential of the poultry sector, currently constrained by the unavailability and unaffordability of protein raw materials. In 2022, **with the support of *icipe* and partners, Rwanda launched national standards for the edible insects sector;** and established the country's first commercial insect-based animal feed plant.	In alignment, *icipe* has **conducted a market assessment survey that reveals a high level of awareness among poultry keepers on the use of insects in generating quality feed and frass fertilisers, and in recycling biowastes.** More than three-quarters of the poultry farmers interviewed said they are willing to use such products. Over 95 percent of poultry farmers and feed millers are willing to pay for insect-based feeds; and the millers are willing to pay for insect larvae.	This knowledge **confirms the potential of the edible insect-based sector in Rwanda.** *icipe* will continue awareness creation and capacity building to support this goal.

Two adjacent maize plots: (left) thriving maize grown using chitin-fortified fertiliser and (right) a less productive, control plot.

Insects for Feed

Focus	Context	Progress in 2022	Way forward
Insect-based protein feed production in Ethiopia	In 2022, *icipe* with the support of the Swiss Agency for Development and Cooperation (SDC), Ethiopia office, launched the Scaling-Up Insect-Based Protein Feed Technologies and Practices for Enhanced Poultry Production in Ethiopia (SIPFEED). The initiative will build on *icipe*'s success in several East African countries in championing the role of insects in transforming the food system into a more sustainable and vibrant circular economy.	Through SIPFEED, *icipe* and partners are currently demonstrating the numerous benefits of insect-based feeds and insect-composted organic fertiliser, thus addressing the challenges of organic waste management, scarcity of poultry feed and low soil fertility. *icipe* has **established a black soldier fly training hub at Hawasa University, SNPPR,** for poultry farmers, feed millers and potential entrepreneurs, especially women and the youth. Furthermore, **two black soldier fly mass rearing units are being established in Adama, Oromia Region, and Bahir Dar, Amhara Region,** in collaboration with private sector partners. In addition, **several postgraduate students are in progress at Hawassa University and Haramaya University, Oromia Region, to build the capacity of next generation of professionals,** and to generate locally tested scientific evidence for feed regulators and policy and decision makers.	*icipe* in partnership with Institute of Ethiopian Standards (IES), and key stakeholders have **developed and validated product quality standards and gudelines on production and commercialisation of dried insects for animal feed.** The documents have been submitted to the Council of Ministers, Ethiopia, for approval. We will continue trainings on: black soldier fly production and management to selected stakeholders (poultry farmers, youth and women); 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.

Insects for Other Uses

Focus	Context	Progress in 2022	Way forward
Insect-based fertiliser and urban agriculture	With rising urban populations in Africa, there is need for improved agricultural technologies that enable urban households to produce safe and nutritious food, thus reducing over-reliance on rural agricultural production systems. In response, various technologies that optimise space are emerging in urban cities across the continent. However, such innovations are constrained by strategies for pest control, difficulties in enriching soils, irrigation and water use efficiency.	*icipe* researchers have evaluated the potential use of black soldier fly frass fertiliser in vertical farming systems that are tailored for urban settings. We aimed to understand the impact of the fertiliser on growth, yield and pest management in two popular vegetables; Swiss chard and kale. We found that the **amendment of soil with black soldier fly frass fertiliser reduces the incidence of common pests** like aphids, diamondback moth, whiteflies and leaf miner. The fertiliser also **leads to higher vegetable yields and leaf dry matter.**	This study shows the **convergence of black soldier fly rearing and urban farming, leading to more resilient cities.** In addition to food and nutritional security, this combination will help to manage the rising urban waste problem; and enable the emergence of insect-based enterprises and value chains.
Chitin-fortified black soldier fly-frass fertiliser	Soil degradation and soil-dwelling pests are a major agricultural challenges in Africa. Recent studies by *icipe* show that chitin and chitosan extracted from the husks of black soldier fly larvae can control pests.	*icipe* has established that **black soldier fly-composted fertiliser, fortified with chitin suppresses the potato cyst nematode (PCN).** The product reduces PCN cysts, eggs per cyst, and the number of juveniles that hatch. This strategy also boosts potato growth rate, leaf chlorophyll concentration, as well as tuber yield and marketability. It also improves key soil chemical properties such as nutrients (available phosphorus, exchangeable calcium and magnesium, and mineral nitrogen), cation exchange capacity, and organic carbon. The product also suppresses the cabbage root fly (*Delia radicum*), Rhodophorus and root knot nematodes.	Our findings demonstrate the high potential of **chitin-fortified black soldier fly-frass fertiliser as a high-quality and multipurpose soil booster.** We will continue studies to explore the use of the product in IPM strategies.

Insects for Other Uses

Focus	Context	Progress in 2022	Way forward
Production of insect frass fertilisers	Globally, there is growing interest in the use of insects to recycle organic waste into high-quality frass fertiliser, thus supporting circular economies. *icipe* research has demonstrated the superiority of frass fertiliser developed using black soldier larvae, in improving crop yield and soil fertility. Using this knowledge, **we are developing a range of black soldier fly frass fertiliser products for diverse agricultural production requirements and economic conditions of smallholder farmers.**	Our portfolio includes **seven products: one liquid fertiliser that is appropriate for fertigation and horticulture; and six chitin-fortified liquid products for pest and disease control.** The products have high concentrations of macronutrients, secondary nutrients and micronutrients required for optimal crop growth.	We aim to accelerate commercialisation of these products.

***Ripiphorus* sp.**
This unique looking beetle is a male of Ripiphoridae, a small family that is uncommonly sampled. All species whose the biology is known are parasitoids, particularly of bees and wasps. Rhipiphoridae are also hypermetamorphic. Females lay eggs on vegetation or sites where potential hosts are found.

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.

2022 IN BRIEF

New knowledge

Malaria, agriculture and gender; *icipe* push-pull technology and fruit fly IPM as models for sustainable growth; impact of managed bees on livelihoods; the economics of beekeeping; socio-economic benefits of insect-based farming in Uganda; and crop-poultry systems for climate smart agriculture.

Policy contributions

Recommendations for: access of women and children to malaria control and prevention services; strengthening of beekeeping extension services; and policies, practices and investments in the insect-based sector.

One Health / Circular economy

Crop-poultry systems for climate smart, resilient agriculture, food security and incomes.

Social Science and Impact Assessment Unit

Focus	Context	Progress in 2022	Way forward
Malaria, agriculture and gender	Across Africa, malaria is a major constraint to economic growth and agricultural productivity. Thus, it is important to understand the disease's impact on various social groups, to develop inclusive solutions to mitigate its burden.	A recent study by *icipe* has examined the direct and indirect effects of malaria on agricultural productivity among smallholder farmers. **Uniquely, we disaggregated the effects of the disease by gender and age of infected household members.** Our evaluations have confirmed the continued, heavy burden of malaria in Africa, and specifically, the disease's impact on agricultural labour, yields and productivity. In addition, we established that the **household toll is greatest when women and children below 14 years old fall sick.**	Our findings strengthen the case for **boosting the access of women and children to malaria control and prevention services.** These results also reinforce the need to integrate malaria interventions into efforts to boost agriculture.
The economics of beekeeping	As evidenced through various *icipe* initiatives, beekeeping has numerous benefits. It helps to diversify household incomes thus relaxing liquidity constraints; contributes to household nurition and food security; supports investments in agriculture and children's education; empowers women and the youth; and it helps to safeguard biodiversity and natural resources.	In a study, conducted in north-western Ethiopia, we found differences between beekeepers and non-beekeepers in skills and resource endowments, like training, safe crop protection, safeguarding of natural resources, climate change resilience and pollination services. **Beekeeping increases individual incomes by over 50 percent and makes livelihoods more resilient.** We observed income gains that are 22–44 percentage points higher than those reported in previous studies. This is possibly due underestimation of the indirect beekeeping benefits, and unobserved differences among households.	Future studies could focus on the impact of beekeeping on pollinator-dependent and independent crops, as well as on landscapes. We recommend **policies to strengthen beekeeping extension services and strategies for knowledge exchange on the pollination benefits of bees and the negative impact of agricultural practices,** for example use of harmful pesticides.

Social Science and Impact Assessment Unit

Focus	Context	Progress in 2022	Way forward
Managed bees, ecosystem and pollination services	In addition to their direct income generation benefits through the sale of honey and bees wax, managed bees also provide essential ecosystem services through pollination. Using nationally representative panel data from Ethiopia, we determined the overall and pure external ecosystem service impact of managed honeybees on household gross crop income. Further, we tested the quality and quantity mechanism using selected crops categorised into pollinator-dependent and pollinator independent.	Our findings show that **managed bees increase the gross crop income by between USD 5,500 and USD 7,000 per year, representing about 28-39 percent of the average gross income.** Pure external benefits for households living in a locale with beekeepers are about USD 3,200 per year. A back-of-the-envelope calculation shows that the **contribution of managed bees to Ethiopia's economy is about USD 1.7 billion annually, amounting to about 9.6 percent of the agriculture gross domestic product.** We also found that managed bees increase the value of agricultural production by elevating yield and quality of pollinator-dependent crops, with potential spillovers to some pollinator-independent crops.	Managed bees play a significant role at the household and national levels and could offer a solution to the declining pollinators problem.

Social Science and Impact Assessment Unit

Focus	Context	Progress in 2022	Way forward
Evidence for insect-based feed sector in Uganda	Over the past decade, through efforts by *icipe*, various organisations and support of governments in East Africa, there has been tremendous growth of the insect-based livestock feed sector. In Uganda, black soldier fly larvae meal production is a fast-growing value chain. Insect-based feed is more affordable than conventional feed. Farmers, feed dealers, processor, agribusiness start-ups have shown great enthusiasm for insect based feed and insect farming.	A recent *icipe* study found that **replacing existing protein sources with insect-based feed would generate net economic benefits of USD 0.73 billion (USD 0.037 billion per year) and a return of USD 28 for every dollar spent.** The estimated economic benefit can lift 4.53 million people above the poverty line in Uganda. It can also create between 1,252 – 563,302 new jobs per annum (on a substitution rate of 0.1 – 45 percent). About 695 – 312,678 tonnes of fertiliser can be produced, and 0.09 – 41 million tonnes of biowaste recycled.	This evidence will **inform policies and practices, and help to attract investments in the insect feed value chain in Uganda.** It will also stimulate further research and debate on the promotion of insect agriculture and insect-based feed for socio-economic, and environmental sustainability.
Farmers' perceptions of commercial insect-based feed for sustainable livestock production in Kenya	The cost of chicken production in Africa is high, primarily due to over-reliance on protein feed ingredients especially soybean and fishmeal, that are constrained by food-feed competition and supply chain impediments. As is the case globally, the use of insect-based protein as a sustainable alternative has attracted attention of value chain actors.	*icipe* has evaluated the willingness of farmers to pay for attributes of insect-based commercial chicken feed in Kenya. We found that **farmers are willing to pay premium prices ranging between USD 0.35 and USD 3.45 for insect-based feed** either as pellets or mash; feed explicitly labelled as containing insects; insect protein feed mixed with black soldier fly larvae and dark-coloured feed.	These findings will support **multi-stakeholder collaborations to facilitate the creation of an inclusive insect-based feed regulatory framework for sustainable feed and chicken production.**

Social Science and Impact Assessment Unit

Focus	Context	Progress in 2022	Way forward
Crop-poultry systems for climate smart agriculture	Climate-smart agricultural, sustainable and resilient food systems that can protect the livelihoods of smallholder farmers are needed. In rural areas, indigenous chickens, which are mostly kept free-range, are a major part of the diversified assets that are valuable in climate change resilient livelihoods. They do not depend on pasture, and they have low water and feed needs. Indigenous chickens are mainly kept by women, thus contributing to household food security.	In a study in semi-arid Kenya, we investigated the effect of crop-poultry integrated systems as a climate smart practice. We found that all crop-poultry combinations had significantly larger effect on food security and income. **Adopting a combination of crop-based climate-smart agricultural technologies, especially those involving indigenous chickens, leads to better income and food security.**	We recommend integration of indigenous chickens into crop agriculture, to enhance the resilience of households to climate shocks.
Assessment of the *icipe* push-pull technology, and fruit fly IPM packages	At the heart of all *icipe* activities is the wellbeing of smallholder farmers, aiming to provide them with yield-improving, integrated pest management (IPM) strategies that are holistic, environmentally safe, as well as economically and technically feasible. Among the key technologies developed by *icipe* are the push-pull technology for the management of cereal pests, and the fruit fly IPM packages.	Our assessment of the push-pull technology and the fruit fly IPM packages, conducted in Kenya and Uganda, show that **the two sets of technologies have contributed to 640,000 households becoming food secure; about 445,000 have risen above poverty thresholds;** and USD 3.2 have been generated for every dollar invested. The technologies have pre-empted the use of more than 11 million litres of pesticides and 2.7 million tonnes of carbon dioxide have been captured on farms using the push-pull technology.	These findings demonstrate the **push-pull technology and the fruit fly IPM packages as models for achieving sustainable development.**

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).

2022 IN BRIEF

New knowledge

Insights from *icipe*'s two decades of fruit fly IPM in Africa.

Inclusive innovations

Development, validation and deployment of inclusive innovations and pathways for: maize, *P. absoluta* and vegetable IPM in eastern Africa; IPM and community participation in fall armyworm control in eastern Africa; wide-scale and inclusive adoption of *icipe*'s fruit fly IPM packages in Southern Africa; support for expansion of access to knowledge on organic agriculture and agroecology; management of disease pests; early warning systems for key pests and diseases in Malawi; and upscaling of the emerging edible insects sector.

Policy contributions

Evidence-based research for policymakers and other stakeholders on technology adoption.

One Health

Establishment of training sites to build capacity of stakeholders and researchers on the One Health approach.

Technology Transfer Unit

Project	Context	Progress in 2022	Way forward
Development, testing and scaling of maize and vegetable IPM (CGIAR Plant Health Initiative)	The Plant Health Initiative is a joint initiative by *icipe*, CIMMYT, CABI and KALRO that aims to protect agriculture-based economies of low- and middle-income countries in Africa, from fall armyworm incursions and aflatoxin outbreaks. The goal is to develop, validate and deploy inclusive innovations, and to leverage and build viable networks across an array of national, regional and global institutions.	*icipe* is **testing and disseminating several strategies including the push-pull technology; intercropping; and the release and development of mass rearing protocols of natural enemies.** We have collected data on the impact of these strategies on fall armyworm damage severity, maize yield and the levels of aflatoxin in the trial fields.	We will validate data through further trials to improve the robustness of the strategies and to generate evidence-based knowledge for policymakers and other stakeholders.
Malawi Digital Plant Health Service	*icipe* is a partner in a newly launched initiative supported by NORAD and led by NIBIO, which will develop early warning systems for the key pests and diseases of major crops in Malawi.	A key focus of the project is the management of the invasive tomato leafminer (*P. absoluta*). We are **strengthening institutional capacity at the national level, and promoting awareness both at district and village level** in tomato growing areas through monitoring, data gathering and reporting. Also, we have **developed a protocol for the project implementation.**	*icipe* will conduct technical backstopping missions to promote awareness at district and village level among tomato growers on *P. absoluta*.
Fruit fly IPM in Southern Africa	Since 2019, *icipe* and partners have implemented an initiative to adapt, promote and enable wide-scale adoption of the Centre's holistic and scientifically proven IPM packages to tackle alien invasive fruit flies in Southern Africa.	Technology transfer activities have focused on **closing the knowledge gap and enhancing human and institutional capacity for research, development, and sustainability. Women and youth participation in the mango value chain has been boosted** through training and interactive digital platforms.	From a broader perspective, we have **conducted an assessment of *icipe*'s two decades of fruit fly research across Africa** and produced two video documentaries. We intend to use ICT and mobile-based technologies to evaluate the Centre's ongoing fruit fly IPM initiatives to obtain feedback.

Technology Transfer Unit

Project	Context	Progress in 2022	Way forward
Knowledge Centre for Organic Agriculture in Africa (KCOA)	*icipe* is supporting the development and validation of products to expand access to knowledge on organic agriculture and agroecology. We are **collecting, validating and converting the information into suitable formats and languages, and making it available on a centralised database.**	In 2022, we developed manuals on the biological control of stemborers and fall armyworm and maize IPM, which were disseminated to country implementing partners.	We will develop method guides for lead farmers and community focal persons. These products will be translated into French for French-speaking countries.
Community-based Fall armyworm Monitoring, Forecasting, and Early Warning System (CBFAMFEW II)	The initiative aims to **strengthen community capacity, while also introducing actionable IPM options.** In 2022, the project entered its fifth and sixth phases (January – June 2022; and July – December 2022, respectively), focussing on seven countries: Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda, and Zambia. We continued to produce bi-annual newsletters that indicate the pest's distribution, occurence, predicted density, areas of risk, actionable solutions and adaptation mechanisms.	These newsletter materials were distributed in Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia. Data collection and field scouting of the pest continues in the seven target countries. We conducted: pheromone trapping using FAMEWS, a mobile application from FAO; baseline surveys and studies to support the development of biopesticides; the search for natural enemies of the fall armyworm in Southern Africa countries; and training of extension officers, research assistants, and community focal persons in these countries.	Activities to collate data for better fall armyworm predictions are ongoing. We will also produce an analytical report on the fall armyworm since its arrival in Africa in 2016. We will also extend our outreach by partnering with more private sector actors to disseminate fall armyworm management tools.

Technology Transfer Unit

Project	Context	Progress in 2022	Way forward
Integrated pest management strategy to counter the threat of invasive fall armyworm to food security in eastern Africa (FAW-IPM)	The FAW-IPM project aims to develop and scale-out IPM approaches for the pest. In the immediate term, we are focusing on available IPM options; in the medium to long term, adaptive research is being conducted to generate Africa-specific solutions for the management of the fall armyworm. *icipe* has trained more than 3,500 smallholder maize growers (70 percent female) and about 500 (45 percent female) technology disseminators on fall armyworm monitoring and management.	About **3 million people in Ethiopia, Kenya, Rwanda, Tanzania and Uganda, have been reached** through the media and other outreach efforts. We have developed various digital materials, and TV and radio programmes on fall armyworm IPM. We have also conducted awareness campaigns, in partnership with Biovision Africa Trust, reaching more than 2 million people. Farmer exposure and experience visits have also been conducted.	We will partner with national agricultural institutions and private sector partners to enhance the reach of the FAW-IPM project. We will conduct on-farm validation and efficacy trials for emerging technologies for the management of the fall armyworm. Also, we will undertake multi-site demonstrations, and awareness creation of the *icipe* biopesticides and the use of natural enemies.
Combating Arthropod Pests for Better Health, Food and Resilience to Climate Change (CAP-Africa)	CAP-Africa focuses on: 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).	We conducted five **training workshops in Ethiopia, Kenya, Tanzania and Uganda, involving 250 stakeholders,** including extension officers, policymakers and private sectors partners. Representatives from government, non-governmental and private sector institutions were trained on the knowledge and how to expand dissemination of various IPM and IVM technologies to the farmers. **We established nine technology learning sites in Kenya and Uganda,** enabling us to conduct six field days; and to train 2,643 farmers (1,320 females; 1,322 males) on fall armyworm management.	We will **use the training sites to build capacity of stakeholders and researchers using the One Health approach.**

Technology Transfer Unit

Project	Context	Progress in 2022	Way forward
Scaling-up climate-smart pest management approaches for enhanced maize and tomato systems productivity in eastern Africa (SCLAMP-EA)	The SCLAMP-EA project aims to facilitate 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.	The Technology Transfer Unit is **supporting the development, and distribution of manuals on the biology and management of the fall armyworm and *P. absoluta*, and maize IPM** to partners.	We will complete the production of a video documentary on *P. absoluta* management and maize IPM technologies.
Insect Farming for Health and Livelihoods (Healthynsect)	The Healthynsect project aims to generate new knowledge to accelerate insect farming and insect consumption in Africa for improved nutrition, health and livelihoods.	We developed a manual on cricket rearing and a video series on black soldier fly, including: introduction; waste sourcing; bait preparation; larvae feeding; larvae harvesting; and frass fertiliser.	We will **strengthen collaboration with partners in Kenya, Ghana and Uganda, and develop more dissemination pathways to promote healthy insect farmers.**
African Association of Insect Scientists (AAIS)	The Technology Transfer Unit spearheads a network of 300 entomologists, mainly from Africa, which focuses on information sharing among scientists and practitioners; and introduces new technologies or approaches.	In 2022, we organised and conducted five lecture series to **promote *icipe*'s place as a centre of excellence; as well as insect science and its application in Africa.**	Inspired by the feedback from the Association's members, **we will continue to develop the forum as a space for deliberation of scientific findings and innovations.**

DATA MANAGEMENT MODELLING AND GEO-INFORMATION UNIT

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 (CIAT) (ABC); Bill & Melinda Gates Foundation; BioInnovate Africa Programme; Centre De Suivi Ecologique (CSE), Italy; 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; IKEA Foundation; International Development Research Centre (IDRC), Canada; Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF), Germany; Norwegian Agency for Development Cooperation (Norad); One CG Initiative; US Agency for International Development (USAID).

A comprehensive list of partners is included in the annexes.

2022 IN BRIEF

New knowledge

Models for site-specific risk of desert locusts breeding and to predict their migratory patterns and intensity; models and early warning platforms to monitor crop pests and their natural enemies; model to couple climate change and insect pests induced impacts; maps to enable farmers to make anticipatory fall armyworm control decisions; farmer-friendly digital support systems for key pests and diseases in Malawi; models to predict the factors that can influence *Microsporidia MB* under field conditions, and foresight for malaria disease incidence, towards the use of the microbe as a malaria control tool; and data abstraction of occurrence, bionomic and insecticide resistance for a Malaria Vector Atlas.

Inclusive innovations / Policy contributions

Decision support tools for improved locust surveillance and monitoring, and to support early warning, rapid response and localised interventions of crop pests, leading to better crop health and more resilient agricultural systems; and decision support tools for vectors of human and animal diseases.

Establishment of the *icipe* Data Research Management and Archiving policy for adherence to FAIR principles.

One Health

The DMMG Unit supports *icipe*'s One Health vision and resource mobilisation goals by reinforcing the alignment of the institution's scientific data infrastructure and practice to universal standards such as the FAIR principles of data management, while also showcasing elements of open data, open science and reproducible science.

Data Management Modelling and Geo-information Unit

Focus	Context	Progress in 2022	Way forward
Data archiving and data management	Data is one of the main pillars of research. Thus, research institutions must have a plan on how data are collected, analysed, organised, standardised, stored, published and shared, while adhering to ethics to uphold the FAIR (findable, accessible, interoperable and reusable) principles. The DMMG Unit is responsible for the establishment and enhancement of the *icipe* data management and data sharing workflow, including setting up the relevant policies, rules and governance mechanisms, in compliance with international standards.	A key achievement of the DMMG Unit is the **establishment of the *icipe* Data Research Management and Archiving Policy.** Aligned to the policy is the **Centre's data infrastructure,** which has several interconnected components, namely: common ontology, legacy data, data management plan, digital data collection tools, the data warehouse, and a software version of the data management tool (GitHub). Google analytics accessibility metrics of the *icipe* information systems show that the Centre's data is accessed globally, at a fast-rising rate.	Several components of the data management workflow are in progress, for example tools to load clean and annotated raw data to the data lake for analysis and visualisation; and the setting up of data analysis pipelines such as modelling and machine learning.
Locust surveillance and monitoring	From late 2019, several eastern African countries were devastated by catastrophic desert locust swarms. *icipe* and partners including the Food and Agriculture Organization of the United Nations (FAO) and the Desert Locust Control Organization for Eastern Africa (DLCOEA), analysed 40 years of long-term monitoring data and applied machine learning algorithms to identify locust swarms breeding sites in the region using key bioclimatic and edaphic factors.	Upon request and support from the FAO Commission for Controlling the Desert Locust in the Central and Western Region, ***icipe* is rolling out decision support tools to assess site-specific risk of desert locusts breeding and to predict their migratory patterns and intensity.** The Centre is also helping to improve monitoring systems, determine the socio-economic impact of desert locust invasions and build the capacity of national partners to apply the decision support tools.	We have developed an interactive modelling framework to determine the timings of locust hatching in Turkana County, northern Kenya; and a geospatial model to monitor desert locust occurrences in Djibouti, Ethiopia, Eritrea, Somalia and Sudan. Also, we are developing an artificial intelligence model to predict distribution and populations of desert locusts.

Data Management Modelling and Geo-information Unit

Focus	Context	Progress in 2022	Way forward
Crop pests and natural enemies	Against the context of climate change, strategies for adaptation, as well as surveillance to detect and monitor plant stress and predict insect pests in a timely manner, are needed. In accordance, ***icipe* has developed models and early warning platforms that use earth observations and geospatial tools to monitor crop pests and their natural enemies, as well as parasitic weeds;** to support early warning, rapid response and localised interventions.	We have applied geospatial and remote sensing models at global, regional and local scales, under diverse climate scenarios, to explain the distribution and dynamics of various insect pests such as the fall armyworm, stemborers, invasive fruit flies and mealybugs as well as the parasitic *Striga* weed. We have also created a novel and systematics methodology to estimate the impacts of the dispersal of classical biological control agents.	These **tools and strategies will ensure improved crop health and yield, as well as more resilient agricultural systems.**
Coupling climate change and insect pest induced impacts	Often, research on insect-mediated crop losses is disconnected from models predicting changes in crop yield due to climate change. And yet, as climate changes, it is important to establish the relationships among insect metabolism, physiology, life history traits, demography; and environmental variables like temperature and carbon dioxide concentration in the atmosphere.	We have **developed a novel methodological framework to couple crop and insect pest models.** Using the model, we have produced worldwide maps of the temperature- and carbon dioxide-dependent damage in maize, combined with yield losses due to insect pests, under several climate change scenarios.	

Data Management Modelling and Geo-information Unit

Project	Context	Progress in 2022	Way forward
Fall armyworm management	Since the arrival of the fall armyworm in 2016, *icipe* has embarked on the implementation of an integrated pest management package that integrates the push–pull technology; natural enemies; biopesticides; and cereal varieties that are resistant to the pest.	The DMMG Unit has helped to reinforce and expand community-based monitoring, forecasting for early warning and timely management of the fall armyworm. **Using a machine learning predictive model, we generate quarterly maps on the occurrence and density of the pests.** These tools **enable farmers to make anticipated control decisions.** We have also developed an ecological niche model at a regional scale to predict the distribution of the fall armyworm in Ethiopia, Kenya, Rwanda, Uganda and Tanzania.	Our decision support systems will guide the scaling-up of the fall armyworm biological control agents; identification of the natural enemies of the fall armyworm; as well as sites that are suitable for the implementation of the push-pull technology.
Farmer-friendly digital support systems in Malawi	*icipe* is a partner in a newly launched initiative supported by NORAD, and led by NIBIO, which will develop early-warning systems for key pests and diseases of major crops in Malawi.	*icipe* scientists will **establish the backbone for farmer-friendly digital support systems,** by harnessing available data and collecting new data, to devise predictive models.	Ongoing studies within the DMMG Unit include: review of existing models focusing on geospatial mapping, system dynamics and phenology of *P. absoluta*, fall armyworm and the parasitic *Striga* weed; development of their ecological niche models; climate- and environmental-based clusters to guide the selection of sampling sites and pests traps; and modeling of maize and tomato suitability based on current and future scenarios.

Data Management Modelling and Geo-information Unit

Project	Context	Progress in 2022	Way forward
Models for *Microsporidia MB* as a malaria control tool	As part of *icipe* studies to deploy *Microsporidia MB* as a malaria control tool, we aim to investigate, model and predict the factors that can influence the microbe's levels under field conditions; and to provide foresight for malaria disease incidence.	We are using an **integrated system dynamics simulation model** to explain the interactions among people, the malaria vectors and parasites, the environment and implications for malaria transmission; and an **individual based modelling system** to predict the changes in malaria characteristics after interventions using *Microsporidia MB*.	The models we have developed are currently being fine-tuned and calibrated.
Malaria Vector Atlas	*icipe* is the lead partner in the Malaria Vector Atlas Project, an initiative that brings together various partners to build an online, open access repository to hold and share analyses-ready malaria vector occurrence, bionomics, abundance and insecticide resistance data.	The Unit has collated and processed data abstraction of occurrence, bionomic and insecticide resistance. We have conducted training on databases and developed a library for data abstraction.	We are in the process of **developing a data hub and platform to store and share vector datasets and analytical products.** Also, we are creating a computational framework to automate data abstraction and uploading to the Malaria Vector Atlas data hub.
Controlling and progressively minimising the burden of animal trypanosomosis (COMBAT)	There is a need to develop and adapt adequate strategies to timely detect, monitor and predict vectors that cause animal diseases, and to monitor animal movements to reduce exposure to infections for a sustainable livestock production system.	We have collated and processed occurrence and density data on tsetse flies and climate. Also, we have **developed an ecological niche model to predict tsetse fly suitable habitats in Kenya.** Historical tsetse fly data from different sources has been collated to contribute to developing the tsetse atlas in Africa.	This knowledge will **guide the design and deployment of cost-effective, large-scale tsetse control tools.**

Data Management Modelling and Geo-information Unit

Project	Context	Progress in 2022	Way forward
Data science capacity building	With the growing global importance of data, including the emergence of big data, that is large volumes that have a variety of data types and are streamed with high velocity; the increasing cost of gathering data; the need to gather data rapidly, comprehensively, affordably and accurately, and to make connections among various data; data science capacity has become correspondingly vital.	*icipe* is unique in Africa in terms of advancement in data science. Thus, the Centre is training young data scientists through internships, graduate, postgraduate and postdoctoral level programmes. We are also providing support to Rsif scholars and researchers. Moreover, the Centre's strength in data science is being recognised by partners, including research organisations, government institutions, international organisations and development agencies. We are receiving an increasing number of requests from across Africa and the globe, to support capacity building and to share experience in data science.	We will continue to nurture young African capacity, and we are also in the frontline in creating awareness for data science and its application.

Sclerogibbidae (*Sclerogibba* sp.)
A female Sclerogibbidae, a very small and rarely collected family related to the comparatively species-rich Chrysididae (jewel wasps) and placed in the same superfamily as the latter (Chrysidoidea). The Afrotropical region has just three genera encompassing 15 species. To date, a total of 12 Sclerogibbidae species have been published from Kenya, from the three genera; Caenosclerogibba, Probethylus and Sclerogibba. Adults search beneath rocks where they attack Embioptera (webspinners) exclusively.

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); Welcome 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 Combatting Arthropod Pests for better Health, Food and Climate Resilience (CAP-Africa) project.

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; 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); Good Venture Foundation; International Development Research Centre (IDRC); Australian Centre for International Agricultural Research (ACIAR); Mastercard Foundation; JRS Biodiversity Foundation; Kenya Medical Research Institute –Wellcome Trust Programme; Newton Fund; Norwegian Agency for Development Cooperation (Norad); 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).

Postdoctoral and postgraduate training

A total of 236 fellows and scholars were undertaking their research at *icipe* in 2022, while 40 postgraduate scholars completed their studies, impacting on activities across the Centre's four themes.

Geographical representation

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

Gender equity

Of the combined number of PhD and MSc scholars, and interns at *icipe*, 48 percent are women.

Research and development impact

Of the 261 journal articles published by *icipe* in 2022, 72 were lead-authored by postgraduate scholars, and 27 by postdoctoral fellows.

Awards, recognitions, grants and presentations

icipe scholars made 12 presentations at various fora. They received 8 external awards; 7 internal awards; and 4 grants.

Institutional strengthening

A total of 181 training events were conducted, reaching 28,259 participants (47 percent women) from 33 African countries.

Capacity Building and Institutional Development Programme

Project	Context	Progress in 2022	Way forward
Nurture and mentor young African scientists	The *icipe* postdoctoral fellowship programme provides opportunities for doctoral graduates to undertake research at *icipe* to develop their research skills and careers, and collaborative research programmes. The Centre's postgraduate training is conducted through the African Regional Postgraduate Programme in Insect Science (ARPPIS); and the Dissertation Research Internship Programme (DRIP); with support from German Academic Exchange Service (DAAD) and other donors. The *icipe* internship programme provides opportunities for hands-on professional skill development.	In 2022, a total of 236 fellows and scholars were undertaking their research at *icipe*. They included 29 postdoctoral fellows; 60 PhD; 89 MSc students; and 58 research interns.	We aim to: **ensure that capacity building and institutional development is strongly embedded in all *icipe* projects and programmes; strengthen the resource base of the programme; and increase participation of women.**
Foster research and development impact of *icipe* scholars	The postdoctoral fellows and postgraduate scholars are integrated into projects across the Centre. Their research extends from strategic basic research, technology development and validation, to community-based adoption. As a result, **they make outstanding discoveries and contribute to the global knowledge hub, and to sustainable development.**	In 2022, of the 261 peer-reviewed journal articles published by *icipe*, 72 were lead-authored by postgraduate scholars; and 27 by postdoctoral fellows. A total of 40 *icipe* postgraduate scholars completed their studies.	As *icipe* graduates continue to establish themselves in academia, research sector, government and industry, we will assess the socio-economic impact of their contribution to research and development. An **updated tracer study is underway** in collaboration with the Social Sciences and Impact Assessment Unit and Technology Transfer Unit. Similar efforts are ongoing to **revamp and strengthen the ARPPIS alumni** in partnership with the African Association of Insect Scientists.

Capacity Building and Institutional Development Programme

Project	Context	Progress in 2022	Way forward
Enhance geographical representation in the *icipe* capacity building programmes	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.** Moreover, *icipe* stands out as a model for insect science training, not just in Africa, but across the world.	Currently, a total of 19 African countries are represented in the *icipe* capacity building programmes: Benin, Cameroon, Comoros, DRC, Ethiopia, Ghana, Kenya, Liberia, Malawi, Nigeria, Rwanda, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe. Seven non-African countries are currently represented in *icipe* postgraduate and postdoctoral training programmes. They are: Belgium, Colombia, Costa Rica, Germany, The Netherlands, Portugal and United States of America.	In recent years, concern has been raised about the global slump in certain fields of science, entomology included. ***icipe* intends to sustain its efforts in enhancing Africa's, and indeed global, entomological capacity.** We will build on *icipe*'s expansion to West Africa, to ensure more representation of the region in our capacity building programmes. We will also take advantage of new programmatic footprints to tackle entomological challenges in North and Southern Africa.
Pursuing gender equity	***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.	About 48 percent of the combined number of PhD and MSc scholars, and interns at *icipe* are women, as follows: 27 percent of ARPPIS PhD scholars; 41 percent of DRIP PhD scholars; 48 percent of DRIP MSc scholars and 64 percent of interns. Among the postdoctoral fellows, 21 percent are women.	**Gender equity will continue to be a key focus of the *icipe* capacity building activities.**
Awards, recognitions, grants and presentations	The ***icipe* capacity building programmes pivot the young researchers** through world class training and skills, and also enables them to access the global reward system, which includes resources, knowledge and recognition.	In 2022, *icipe* scholars made 12 presentations at various fora. They received eight external awards; seven internal awards; and four grants.	*icipe* will **continue to support scholars, incentivise academic excellence, as well as competition for national, regional and global opportunities.**

Capacity Building and Institutional Development Programme

Project	Context	Progress in 2022	Way forward
Institutional strengthening	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 a range of activities, from basic and strategic research, technology development and validation, and technology implementation and commercialisation.	In 2022, we conducted 181 training events, and reached 28,259 participants (47 percent women) from 33 African countries: Angola, Benin, Burkina Faso, Burundi, Cameroon, Cape Verde, Chad, Comoros, Congo, Côte d'Ivoire, Eritrea, DRC, Eswatini, Ethiopia, Ghana, Kenya, Liberia, Malawi, Mali, Mozambique, Niger, Nigeria, Rwanda, Senegal, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe. The trainings were held in 11 countries in Africa: Benin, Cape Verde, Eswatini, Ethiopia, Ghana, Kenya, Rwanda, South Africa, Tanzania, Uganda and Zambia.	*icipe* will **continue to contribute to institutional development activities in tandem with the Centre's R4D activities at the local and regional levels.**

Eastern Africa Network of Bioinformatics Training (EANBiT) project

Focus	Context	Progress in 2022	Way forward
Strengthening bioinformatics training in eastern Africa	Since 2017, through the Eastern Africa Network for Bioinformatics Training (EANBiT), *icip*e is coordinating a network of three universities: Pwani University, Kenya; Makerere University, Uganda; and Muhimbili University of Health and Allied Sciences, Tanzania; and four research institutes: *icipe*; Kenya Medical Research Institute – Wellcome Trust Research Programme; Biosciences eastern and central Africa – International Livestock Research Institute (BecA-ILRI Hub); and Uganda Virus Research Institute (UVRI). The goal is to create a critical mass of practitioners who can develop and use bioinformatics approaches to biosciences.	By end of 2022, the following achievements had been made through EANBiT: Msc in Bioinformatics programmes have been established at the three partnering universities. Four cohorts, amounting to a total of 44 MSc in Bioinformatics fellows have been supported and trained. 18 fellows have secured PhD positions, 4 are working as data scientists and one fellow was selected as one of the Pan-African Mosquito Control Association (PAMCA) MalariaGEN four rising stars in bioinformatics. A total of 116 fellows had been trained through the bioinformatics residential training course. A collaborative platform to promote and strengthen bioinformatics training and career development has been formed, including: a network of supervisors and mentors; establishment of the Bioinformatics Hub of Kenya; collaborations with University of Glasgow, UK; University of Milano – Bicocca, Italy; Centre for Genomic Regulation, Barcelona, Spain; and Örebro University, Sweden.	EANBiT will **continue to support the MSc in Bioinformatics programmmes including, project placement and co-supervision.** Thus, EANBiT will broaden its network of collaborating institutions. EANBiT also aims to support partnering university towards ensuring sustainability of the MSc programmes. For example, Pwani University has received DAAD in-country/in-region grant for fellowships in the programme. **The Bioinformatics Hub of Kenya, with young graduates conducting outreach activities, will serve as a key platform for boosting the vision of EANBiT.**

BIOINNOVATE AFRICA PROGRAMME

In 2016, the Swedish International Development Cooperation Agency (Sida) and *icipe* reached an agreement for the Centre to host and manage the Bioresources Innovations Network for Eastern Africa Development (BioInnovate Africa) Programme, Phase II (2016–2021). One of Africa's largest regional science and innovation-driven initiatives, BioInnovate Africa was established in 2010 with support from Sida, its first phase running up to 2015. The Programme provides grants to enable scientists, researchers, innovators and entrepreneurs in eastern Africa (Burundi, Ethiopia, Kenya, Rwanda, Tanzania and Uganda), to work together to turn innovative ideas and technologies based on biological sciences into viable businesses. Over the past two decades, BioInnovate Africa Programme, supported by Sida, has served as the region's premier science and innovation initiative. Since 2016, BioInnovate Africa Programme has been managed by *icipe;* its emphasis being to develop and pilot economically viable biobased technologies and products; and to engage policymakers to evaluate relevant policy options that support bioscience innovations.

Donor: Swedish International Development Cooperation Agency (Sida).

A comprehensive list of partners is included in the annexes.

New cooperation agreement

between the Swedish International Development Cooperation (Sida), and *icipe* to implement phase III of BioInnovate Africa Programme.

Commercialised innovations

More than 20 regional innovation projects, supported by BioInnovate Africa Programme, over the past five years, have been successfully tested and are gaining market entry.

New partners

New grants awarded for innovations on: improving food production and food safety; reducing post-harvest losses; providing alternative biodegradable packaging materials; and improving human and animal health.

Techno-economic analysis (TEA) capacity

building in East Africa by BioInnovate Africa and the Thayer School of Engineering, USA.

Development of a bioeconomy in Africa

Regional bioeconomy strategy, developed through a consultative process spearheaded by the East African Science and Technology Commission (EASTECO), with partners including BioInnovate Africa Programme, approved.

Ms Hawa Mohamed, Laboratory Technologist, National Veterinary Institute of Ethiopia, observing the growth of the Vero cells, as part of research supported by BioInnovate Africa Programme and led by the Bio and Emerging Technology Institute (BETin), to develop diagnostic tools for the SARS-CoV-2 virus. The team has developed a monoclonal antibody against the spike protein of SARS-CoV2 and a prototype Indirect ELISA to detect SARSCoV2 antibody. The research is ongoing.

New Agreement

Focus	Context	Progress in 2022	Way forward
New five-year cooperation agreement by the Swedish International Development Cooperation (Sida) and *icipe*	Over the past five years, BioInnovate Africa Programme has supported more than 20 regional innovation projects in Burundi, Ethiopia, Kenya, Rwanda, Tanzania and Uganda. Examples of products that have been successfully tested and are gaining market entry include: biofertilisers from agricultural wastes; a seed delivery system for virus free sweet potato vines; nutrient enriched foods from sorghum and millet; edible insect enriched food; aroma honey toffees; orange fleshed sweet potato puree for bakery products; black soldier fly larvae for chicken feed; mushroom substrate blocks; and an integrated solution for treating industrial wastewater.	In 2022, Sida and *icipe* signed a new five-year cooperation agreement to implement phase III of BioInnovate Africa Programme. Taking into account previous support to BioInnovate Africa phase I (2010 – 2015); and phase II (2016 –2021); **Sida's support remains the biggest single investment in a regional bioscience research and innovation-driven initiative to date in eastern Africa.** The resources will benefit scientists in Burundi, Ethiopia, Kenya, Rwanda, Tanzania and Uganda; with the Democratic Republic of the Congo (DRC), and South Sudan as new entrants. The support to BioInnovate Africa phase III is timely, within the context of United Nations Decade of Action (2020-2030) for accelerating efforts towards achieving the Sustainable Development Goals (SDGs). It also also aligned to the aspirations of the African Union Agenda 2063, and the targets of the East African Community vision 2050 of boosting value addition and agro-processing as the biggest direct employer of all manufacturing industries in the region.	BioInnovate Africa Programme has announced new grants for regional innovation projects in eastern Africa, to be implemented between 2022 and 2025. The Programme will continue to support initiatives for value addition to biological materials, including converting biological waste into useful substances, and conserving biodiversity. In addition to this primary focus on agriculture and environment, in phase III, BioInnovate Africa will also boost projects in the thematic area of health.

An internationally certified, nitrogen biofortified organic fertiliser developed from biodegradable municipal waste has been developed and commercialised by Guavay Company Ltd, Tanzania, in collaboration with partners from Tanzania and Uganda, with support from BioInnovate Africa Programme. Aptly branded Hakika, Kiswahili for 'for sure', the fertiliser contains natural growth promoters, beneficial micro-organisms that help to preserve soil moisture, and superior qualities like rapid biocomposting and fermentation.

New Grants

	Project	Lead partner	Partners
Improving food production and food safety	Rhizobia-mycorrhizae-based biofertiliser for smallholder farmers	Evangelical University in Africa, Democratic Republic of Congo	Hope Africa University, Burundi; University of Nairobi, Kenya; ITRACOM Fertiliser Ltd, Burundi
	Plant based insecticides for controlling maize storage insect pests and other insect pests of economic relevance to smallholder farmers	Egerton University, Kenya	The Open University of Tanzania; University of Rwanda; *icipe*; and Farm Track Consulting Ltd, Kenya
	Biofungicides for the management of coffee wilt disease in East Africa	Kaffabio Control Agro-Industry Private Ltd Company, Ethiopia	Kenya Agricultural and Livestock Research Organization-Coffee Research Institute (KALRO) Kenya; and Tanzania Coffee Research Institute
	Novel biodegradable carrier (from banana fibre) for efficient crop protection	International Institute of Tropical Agriculture, Tanzania	International Fertilizer Development Corporation, Uganda; *icipe;* and Bio-Corn Products EPZ Ltd, Kenya
	Using *Lactobacillus* for aflatoxin decontamination of value added peanut products	Centre for Agriculture and Bioscience (CABI) International, Kenya	Makerere University, Uganda; Burundi Institute for Agricultural Sciences; Uganda National Farmers' Federation
Reducing post-harvest losses	Smart-hybrid solar dryers for fruits and vegetables	African Centre for Technology Studies	Kenya Industrial Research and Development Institute; Tanzania Industrial Research and Development Organization; National Agricultural Research Organization, Uganda, and GREKKON Ltd, Kenya

New Grants

	Project	Lead partner	Partners
Providing alternative biodegradable packaging materials	Eco-friendly packaging products from cassava and other agricultural wastes	Kyambogo University, Uganda	Institute of Policy Analysis and Research, Rwanda; Ardhi University, Tanzania; and Oribags Innovations Ltd, Uganda
Improving human and animal health	Supplements to 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 Congo; and Jena Herbals Ltd, Uganda
	Nanoencapsulated-bromelain from pineapple and seafood waste for control on helminths and other livestock to diseases	Jomo Kenyatta University of Agriculture and Technology in Kenya	Université Evangélique en Afrique, Bukavu, Democratic Republic of Congo; Sokoine University of Agriculture, Tanzania; and Vetcare® Africa, Kenya
	Novel bio-rational products for controlling Tungiasis in East Africa	Masinde Muliro University of Science and Technology (Centre for African Medicinal and Nutritional Flora and Fauna), 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

Bioeconomy in Eastern Africa

Focus	Context	Progress in 2022	Way forward
Regional bioeconomy strategy	While funding bio-based innovation projects remains the core activity of BioInnovate Africa, **the Programme's strategy also includes support for the development of a sustainable and circular bioeconomy in eastern Africa.** This vision is built on the premise that Africa, with its rich biological diversity and a relatively large proportion of arable land, is well positioned to build a competitive, sustainable bioeconomy. Thus, **BioInnovate Africa has been a partner in the development of a regional bioeconomy strategy, 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.	In April 2022, **the East African Community (EAC) council of ministers approved the 10-year regional bioeconomy strategy;** the first of its kind in Africa and the second in the world after the European Union. The strategy builds on existing national and regional science, technology, and innovation policies and related instruments that aim to create an enabling environment for increased investments to support sustainable development and socio-economic transformation. It will be key in promoting food security and sustainable agriculture in the region; enable countries to scale-up their bio-innovations, share scientific knowledge, and harmonise policies, standards, and regulations for bio-manufacturing and regional trade.	The eastern Africa regional bioeconomy strategy provides a compelling framework for Partner States to integrate the aspirations of Agenda 2063 and the SDGs into inter-sectoral national development plans. It will also pivot the East African Community Vision 2050, through which Partner States aspire to become middle income countries. In addition, the strategy serves as a model for the rest of the continent.

TEA Capacity

Focus	Context	Progress in 2022	Way forward
Building techno-economic analysis (TEA) capacity	Techno-economic analysis (TEA) is a method to analyse the economic performance of processes in industries. **BioInnovate Africa Programme and the Thayer School of Engineering, USA, are building TEA capacity for innovation initiatives in eastern Africa.** This is through a course that was jointly established in 2019 to provide human resource development to assess potential economic feasibilities and bottlenecks, and to identify research and development requirements during early stages of biobased technologies that have real world application in developing countries settings.	The course addresses the application of TEA to evaluate the profitability and broader social and environmental impact of potential business ventures. It also provides indepth exposure to the design of processes featuring chemical and biochemical transformations including integration of unit operations, simulation of system performance, sensitivity analysis, system-level optimisation, and process economics and investment return. The course is open to students who have enrolled for a Master's or a PhD programme at a university in any of BioInnovate Africa Programme's partnering eastern African countries. **Eight students have been trained so far. The skills that the students have gained have enabled them to conduct TEA on selected BioInnovate Africa projects.**	Expanding TEA capabilities in eastern Africa will enable BioInnovate Africa Programme 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.**

Diparinae Pyramidophoriella
Until recently this amazing species was considered a member of the subfamily Diparinae of the family Pteromalidae. However, Diparinae have now been elevated to family status and the group is now known as the Diparidae. Little is known of the biology of this small family, with records of species parasitising weevils, mantids and tsetse flies. The Kenyan Pyramidophoriella may be a new species. The genus name means “carrying pyramids” and refers to the pyramid-shaped processes on the mesothorax. We have collected six specimens of this species in the East African Coastal Forests biodiversity hotspot.

REGIONAL SCHOLARSHIP AND INNOVATION FUND

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. As a competitive grants scheme, the mission of Rsif is to strengthen the institutional capacity for quality and sustainable doctoral training, research and innovation in sub-Saharan Africa in five priority thematic areas identified by PASET as strategic economic sectors for growth and development in Africa. In 2018, *icipe* was appointed as the Regional Coordination Unit (RCU) of Rsif.

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, and ACP Innovation Fund of the European Union through the Organisation of African, Caribbean and Pacific States (OACPS).

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; 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 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; Seoul National University Global Research & Development and Business Center (GRC), South Korea; Télécom SudParis, France; Université Côte d'Azur, France; University of Greenwich, Natural Resources Institute, UK; University of Lisbon, Portugal; University of Michigan, USA; University of Pretoria, South Africa; Virginia Tech College of Agriculture and Life Sciences, USA; Worcester Polytechnic Institute (WPI), USA.

Resource mobilisation

By end of 2022, nine African governments had committed investments in Rsif. They are the governments of Benin, Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Mozambique, Nigeria, Rwanda and Senegal.

Rsif scholarships

A total of 291 Rsif PhD scholarships awarded; and 8 out of 15 cohort 1 scholars had completed their studies.

Gender diversity

Currently, 37 percent (104 scholars) of the 278 active Rsif scholars are women.

Knowledge generation

By 2022, the Rsif scholars had published a total of 122 peer reviewed papers.

Network

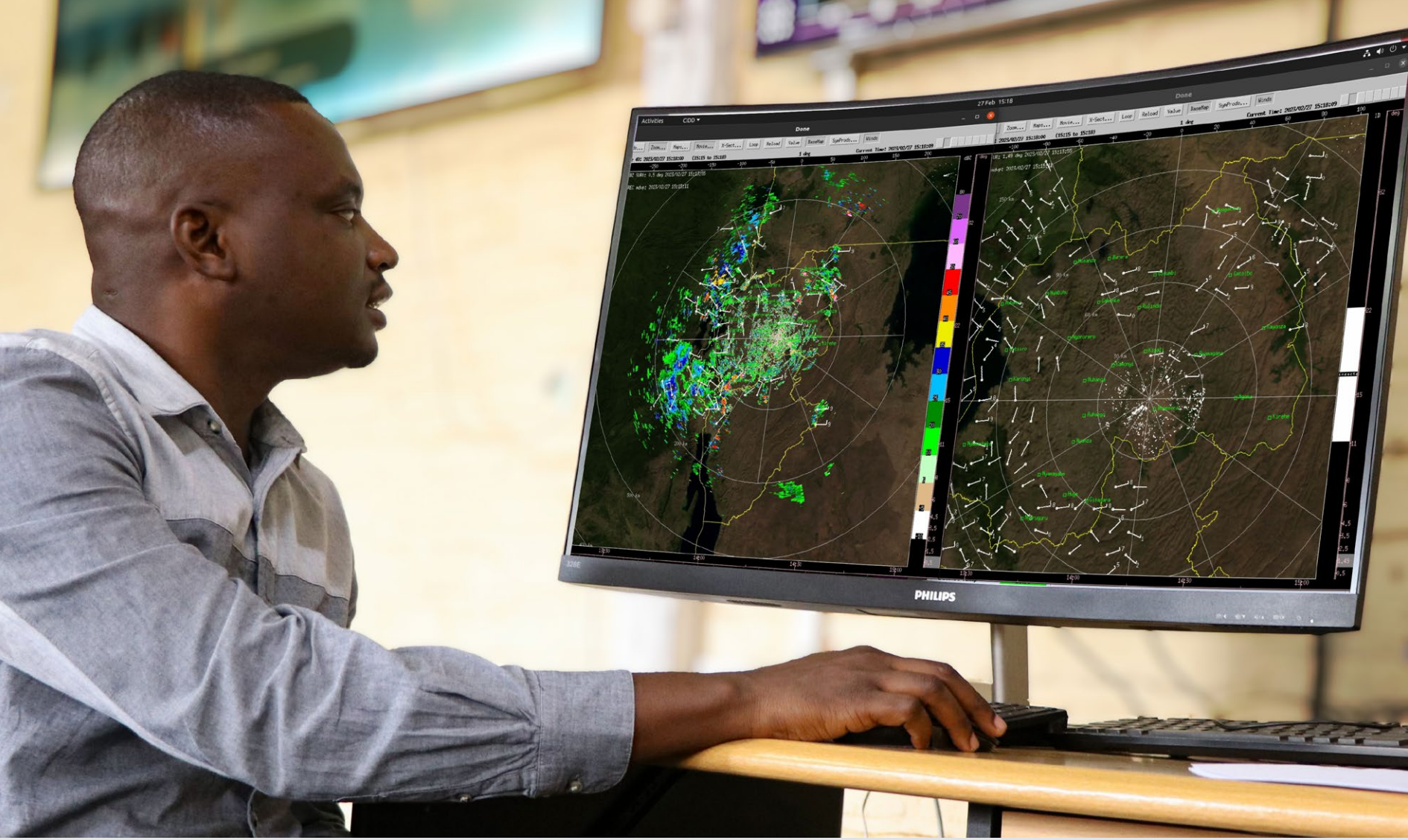
There are 15 AHUs in 11 African countries; and 23 IPIs, three in African countries and the rest spread in Europe, America and Asia.

Research and innovation

A total of 27 research and innovation grants have been awarded to faculty in Rsif AHUs; five Junior Investigator Research Award Grants to Rsif PhD graduates; and 12 research and innovation grants to faculty and researchers in Mozambique.

Resource Mobilisation

Focus	Context	Progress in 2022	Way forward
Foster Rsif as a sustainable pan-African science fund	Over the past five years, Rsif has gained incredible momentum with rapid evidence of the Fund as an outstanding platform for socio-economic transformation in Africa, for example by enabling the continent to embrace the fourth industrial revolution. Indeed, many stakeholders are appreciating Rsif as an effective channel for resources to achieve national developmental aspirations, as well as Agenda 2063 of the African Union, and acceleration of the sustainable development goals (SDGs).	In 2022, we reached several milestones in investments in Rsif. The Federal Government of Nigeria announced a contribution of USD 4 million, through the World Bank-funded Africa Higher Education Centers of Excellence for Development Impact Project (ACE-Impact), to Rsif. The amount will support training of 32 PhD students from Nigeria, and an additional eight students from sub-Saharan African countries. Nigeria joins eight other African countries that are investing in PASET and Rsif. They are: Benin, Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Senegal, Rwanda and Mozambique. 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. PASET members, together with the World Bank, the Government of Korea and the European Union, have now invested a total of USD 54.7 million in RSIF. Private sector partners include Nestlé, South Africa; IBM Research Africa and the Samsung Dream Scholarship Foundation.	PASET members, together with the World Bank, the Government of Korea and the European Union, have now invested a total of USD 54.7 million in RSIF. Private sector partners include Nestlé, South Africa; IBM Research Africa and the Samsung Dream Scholarship Foundation. From 28 - 29 June 2022 Rsif in collaboration with one of the Fund's international partner institutions; University Mohammed VI Polytechnic (UM6P), Morocco, convened a pan-African conference on 'African-led science, technology and innovation for contributing to the SDGs and stimulating global development'. A Donor Roundtable was held with private funders, and follow-up discussions are ongoing. Potential partnerships exploring how to tap into green innovative financing through carbon offsets to widen the revenue base for an Rsif Permanent Fund have been initiated, and are ongoing under the leadership of the PASET Consultative Advisory Group.



Fidele Maniraguha (Rwanda), an Rsif PhD scholar registered at the University of Rwanda, whose research is on monitoring agricultural insect pest using dual-polarisation weather radars. Here, he is monitoring the spread of the fall armyworm in Rwanda. His sandwich placement will be at the Global Research and Development Business Centre of Seoul National University, Korea.

PhD Scholarships

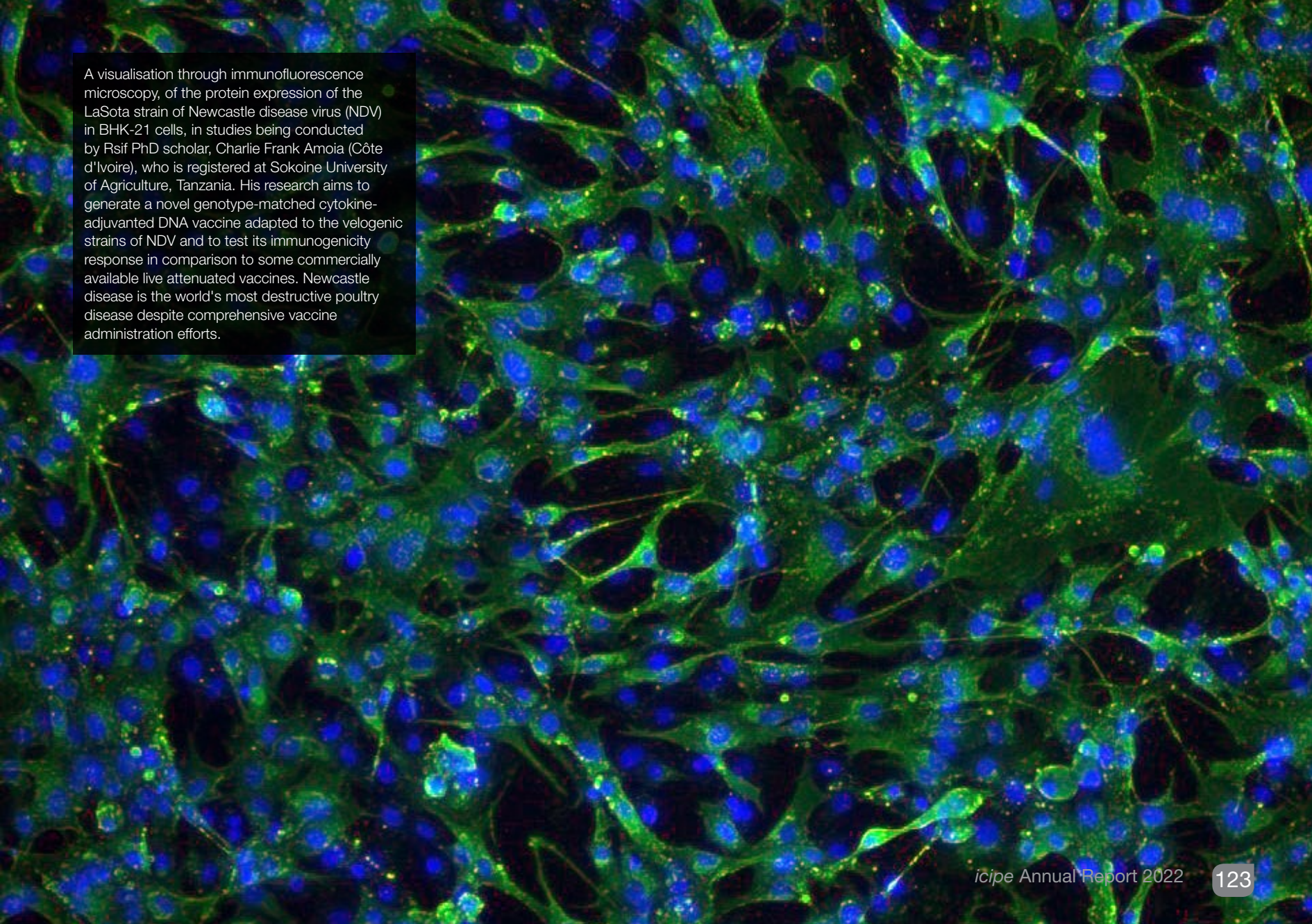
Focus	Context	Progress in 2022	Way forward
Increase interest and inclusivity in Rsif scholarships	The goal of Rsif is to attract the best and brightest talent from across Africa, ensuring geographic and thematic representation. Thus, we have made several improvements in the Rsif Scholarship Calls, including dissemination strategies.	In 2022, 107 scholarships were awarded, bringing the total of Rsif PhD scholarships to 291. The active scholars represent 24 African nationalities. Eight out of 15 cohort 1 scholars had completed their studies by end of 2022.	We will continue to implement strategies to enhance geographic and thematic representation in the Rsif PhD scholarships.
Achieve gender diversity in Rsif	In Africa, women constitute 30 percent of researchers in science fields, about the same as the global average of 28 percent. 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.	Currently, 37 percent (a total of 104 scholars) of 278 active Rsif scholars are female. In 2022, we made several revisions to 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.	We will implement the recommendations of the strategy to enable more women to enter and thrive in the applied sciences, engineering and technology field. The Rsif mentorship platform that is being developed will have resources to support special groups including female scholars.

PhD Scholarships

Focus	Context	Progress in 2022	Way forward
Strengthen Rsif's unique training model	Rsif has a unique approach that combines intra-Africa exchange and international training. The Fund incorporates a network of AHUs. These AHUs are 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.	As of 2022, Rsif had a network of 15 AHUs in 11 African countries and 23 IPIs, three in African countries and the rest spread in Europe, America and Asia.	We continue to strengthen partnerships between the AHUs and IPIs, and to explore innovative intra-Africa mobility exchange opportunities for scholars and partners.
Boost knowledge generation and thought leadership through Rsif	One of Rsif's goals is to contribute to the mentoring and nurturing of doctoral students. This enables them 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.	By 2022, the Rsif scholars had published a total of 122 peer reviewed papers. 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. Building on the success of the trainings and webinars, we have developed an Rsif scholars mentorship platform.	In 2022, we completed the Rsif Capacity Building Strategy, which aims to: prepare the scholars to undertake excellent PhD research and to successfully complete their doctoral studies; and to enhance their post-PhD employability and successful careers whether in academia or in the broader research and innovation sector.

PhD Scholarships

Focus	Context	Progress in 2022	Way forward
Boost research excellence in AHUs **Creating enabling environments for innovation**	One of Rsif's key goals is to promote research excellence, capacity for innovation, as well as enabling environments for entrepreneurship and research commercialisation in Africa, by providing grants and support to faculty in AHUs to implement projects aligned to the PASET priority thematic areas.	A total of 27 research and innovation grants have been awarded to faculty in Rsif AHUs and are at various stages of implementation. A total of 17 peer-reviewed journal articles have been published in international journals by scholars and faculty involved in the research projects. The grantees have made 26 presentations at local and international conferences. Rsif is supporting innovation and entrepreneurship through tailor-made courses offered to students and faculty, and improved frameworks for technology transfer and intellectual property management by helping to develop strategic policies on innovation. Rsif is also promoting university-industry linkages, with 15 partnerships established so far between project teams in the AHUs and industrial partners.	Rsif aims to continue to work with partners to provide technical support to AHUs. Within the pan-African vision of Rsif, we recognise the need to create synergies among organisations, initiatives, sectors and researchers. This will be a key goal as it will lead to stronger research networks and innovation capacity across the continent.
Research commercialisation	Rsif has supported five innovation projects to develop prototypes and business plans for commercialisation. Two biopesticides for the control of postharvest yam fungi have been developed by the Université Félix Houphouët-Boigny and registered for use by by the Ministry of Agriculture, Côte d'Ivoire.	Three patents have been registered by University of Port Harcourt, Nigeria: bioethanol production from non-food starch crops; development of cashew nut shell liquid into pour point depressants for waxy crude oils; and flavonoids in the formulation of gas hydrates inhibitors.	A patent application has been made for a prototype solar heat pump dryer for drying fruits and vegetables, developed by Nelson Mandela African Institute of Science and Technology, Tanzania. Rsif is supporting various projects to advance their research towards commercialisation.



A visualisation through immunofluorescence microscopy, of the protein expression of the LaSota strain of Newcastle disease virus (NDV) in BHK-21 cells, in studies being conducted by Rsif PhD scholar, Charlie Frank Amoia (Côte d'Ivoire), who is registered at Sokoine University of Agriculture, Tanzania. His research aims to generate a novel genotype-matched cytokine-adjuvanted DNA vaccine adapted to the velogenic strains of NDV and to test its immunogenicity response in comparison to some commercially available live attenuated vaccines. Newcastle disease is the world's most destructive poultry disease despite comprehensive vaccine administration efforts.

Research and Innovation Grants

Focus	Context	Progress in 2022	Way forward
Promote gender in innovation	Working collaboratively with AHUs, Rsif has a concerted goal of enabling more female scientists access research and innovation opportunities within the Fund.	Currently, seven female faculty are principal investigators while several others are part of teams in Rsif-supported research and innovation projects.	We will implement the recommendations of the Rsif gender strategy, and also take advantage that will be available on the Rsif mentorship platform for female researchers.
Support Rsif PhD graduates to launch their research and innovation careers	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.	Rsif has introduced the Junior Investigator Research Award Grants. Five grants of up to USD 80,000 each have been awarded to the first cohort of Rsif PhD scholars, who have completed their studies and now hold various positions in universities in Africa.	Our aim is to support the Rsif PhD graduates to transition into employment and to establish research, managerial and other complementary skills that will enable them to become independent researchers.
Rsif-Mozambique innovation partnership	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 PhDscholarships, while USD 1.8 million will be dedicated to research and innovation.	Rsif in collaboration with the Ministry of Higher Education, Science and Technology, Mozambique, has awarded 32 PhD scholarships to Mozambican students, and 12 research and innovation grants to faculty and researchers in universities and research institutions in the country. In November 2022, a results sharing seminar was held in Maputo, Mozambique, bringing together stakeholders from the government and academia in Mozambique, representatives of the World Bank, Mozambican Rsif scholars and the Rsif team, to deliberate progress.	The partnership between Rsif and the government of Mozambique is indicative of the Fund's rapid acceptance among African countries, as an important actor in national development. The progress provides evidence of Rsif as a platform for scientists and innovators to tap into the Rsif network; its pan-African vision for scientific research and innovation capacity building; and *icipe*'s extensive research and innovation expertise.

Corononcodes (*C. siculus*)
A delicate (but courageous) small fly, which is a species of Corononcodes of the Dipteran family Acroceridae, commonly known as small-headed flies. Observations of Acroceridae indicate that members of the family are exclusively parasitoids of spiders (hence the “courage”). With no information to the contrary, Corononcodes are also thought to be spider parasitoids. In Kenya, *icipe* researchers have collected two species of Corononcodes, the first records of the genus from East Africa.

2022, 2021 AND 2020 FINANCIAL STATEMENTS

Statement of Financial Position

DESCRIPTION	2022 "USD 000"	2021 "USD 000"	2020 USD "000"
Non-CurrentAssets	8,551	8,270	9,087
CurrentAssets	61,735	62,337	41,664
TotalAssets	70,286	70,607	50,751
Less:Liabilities	(45,497)	(46,583)	(26,704)
Total Assets less Total Liabilities	**24,789**	**24,024**	**24,047**
Financed By:			
Capital Fund and Reserves	**24,789**	**24,024**	**24,047**

Statement of Comprehensive Income & Activities

DESCRIPTION	2022 "USD 000"	2021 "USD 000"	2020 "USD 000"
Income			
UnrestrictedGrants	2,467	3,592	4,977
RestrictedGrants	33,401	32,150	25,128
Other	3,473	2,164	2,107
Total Income	**39,341**	**37,906**	**32,212**
Appropriation			
Research	36,095	34,219	27,630
Institutional	5,489	5,649	5,929
Overheads	(2,273)	(2,491)	(1,859)
Transfer to Reserves	30	529	512
Total Appropriations	**39,341**	**37,906**	**32,212**

Note: The detailed Financial statements are available at www.*icipe.org*

Annexes

Annex A: Awards

External awards to *icipe* Staff

icipe 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, *icipe* 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 *icipe* 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.

icipe Governing Council Student Awards Winners

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; Ceva Santé Animale (CEVA), France; 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), Leipzig, Germany; Ifakara Health Institute, Tanzania; International Livestock Research Institute (ILRI); Johns Hopkins University, USA; Kenya Medical Research Institute (KEMRI); Kenya Wildlife Service (KWS); Kilimanjaro Christian Medical University College (KCMUCo), Moshi, Tanzania; KTH Royal Institute of Technology in Stockholm, Sweden; Liverpool School of Tropical Medicine, 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, Kenya (Directorate of Veterinary Services); 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; 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; Kenya Medical Research Institute (KEMRI) (Wellcome Trust Research Programme, Kenya, and Centre for Virus Research); Ultimate Products (Aust) Pty Ltd, Australia; Umeå University, Sweden; University of Bonn, Germany; University of Glasgow, UK; University of Nairobi, Kenya; University of Pretoria, South Africa; United States Department of Agriculture (USDA), USA; 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 of Marsabit and Isiolo, Kenya; Director of Veterinary Services (DVS) (Kabete Veterinary Research Laboratories), Nairobi, Kenya; Kenya Livestock Producers Association (KLPA); Kenya Tsetse and Trypanosomiasis Eradication Council (KENTTEC); Kenya Wildlife Service (KWS); Marsabit County Livestock Office, Kenya; Max Planck Institute for Chemical Ecology, Jena, Germany; Ministry of Agriculture, Livestock & Fisheries and Department of Veterinary Services in Kwale County; Mount Kenya University, Kenya; National Museums of Kenya; Smithsonian Institution, USA; Sokoine University of Agriculture, Tanzania; Tanzania National Parks; Tanzania Wildlife Research Institute (TAWIRI); University of Maryland, USA; University of Würzburg, Germany; 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; Agricultural Research for Development (CIRAD), France; Agroscope, Switzerland; Anglican Development Services, Kenya; Anglican Development Services Eastern (ADSE), Kenya; Austin Investment Ltd; Avocado Growers Association, South Africa; Biocontrol Research Laboratories, India; Bioversity International, Italy; Busitema University, Uganda; CABI Africa; 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 Seed Co. Ltd, Kenya; Éléphant Vert Kenya; Embu University, Kenya; Ethiopian Institute of Agricultural Research (EIAR); Ethiopian Agricultural Transformation Agency; Farmer groups and mango growers; Farmtrack 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;

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; 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; Mikocheni Agricultural Research Institute, Tanzania; Ministries of Agriculture in Botswana, Namibia, Zambia and Zimbabwe; Ministry of Agriculture and Natural Resources, Ethiopia; Ministry of Agriculture, Animal Industry and Fisheries, 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; 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; Real IPM Ltd, Kenya; Research Institute of Organic Agriculture (FiBL), Switzerland; Rothamsted Research, United Kingdom; Royal Museum for Central Africa, Tervuren, Belgium; Sanergy Ltd, Kenya; Seed Co. Zimbabwe Limited; Send a Cow; Sokoine University of Agriculture, Tanzania; Tanzanian Pesticide Research Institute, 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; 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; University of Bonn, Germany (Center for Development Research - ZEF); University of Hohenheim, Germany; University of Nairobi, Kenya; University of Pavia, Italy; University of Tennessee, USA; University of Sousse (Higher Agronomic Institute of Chott-Mariem), Tunisia; University of Zambia; Wageningen University and Research Centre (WAU) (Plant Research International), the Netherlands; WeRATE; World Agroforestry Centre (ICRAF); Zambia .

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 Agrononia 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, Zimbambwe; 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.

Environmental Health Theme

Addis Ababa University, Ethiopia; African Union Inter-African Bureau for Animal Resources (AU-IBAR); Agricultural Sector Development Programme, Zanzibar, Tanzania; Aklilu 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.

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
AFD	French Development Agency
AHUs	African Host Universities
ANR	Agence Nationale de la Recherche / French National Research Agency
ARPPIS	African Regional Postgraduate Programme in Insect Science
AU	African Union
AU-IAPSC	African Union Inter-African Phytosanitary Council
AWARD	African Women in Agricultural Research and Development
BBSRC	Biotechnology and Biological Sciences Research Council, UK
BCCN	Basic Crash Course Nematology
BecA-ILRI Hub	Biosciences eastern and central Africa – International Livestock Research Institute Hub
BioInnovate Africa Programme	Bioresources Innovations Network for Eastern Africa Development Programme
BLE	German Federal Agency for Food and Agriculture
BMZ	Federal Ministry for Economic Cooperation and Development
BMZ	Federal Ministry for Economic Cooperation and Development, Germany
CAP-Africa	Combating arthropod pests for better health, food and resilience to climate change
CBFAMFEW II	Community-based fall armyworm monitoring, forecasting, and early warning system (phase II)
CIAT	International Center for Tropical Agriculture
CIRAD	French Agricultural Research Centre for International Development
COMBAT	Controlling and progressively minimising the burden of animal trypanosomosis
COVID-19	Coronavirus disease 2019
CultiAF programme	Cultivate Africa's Fund, a partnership between Future Australian Centre for International Agricultural Research (ACIAR) and International Development Research Centre (IDRC).
DAAD	German Academic Exchange Service
Danida	Danish International Development Agency
DEVCO	Directorate General for International Cooperation and Development Offices
DFG	German Research Foundation
DFG	German Research Foundation
DLCO-EA	Desert Locust Control Organization of Eastern Africa
DRIP	Dissertation Research Internship Programme
EAC	East African Community
EANBiT	Eastern Africa Network for Bioinformatics Training
EASTECO	East African Science and Technology Commission
EC	European Commission
ESA	Entomological Society of America
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAW-IPM	Integrated pest management strategy to counter the threat of invasive fall armyworm to food security in eastern Africa
FCDO	UK's Foreign, Commonwealth & Development Office
FiBL	Research Institute of Organic Agriculture
FNIH	Foundation for the National Institutes of Health
GC-MS	Gas chromatography – mass spectrometer
GFFA	Global Forum for Food and Agriculture
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

INSFEED	Insect feed for poultry and fish production in sub Saharan Africa
IPIs	International partner institutions
IPM	Integrated Pest Management
IRD	French National Research Institute for Sustainable Development
IVM	Integrated vector management
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
NENA	Near East and North Africa region
NIH	National Institutes of Health, USA
Norad	Norwegian Agency for Development Cooperation
NRF	National Research Fund
NSF	National Science Foundation
NTD	Neglected tropical diseases
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
PCN	Potato cyst nematode
RCU	Regional Coordination Unit
Rsif	Regional Scholarship and Innovation Fund
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
SIPFEED	Scaling-Up Insect-Based Protein Feed Technologies and Practices for Enhanced Poultry Production in Ethiopia
SNNPR	Southern Nations, Nationalities and Peoples' Region
SNSF	Swiss National Science Foundation
SRC	Swedish Research Council
STEM	Science, technology, engineering and mathematics
SwECCA	Swedish Development Cooperation team for Environment and Climate Change in Africa
TEA	Technoeconomic analysis
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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A frontal of the nymph (larva) of a tree hopper (family, Membracidae; genus Oxyrhachis), a member of the order Hemiptera, the true bugs. Membracids are renowned for their bizzare forms and for their mimicry of thorns on the branches of shrubs and trees.

Annual Report
2022

icipe was established in 1970 in direct response to the need for alternative and environmentally friendly pest and vector management strategies. Headquartered in Nairobi, Kenya, *icipe* works through the 4Hs Themes – Human Health, Animal Health, Plant Health and Environmental Health – a holistic and integrated framework aimed to improve the overall well-being of communities in Africa, with sustainable development as its basis.

Our mission is to help alleviate poverty, ensure food security and improve the overall health status of peoples of the tropics, by developing and extending management tools and strategies for harmful and useful arthropods, while preserving the natural resource base through research and capacity building.

Our vision is to pioneer global science in entomology, to improve the well being and resilience of people and the environment to the challenges of a changing world, through innovative and applied research, alongside deep exploratory study, impact assessment, evaluation and sustainable capacity building.

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WOAH Collaborating Centre for Bee Health in Africa
Reference Centre World Organisation for Animal Health Founded as OIE

STOCKHOLM CONVENTION
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