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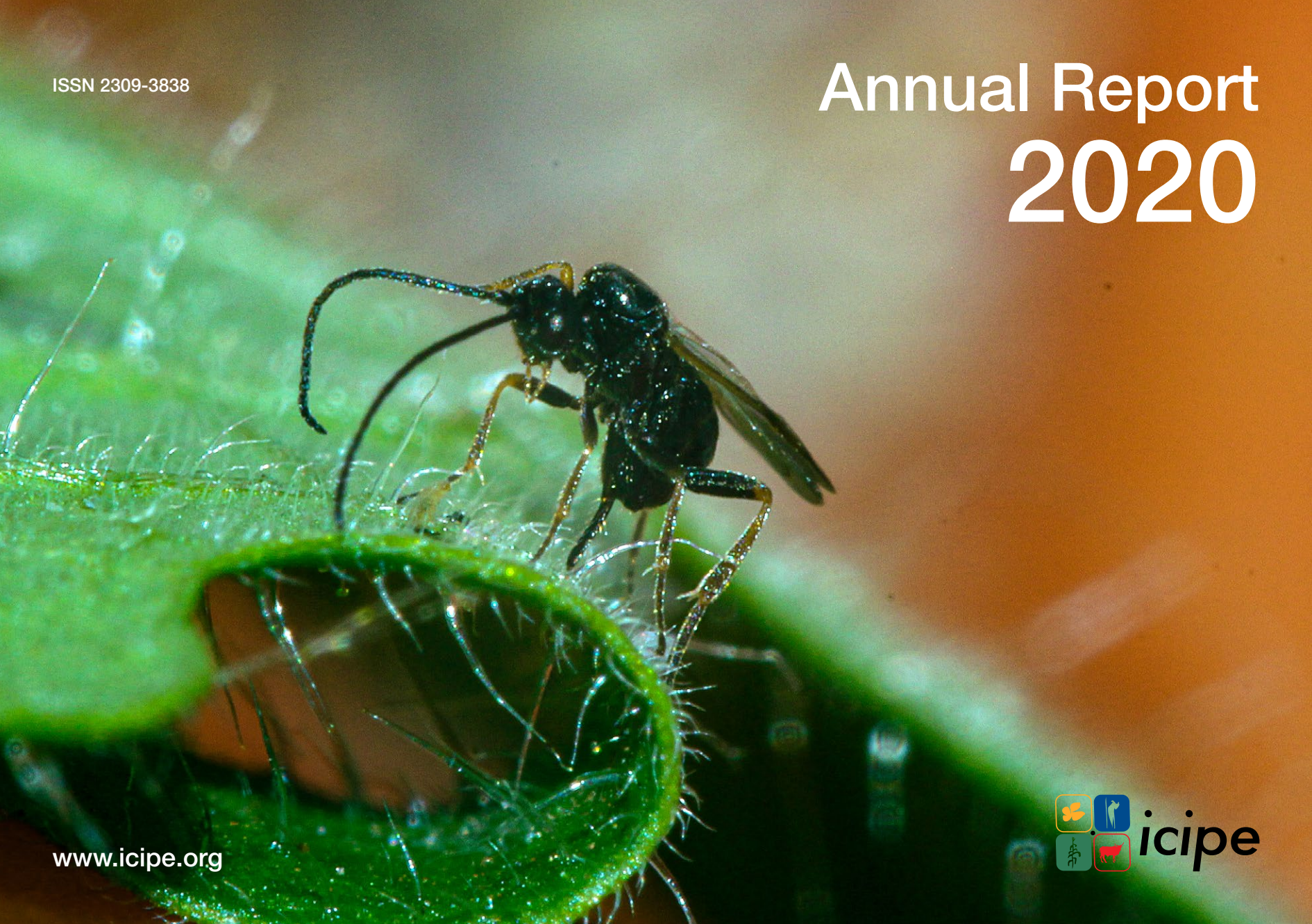
Annual Report 2020



www.icipe.org

icipe

Caura rufiventris, also known as the stink bug, has a brownish ventral side, while the dorsal side is exquisitely coloured.

Annual Report
2020

April 2021

International Centre of Insect Physiology and Ecology
PO Box 30772-00100 Nairobi, Kenya | icipe@icipe.org | www.icipe.org

ACKNOWLEDGEMENT

We gratefully acknowledge the financial and technical support of our core donors: Swiss Agency for Development and Cooperation (SDC), Switzerland; Swedish International Development Cooperation Agency (Sida), Sweden; UK's Foreign, Commonwealth & Development Office (FCDO); Ministry of Education, State Department of University Education and Research, Kenya; and Government of the Federal Democratic Republic of Ethiopia.

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

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April 2021

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

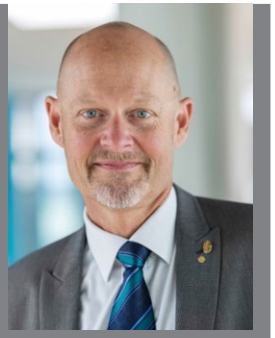
Cover photo: A wasp known scientifically as *Dolichogenidea gelichiidivoris*, imported from Peru and released in Kenya by *icipe* for the control of the devastating tomato leafminer, *Tuta absoluta*.

All photos, unless otherwise specified, belong to *icipe*.

The full-page insect photos have all been taken at the *icipe* Duduville campus and its environs, by our budding macro photographer, Dr Sevgan Subramanian, Principal Scientist and Head, Environmental Health Theme.

Contents

Foreword



Prof. Dr Bill Hansson
Chair, *icipe* Governing Council

As the world begins the recovery journey from the COVID-19 pandemic, we re-emphasise the importance of insects, and insect science.

In 2020, as part of reflections on *icipe*'s 50th anniversary, we demonstrated the validity of insects, and insect science, as a basis for better agricultural production, better health, and better livelihoods. And the *icipe Vision and Strategy 2020 – 2025* calls for renewed attention on critical, yet neglected areas of insect science; and the need to address the global decline in insects and biodiversity.

As the COVID-19 pandemic recovery journey begins, these messages are worth emphasising, in harmony with broader efforts to protect stability and predictability of funding in science, technology and innovation (STI).

While STI has been at the frontline in the fight against the pandemic, previous examples show that in crises recovery, investments in this sector are among the most affected. Ironically, this is precisely when such commitments are hugely needed.

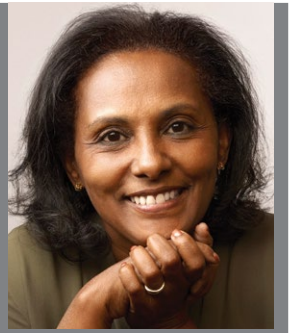
In a policy brief published in 2020, the United Nations Conference on Trade and Development (UNCTAD), makes a case for safeguarding STI budgets during the COVID-19 crisis and its aftermath, as the only true way to achieve the 2030 Agenda for Sustainable Development. This advice is especially important for developing countries, where, despite continued growth in research and development (R&D) expenditure over recent years, levels remain modest and STI capabilities limited.

In Africa, the COVID-19 aftermath is complex: real gross domestic product (GDP) growth, as projected by the United Nations Economic Commission for Africa (ECA), is expected to fall to 1.8 percent in the best-case scenario; or contract to -2.6 percent in the worst case, pushing 27 million people into extreme poverty, with about 19 million workers losing their jobs. Major exports like oil, textiles and fresh-cut flowers; as well as the tourism sector, have all been affected, and the rising debt burden of several African countries is unsustainable.

But, even against this difficult fiscal scenario, the continent's STI sector must not be jeopardised. As UNCTAD recommends, alongside other developing countries, African countries should design recovery packages that leverage STI. They should also revisit and strengthen their R&D budgetary commitments, to treat such expenditures as "protected funding lines", and as a positive signal to other stakeholders. Meanwhile, sustainability of STI funding should be considered in discussions for liquidity and fiscal stimulus, between African countries and international partners.

At *icipe*, we are appreciative of our partners, including African governments, development organisations and numerous others, that have continued or commenced support to the Centre. As evidenced in this report, *icipe* continues to exemplify return of investment in insect science specifically, and in STI in general, as a way of building and securing Africa's prosperity.

Preface



Dr Segenet Kelemu
Director General, *icipe*

We are greatly appreciative of the support and partnerships that made our accomplishments in 2020 possible.

We present this *Annual Report* with utmost humility and gratitude that in one of the most difficult years in recent history, we were able to make commendable progress across all our activities.

The Management and Leadership chapter outlines how the Centre has adapted to the 'business as unusual' scenario occasioned by the COVID-19 pandemic. The chapter also spotlights *icipe*'s golden jubilee as a much-needed beacon of hope, and a time for the Centre to re-dedicate itself to the mission of transforming livelihoods through insect science. This resolve is supported by growing investments, collaborations, as well as recognitions of the Centre and its staff, by national, regional and global partners.

Four chapters of this report are dedicated to achievements across the *icipe* 4H Themes: Human, Animal, Plant and Environmental Health, working together with the Centre's Research Support Units. Our globally exciting discovery of a microbe that can block malaria transmission presents a novel avenue for much-needed tools to control this devastating disease. We have also generated a wealth of knowledge to advance tsetse management, enable development of strategies for camel health, and facilitate integrated control of pathogens and vectors in human–livestock–wildlife interfaces. With accumulating evidence of the benefits of push–pull, *icipe* and partners have developed a third-generation version. Also, we have created a synergistic package consisting of the push–pull technology, biopesticides and natural enemies, to control the invasive and destructive fall armyworm. And the Centre has helped to mitigate the locust invasion in eastern Africa by supporting national control efforts, predicting breeding sites, and advancing basic knowledge on the insects. In addition, we achieved a major milestone for tomato production in Africa with the release of a natural enemy for the devastating leafminer, *Tuta absoluta*, while also tackling a plethora of pests of fruits, vegetables and staple crops.

As we highlight nutrition as a critical, emerging issue that is affecting African honey bees, we also present seminal knowledge on stingless bee gut microbiota, which will enhance domestication and resilience of this variable resource. Meanwhile, in Ethiopia, our initiatives are enabling thousands of young people secure dignified and fulfilling work along honey and silk value chains. The Insects for Food and Feed and Other Uses chapter demonstrates our globally recognised achievements in mainstreaming insects as a transformative force in the food system. Three chapters focus on the pivotal roles played by the: Social Science and Impact Assessment Unit, which continues to flag factors around the adoption, economic benefits, and gender inclusiveness of our technologies and strategies; the Technology Transfer Unit, which has been critical in re-aligning our dissemination efforts around the COVID-19 pandemic scenario; and the Data Management, Modelling and Geo-Information Unit that is integrating advanced data analytics and approaches into our activities.

*icipe'*s sustained contribution to capacity building for science, technology and innovation is presented under the: Capacity Building and Institutional Development Programme; BioInnovate Africa Programme (https://bioinnovate-africa.org); and the Regional Scholarship and Innovation Fund (RSIF – https://www.rsif-paset.org/), of the Partnership for Skills in Applied Sciences, Engineering and Technology (PASET). The latter two are managed by *icipe*.

Management and Leadership

Core donors: Swiss Agency for Development and Cooperation (SDC), Switzerland; Swedish International Development Cooperation Agency (Sida), Sweden; UK's Foreign, Commonwealth & Development Office (FCDO); Ministry of Education, State Department of University Education and Research, Kenya; and Government of the Federal Democratic Republic of Ethiopia.

2020 IN BRIEF

COVID-19 pandemic response
Our adaptation efforts to operate within a "business as unusual" scenario.

icipe@50
Commemoration and re-dedication to transforming livelihoods with insect science. *icipe Vision and Strategy* 2021 – 2025 launched.

Resource mobilisation
Overview of donor agreements, core donors, new donors and project donors.

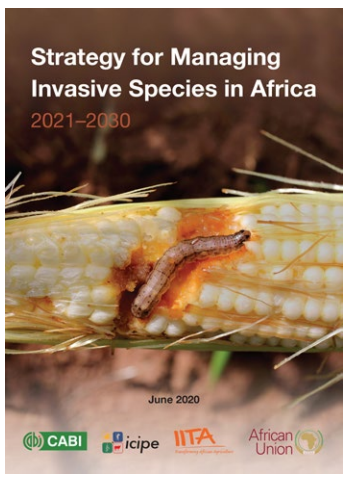
Partnerships
New memoranda of understanding; non-disclosure agreements; and project partner agreements.

Communications
News mentions, top stories, audience reach, geographical reach and social media reach.

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

Awards
External and internal awards and recognitions made to *icipe* and several staff of the Centre.

Staff news
94 staff recruited, bringing the total to 571.



icipe, CABI and the International Institute of Tropical Agriculture (IITA), have developed a 10-year strategy for managing invasive species in Africa. Produced jointly with the African Union Commission, the document originates from a stakeholders' workshop co-organised by the three partners in February 2018, under the theme: Tackling Invasive Species in Africa.

Link: http://www.icipe.org/system/files_force/Strategy-for-Managing-Invasive-Species-in-Africa-20212030.pdf?download=1

Management and Leadership

COVID-19 pandemic response

Alongside the rest of the world, at *icipe* we have aimed to respond to the COVID-19 pandemic with resilience and determination. The goal has been to safeguard our staff and their families, as well as our visitors, while minimising disruptions on commitments to our stakeholders, including our development partners, donors, collaborators and beneficiaries.

We have:

icipe@50

In 2020, *icipe* commemorated its 50th anniversary with a range of activities throughout the year, culminating in a successful event on 20 November 2020. Held under the theme: 'Insects for Life', the hybrid event combined in-person and virtual participation, in observance of COVID-19 safety protocols.

> The centrepiece of the occasion was a recorded address by His Excellency Hon. Uhuru Kenyatta, President of the Republic of Kenya. Other esteemed speakers included: Hon. Peter Munya, Cabinet Secretary, Ministry of Agriculture, Livestock, Fisheries and Cooperatives, Republic of Kenya; Ambassador Raychelle Omamo, Cabinet Secretary for Foreign Affairs, Republic of Kenya; with remarks from Prof. Dr Bill Hansson, Chair, *icipe* Governing Council; Dr Segenet Kelemu, Director General & CEO, *icipe*; and uplifting video messages from our donors and collaborators.

The official commemoration of the Centre's golden jubilee was important: it was an occasion to contemplate the power of visionary thinking, of science and of movements of support and partnerships. *icipe*'s milestone was a much-needed beacon of hope, and a time for the Centre to re-dedicate itself to the mission of transforming livelihoods with insect science.

Fittingly, the ***icipe Vision and Strategy 2021 – 2025* was launched by His Excellency President Uhuru Kenyatta, during the *icipe*@50 celebrations.** The document positions the Centre as a leader in insect science, as well as research, development and innovation in Africa, and across the world. Specifically, the Strategy identifies and proposes responses from *icipe*, in regard to a diverse and tactical set of emerging developmental challenges and opportunities.
Link: http://www.icipe.org/publications/corporate-publications/vision-and-strategy

A commemorative plaque erected to mark *icipe*'s golden jubilee.
The outline is based on the shape of a butterfly – the eternal metaphor of transformation and evolution – to depict our remarkable journey over the past 50 years. The encompassed mosaic of insects is an emblem of the Centre's unwavering commitment to its vision and mission, befitting of the slogan: 'Insects for Life'.

Resource Mobilisation

Overview

Between 1 January – 31 December 2020, *icipe* signed donor agreements with a total value of **USD 16.3 million** in restricted projects. A total of **USD 18.8 million** in restricted projects has been approved by donors with contracts pending signatures. Additionally, several proposals valued at **USD 31.3 million** in restricted and strategic long-term funding projects have been submitted to various donors and are at various stages of review.

Core donors

Swiss Agency for Development and Cooperation (SDC), Switzerland; Swedish International Development Cooperation Agency (Sida), Sweden; UK's Foreign, Commonwealth & Development Office (FCDO); Ministry of Education, State Department of University Education and Research, Kenya; and Government of the Federal Democratic Republic of Ethiopia.

New donors 2020

The Stichting IKEA Foundation through Biovision Foundation for Ecological Development; Cambridge Africa ALBORADA Research Fund; Impaxio GMBH; Open Philanthropy; The Curt Bergfors Foundation Food Planet Prize.

Investors in PASET-RSIF

African governments: Benin*, Burkina Faso*, Côte d'Ivoire, Ghana*, Kenya, Rwanda and Senegal* (*joined in 2020). 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; French Agricultural Research Centre for International Development (CIRAD); Bayer: Science for a Better Life; Bertha Foundation; British Council- Newton Fund Institutional Links; Bill & Melinda Gates Foundation; BioInnovate Africa Programme; Biotechnology and Biological Sciences Research Council (BBSRC); Biovision Foundation for Ecological Development, Switzerland; Biovision Africa Trust; Cultivate Africa's Future (CultiAF) through International Development Research Centre (IDRC)/Australian Centre for International Agricultural Research (ACIAR); Danish International Development Agency (DANIDA); Ethiopian Catholic Church Social Development Commission (ECC-SDCBOM); ETH Zurich; European Union (EU); Food and Agriculture Organization of the United Nations (FAO); Future Leaders – African Independent Research (FLAIR); German Academic Exchange Service (DAAD); Federal Ministry for Economic Cooperation and Development (BMZ), Germany; German Research Foundation (DFG); Global Challenges Research Fund (GCRF); Innovate UK; International Atomic Energy Agency (IAEA); International Development Research Centre (IDRC); International Fund for Agricultural Development (IFAD); Institute of Research for Development (IRD); JRS Biodiversity Foundation; LEAP-Agri (A long-term EU-Africa research and innovation partnership on food and nutrition security and sustainable agriculture); Keele University; Mastercard Foundation; Max Planck Institutes; Mozilla Foundation; Medical Research Council, UK; United States Agency for International Development-Partnerships for Enhanced Engagement in Research (USAID-PEER) Science program with funding from National Academy of Sciences (NAS); United States National Institutes of Health (NIH); National Geographic Society; National Research Fund (NRF), Kenya; Netherlands Organisation for Scientific Research (NWO); National Science Foundation (NSF); Norwegian Agency for Development Cooperation (Norad); Research Institute of Organic Agriculture (FiBL); Rockefeller Foundation; Biotechnology and Biological Sciences Research Council, UK, through Rothamsted Research, UK; The Royal Society, UK; Swedish University of Agricultural Sciences (SLU); Swedish International Development Cooperation Agency (Sida), Sweden; Scottish Funding Council; Swiss National Science Foundation (SNSF); Swiss Agency for Development and Cooperation (SDC), Switzerland; TWAS, The World Academy of Sciences through Organization for Women in Science for the Developing World (OWSD); United Nations Environment Programme (UNEP); United States Agency for International Development (USAID); United States Department of Agriculture (USDA); United Nations Office for Project Services (UNOPS); University of Cambridge; University of Glasgow; USAID—United States Agency for International Development's IPM Innovation Lab (Feed The Future Innovation Lab for Integrated Pest Management) of Virginia Tech, USA; Wageningen University; Wellcome Trust, UK; World Bank Group; World Federation of Scientists; World Health Organization (WHO); World Trade Organization (WTO) – Enhanced Integrated Framework (EIF).

Partnerships

In 2020, *icipe* signed several agreements including: memoranda of understanding (MoUs); non-disclosure agreements; and project partner agreements.

Project partners

Treasure Industries Ltd, Kenya
Insect feed for poultry and fish production in sub-Saharan Africa.
Feed formulation, manufacture of feeds and delivery to study sites.

FH ASSOCIATION (Food for the Hungry)
Scaling-up Climate-Smart Pest Management Approaches for Enhanced Maize and Tomato Systems Productivity in Eastern Africa (SCLAMP-EA).
Selection, training and facilitation of champion farmers and extension agents for digital-based learning and information exchange, in Uganda.

Haramaya University, Ethiopia
SCLAMP-EA
Mass production of parasitoids for maize and tomato IPM, for mass release in Ethiopia.

Kamaki Beekeepers Cooperative Society Ltd, Kenya
Improving beekeeping in arid and semi-arid lands in Kenya (ASALs)
Production of beehives and facilitating farmers participation.

MoUs

Safi Organics, Kenya –
Integrated Sustainable Production of Tomatoes (ISPOT) project
Collaboration in scientific research, knowledge exchange, capacity and institutional development.

Muhimbili University of Health and Allied Sciences (MUHAS), Tanzania
Establishment of the MSc Bioinformatics programme in Tanzania.

Chinese Academy of Agricultural Sciences (CAAS), China
Collaboration in science and technology, and training for the management of pests and natural resources in China and Africa.

Institute of Research for Development (IRD), France
Use of parasitoids to control lepidopteran stemborers and fall armyworm–stemborers interactions and population dynamics.

Jaramogi Oginga Odinga University of Science and Technology, Kenya
Collaboration in scientific research, knowledge exchange, capacity and institutional development.

MOYESH partners

Tigray Agricultural Research Institute (TARI), Ethiopia
Promoting market-oriented smallholder sericulture and apiculture development in Tigray Regional State, Ethiopia.

Debre Berhan University (DBU), Ethiopia
Promoting market-oriented smallholder sericulture development in the North Shewa Zone, Amhara Regional State.

Kifiya Financial Technology PLC, Ethiopia
Developing digital procurement system (B2B marketplace) and B2C E-Commerce marketplaces and asset tracking technology.

Collaborators in provision of flexible and affordable financial services and products to MOYESH project partnering youth
Lion International Bank S.C., Ethiopia
Cooperative Bank of Oromia S.C., Ethiopia
Bunna International Bank S.C., Ethiopia
Debub Global Bank S.C., Ethiopia

Communications

1247 news items published

4.46 billion people potentially reached through the news coverage

72 countries in which coverage was achieved

797 number of publications in which *icipe* was mentioned

85,157 Visitors to *icipe* website

316,987 page views of *icipe* website

109.79 million people potentially reached through the *icipe* social media activity

Some of the media outlets in which *icipe* received coverage:

Al Jazeera; Thomson Reuters; Deutsche Welle; BBC World News; Yahoo! News; Xinhua News; The Guardian, UK; Swissinfo; Mediacongo.net, DailyHunt English, The People, London, UK; AllAfrica.com; Advance Africa; Saada Online; Daily Nation, The Star, Standard Digital News, all in Kenya.

Top countries, ranked in order of visitor numbers to *icipe* website

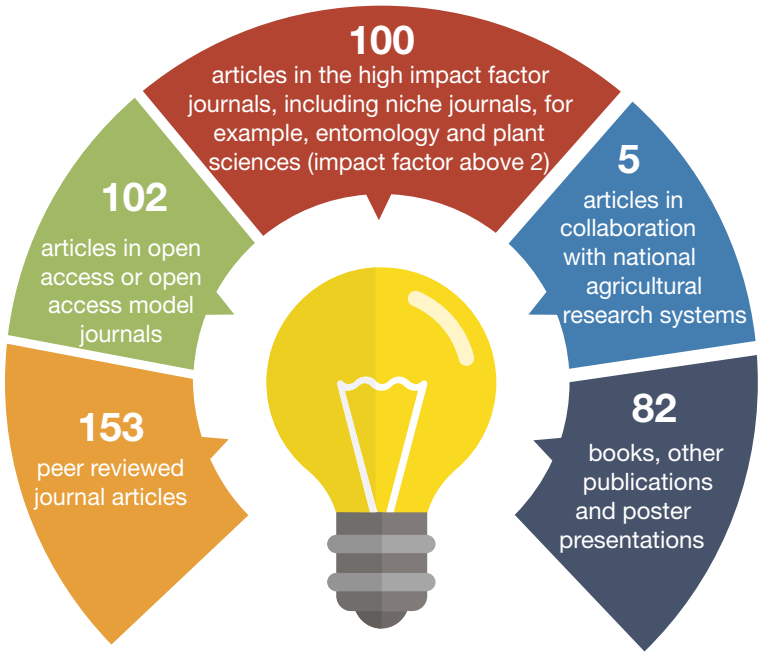
Kenya, United States of America, Ethiopia, United Kingdom, Uganda, Nigeria, Tanzania, India, South Africa, Germany

Top stories

- *icipe* scientists discover malaria transmission-blocking microbe in mosquitoes
- Boost for *icipe* malaria reduction efforts
- New arsenals for fall armyworm control
- *icipe* launches mass release of indigenous natural enemies to control fall armyworm
- *icipe* wins Food Planet Prize
- Total control of *Tuta absoluta*

Scientific Publications

In 2020, *icipe* published and produced:



Some of the top ranked 2020 papers based on online attention:

Herren J.K., et al.; A microsporidian impairs *Plasmodium falciparum* transmission in *Anopheles arabiensis* mosquitoes. *Nature Communications* 11, 2187. https://doi.org/2110.1038/s41467-41020-16121-y. IF 12.121. ALTMETRIC 1129
Ranked first of the three tracked articles of a similar age in *Nature Communications.*

Becker J.M. et al., Pesticide pollution in freshwater paves the way for schistosomiasis transmission. *Scientific Reports* 10, 3650. https:// doi. org/3610.1038/s41598-41020- 60654-41597. IF 3.998. ALTMETRIC 65
Ranked first of the seven tracked articles of a similar age in *Scientific Reports*.
This article is in the 95th percentile (ranked 11,739th) of the 265,923 tracked articles of a similar age in all journals.

Kimathi E. et al., Prediction of breeding regions for the desert locust *Schistocerca gregaria* in East Africa. *Scientific Reports* 10, 11937. https://doi.org/11910.11038/s41598- 11020-68895-11932. IF 3.998. ALTMETRIC 59
Ranked first of the five tracked articles of a similar age in *Scientific Reports*.
This article is in the 95th percentile (ranked 15,000th) of the 301,155 tracked articles of a similar age in all journals.

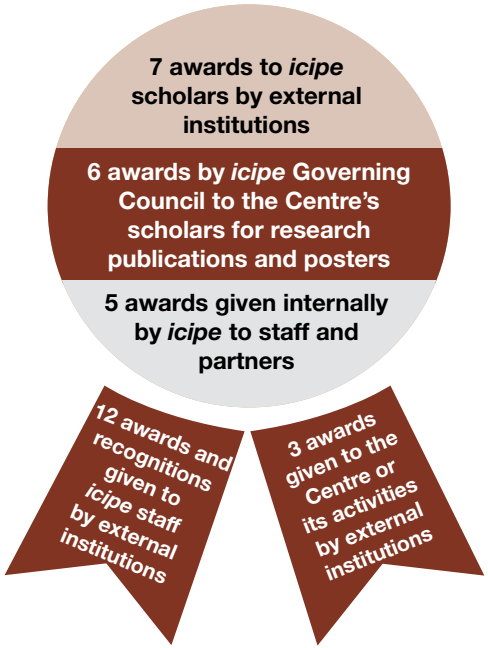
Cheseto X. et al., Chemistry and sensory characterization of a bakery product prepared with oils from African edible insects. *Foods* 9(6), 800; https:// doi.org/810.3390/foods9060800. IF 3.011. ALTMETRIC 28
Ranked in the top 5% of all research outputs scored by Altmetric.

Baleba S.B.S. et al., Stable flies, *Stomoxys calcitrans* L. (Diptera: Muscidae), improve offspring fitness by avoiding oviposition substrates with competitors or parasites. *Frontiers in Ecology and Evolution* 8, 5. https://doi.org/10.3389/fevo.2020.00005. IF 2.08.ALTMETRIC 45
Ranked in the top 5% of all research outputs scored by Altmetric.

Cross F.R. et al., Arthropod intelligence? The case for *Portia*. *Frontiers in Psychology* 11, 568049. doi: 568010.563389/fpsyg.562020.568049. IF 2.067. ALTMETRIC 64
Ranked in the top 5% of all research outputs scored by Altmetric.

Awards, Recognitions and Nominations

In 2020, *icipe* and several staff of the Centre received external and internal awards and other recognitions. These are:



Outstanding Partner of the Year (2020), awarded by *icipe* to the Swiss Agency for Development Cooperation (SDC), for long-standing relationship since 1972. Beyond core funding, SDC has funded other activities including: the "greening of *icipe*" initiative; renovations and upgrades of R&D facilities; periodic reviews; development of the Centre's Vision and Strategy; and the *icipe*@50 celebrations.

Some of the notable awards are listed below:

***icipe* was awarded the prestigious, USD 1 million Curt Bergfors Foundation Food Planet Prize** in recognition of the Centre's pioneering R&D activities on insects for food, feed and other uses.

Prof. Dr Bill Hansson, Chair, *icipe* Governing Council has been awarded the Cross of Merit of the Federal Republic of Germany, 1st Class (Bundesverdienstkreuz 1. Klasse), by the German President Franz Walter Steinmeier.

Recognition of *icipe* as a Food and Agriculture Organisation of the United Nations (FAO) Reference Centre for vectors and vector-borne animal diseases from 2020 – 2024 (initially appointed for the period 2012 – 2016; and 2016 – 2020).

Recognition of *icipe* as a Stockholm Convention Regional Centre from 2020 – 2023 (initially designated for the period 2011 – 2015, with a further formal endorsement for 2016 – 2019).

Workneh Ayalew, Project Coordinator, More Young Entrepreneurs in Silk and Honey (MOYESH) project, was appointed member of the Job Advisory Council of the Ethiopia Jobs Creation Commission from February 2020 for a two-year term.

Segenet Kelemu, Director General, *icipe*, was awarded the Ellis Island Medal of Honor, by the Ellis Island Honors Society, New York, USA. She was also appointed as a member of the newly created Council of Economic Advisors to the Government of Ethiopia, announced by the Office of the country's Prime Minister; and as an International Fellow of the Academy's General section by the Royal Swedish Academy of Agriculture and Forestry.
In addition, Dr Kelemu received the TWAS Regional Award from The World Academy of Sciences Sub-Saharan Africa Regional Partner (TWAS-SAREP)
(See detailed citation in Annex A).

Baldwyn Torto, Head, *icipe* Behavioural and Chemical Ecology Unit, was awarded the 2020 ESA Nan-Yao Su Award for Innovation and Creativity in Entomology by the Entomological Society of America.

Menale Kassie, Head, *icipe* Social Science and Impact Assessment Unit, was awarded the TWAS Siwei Cheng Award in Economic Sciences, for advancing our understanding of the process and impacts of multiple-technology adoption in complex social and agricultural environments in sub-Saharan Africa.

A comprehensive list of all awards, recognitions and nominations is included in the annexes.

Aspavia sp. belongs to the family Pentatomidae, and they are occasional pests of grasses and rice.

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 that can be integrated into other disease management efforts.

Donors: Biovision Foundation for Ecological Development, Switzerland; Bill & Melinda Gates Foundation; German Academic Exchange Service (DAAD); Federal Ministry for Economic Cooperation and Development (BMZ); Foundation for the National Institutes of Health (FNIH), USA; German Research Foundation (DFG), Germany; Global Environment Facility (GEF)/United Nations Environment Programme (UNEP); Government of Kenya; Innovative Vector Control Consortium, UK; Kenya National Research Fund; National Institutes of Health (NIH), USA; National Science Foundation (NSF), USA; Norwegian Agency for Development Cooperation (Norad); Open Philanthropy Project, USA; Swedish International Development Cooperation Agency (Sida); Swiss National Science Foundation (SNSF); Swiss Agency for Development and Cooperation (SDC); The Swedish Research Council, Sweden; UK's Foreign, Commonwealth & Development Office (FCDO); Wellcome Trust, UK; World Health Organization-Regional Office for Africa (WHO-AFRO); Medical Research Council (MRC), UK; European Commission H2020 Model Grant Agreement for Marie Skłodowska-Curie RISE; Institute for Research and Development (IRD), France; Cambridge-Africa ALBORADA Research Fund.

A comprehensive list of partners is included in the annexes.

2020 IN BRIEF

Malaria transmission blocking

Advancing knowledge on *Microsporidia MB*.

Integrated vector management

icipe IVM validity demonstrated; and IVM in southern African countries advanced.

Leishmaniasis

Novel chemical ecology research on sandflies; plant feeding behaviour; studies on their abundance; and distribution of species and bloodmeal hosts.

Yellow fever and dengue fever

Distribution risk mapped; surveillance for circulation in various host systems conducted.

Rift Valley fever

Wildlife loss and counter-intuitive outcomes for people revealed.

One Health

Novel community-based intervention package tested.

Schistosomiasis

Connection between chemicals of emerging concern and host-snails of *Schistosoma* revealed.

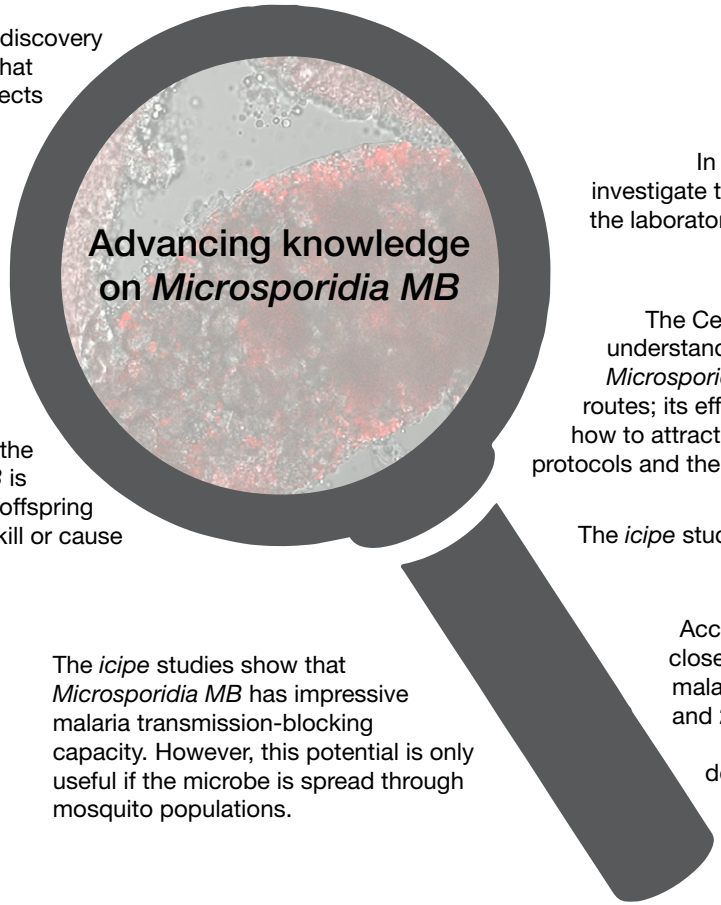
Tungiasis

Testing affordable, improved floors.

Malaria Research

In 2020, *icipe* made the groundbreaking discovery of a microbe in *Anopheles* mosquitoes, that blocks malaria transmission from the insects to people.

The microbe, which the researchers named *Microsporidia MB,* was found through studies conducted on mosquitoes in their natural environments, mainly on the shores of Lake Victoria in Kenya. Mosquitoes carrying *Microsporidia MB* were found not to harbour malaria parasites either in nature, or after experimental infection in the laboratory. In addition, *Microsporidia MB* is passed from female mosquitoes to their offspring at high rates, and the microbe does not kill or cause obvious harm to the mosquito host.



The *icipe* studies show that *Microsporidia MB* has impressive malaria transmission-blocking capacity. However, this potential is only useful if the microbe is spread through mosquito populations.

In late 2020, *icipe* commenced further research to investigate the natural ability of these microbes to spread in the laboratory and in the field, and then determine how they can be used most effectively.

The Centre has assembled an interdisciplinary team to understand a range of variables, including: the capacity of *Microsporidia MB* to disperse via its different transmission routes; its effect on the behaviour of *Anopheles* mosquitoes; how to attract and infect adult mosquitoes; the dissemination protocols and the necessary environmental management factors.

The *icipe* study will be the first in a long time that could open new avenues for widespread control of malaria.

According to the World Health Organization (WHO), close to half a million people still die every year from malaria, 90 percent of them in Africa. Between 2000 and 2014, significant progress was made in tackling the disease, and the number of malaria-related deaths fell by an estimated 40 percent. However, in recent times, progress has stagnated and the search for new initiatives for control is imperative if progress is to be made to achieve malaria eradication by the year 2040.

Integrated vector management validity

Over the years, using our extensive basic science knowledge on mosquitoes and malaria, *icipe* has developed a range of tools and strategies and executed successful integrated vector management (IVM) initiatives across Africa. The validity of these interventions has been demonstrated in two recently published studies.

The first study reports that in Nyabondo, western Kenya, where there is intense all-year round malaria transmission, combined use of long-lasting insecticide-treated nets and screening of house eaves with mosquito-proof wire mesh reduced malaria cases by between 63 percent and 100 percent, compared to when long-lasting insecticide-treated nets (LLINs) were used on their own.

The second study shows that in Tolay, Ethiopia, where malaria prevalence is generally low, the disease was reduced by a further 50 percent when usage of LLINs was supplemented with the application of a biolarvicide, *Bacillus thuringiensis israelensis*.

The aim is to demonstrate the potential benefits of integrating readily available, but not-widely used vector control tools like winter larviciding and house screening, in Botswana, Namibia, Mozambique, Eswatini, Zambia and Zimbabwe, to sustain malaria control and elimination.

A baseline database has been established in five of the six countries, collating data on: socio-demographics; knowledge, attitudes and practices; baseline malaria clinical cases and prevalence; and entomological aspects.

IVM in southern African countries

In Eswatini, *icipe*'s championship of biological larviciding has been commended by the United Nations Environment Programme (UNEP) as a model for "eco-friendly alternatives to toxic solutions".

Installation of house screens in Zambia and Mozambique has been completed and assessment of the first round of interventions initiated. Collection of passive clinical malaria data from health centres is ongoing in Zambia.

In Botswana, the *icipe* team has published a case study in the context of the country's delayed goal of malaria elimination by 2020. Focusing on the vector control aspect, the research identifies challenges and explores opportunities for Botswana to achieve malaria eradication by 2030, as per the Global Technical Strategy for Malaria. The study emphasises the need for timely and quality entomological surveillance, operational research and integrated vector management.

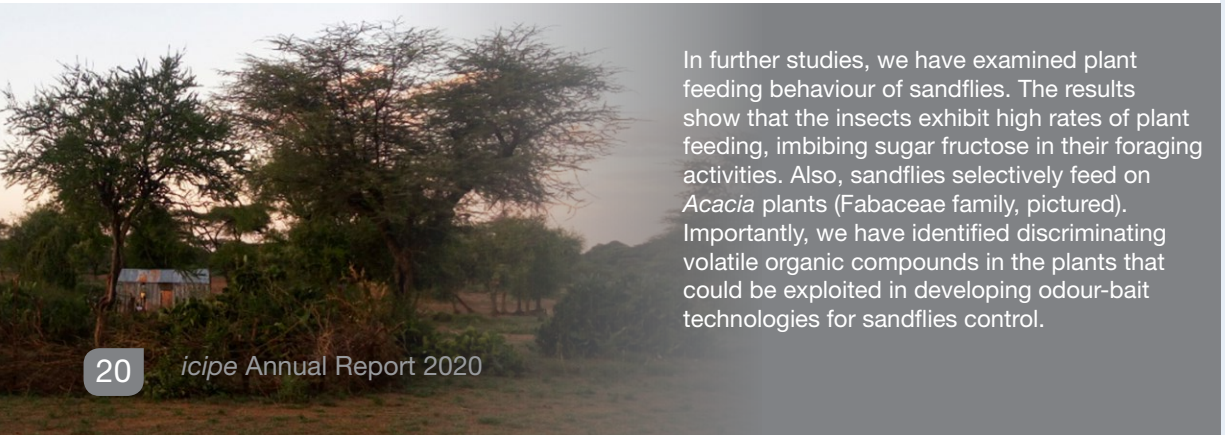
Neglected Tropical Diseases

Leishmaniasis

***icipe* is conducting globally novel research on the chemical ecology of sandflies, vectors of leishmaniasis. These studies are driven by the understanding that any rational control of the insect must be based on thorough understanding of its behaviour.**

We have investigated sandfly habitats — animal sheds, termite mounds and house indoors — to understand the diversity of the insects and reasons for the variations. The findings indicate generally higher sandfly populations in animal sheds, followed by termite mounds and house indoors. The sandfly species, *Phlebotomus martini* and *P. duboscqi*, were selectively abundant in termite mounds and animal sheds, respectively.

These results indicate that indoor control measures, like the use of bednets and indoor residual spraying, would be insufficient in curbing transmission of leishmaniasis. In addition, the research identified various compounds, among them known attractants of sandflies that could be employed in monitoring and trapping the insects.



In further studies, we have examined plant feeding behaviour of sandflies. The results show that the insects exhibit high rates of plant feeding, imbibing sugar fructose in their foraging activities. Also, sandflies selectively feed on *Acacia* plants (Fabaceae family, pictured). Importantly, we have identified discriminating volatile organic compounds in the plants that could be exploited in developing odour-bait technologies for sandflies control.

***icipe* completed studies on the abundance and distribution of sandfly species responsible for *Leishmania* transmission, and their blood-meal hosts.** The findings show that although people are the main source of bloodmeals, certain species, for example *Sergentomyia squamipleuris,* also feed on mice (*Mus musculus*), while two *Phlebotomus orientalis* additionally fed on rock hyrax (*Procavia capensis*).

These findings indicate the potential involvement of *S. squamipleuris* in the transmission of *Leishmania*, challenging the longstanding belief that the parasites are exclusively transmitted by sandflies of the *Phlebotomus* genus. Analysis revealed the possibility of zoonotic transmission of leishmaniasis and other pathogens.

Further studies are needed to determine the reservoir hosts of *Leishmania* spp. Also, *Trypanosoma* spp., parasites causing trypanosomosis, were detected in some sandflies species, indicating mechanical transmission of the disease by the flies, and stipulating the need for more investigations.

Arboviral diseases

Yellow fever and dengue fever are among key emerging arthropod-borne virus threats in Africa. Against the background of lack of (or inadequate supply of vaccines), establishing and mapping the distribution of the risk of these two diseases is vital for effective planning of vector control and vaccination. *icipe*'s research aims to explore the transmission ecology of yellow fever and dengue fever to explain the distribution and bionomics of key vectors, and to produce evidence of infection of their pathogens in people and primates, in three regions in Kenya.

The studies have revealed variations between two regions in regard to the bionomics (composition, abundance, human blood index, survival rates) and breeding ecology among key yellow fever and dengue fever mosquito vectors, *Aedes aegypti*, *Ae. simpsoni* and *Ae. africanus*, indicating differences in risk levels. A protocol for molecular differentiation of mosquito species complexes has been adopted for population characterisation and vectorial capacity estimates. Samples from people and primates have been collected and biobanked for analysis at *icipe*.

Globally, the threat of emerging infectious diseases, including those that are vector-borne, is on the rise. Therefore, sustained surveillance to explore the circulation of these diseases in various host systems is necessary, to identify transmission and establish detection and control systems, for improved preparedness. *icipe* is exploring a network of arbovirus transmissions among diverse arthropods (sandflies, ticks, mosquitoes, biting midges); various livestock (goats, cattle, sheep); and in people and rodents in two pastoral ecosystems in Kenya.

Samples from the different host systems and sites have been collected and biobanked at *icipe* for analysis. Multiple viruses with potential to cause disease in people and animals have been detected in the host systems with indications of potentially novel viruses that require further analysis. Capacity to conduct in-depth virus characterisation and discovery is being enhanced through postgraduate training in collaboration with partnering institutions in Germany.

One Health

In Africa, there is an increasing threat of new and re-emerging zoonotic pathogens transmitted by a plethora of blood feeding insects. These diseases often overlap in terms of geographical preference, and they also co-affect people and livestock. Across the continent, livestock live close to human dwellings, often in shelters within the peridomestic environment.

This scenario might support transmission of diseases by attracting arthropod vectors that they encounter and bite people opportunistically. It also provides an ideal opportunity to control harmful arthropods where they converge, through cost-effective and comprehensive vector control tools or strategies. Therefore, it is necessary to address the ailments and their vectors in a tandem and comprehensive manner, using effective locally-adapted, environmentally friendly interventions.

Over four years *icipe* has been testing a novel community-based, One Health intervention package. In 2020, several strains of the entomopathogenic fungus, *Metarhizium anisopliae*, were tested under laboratory and semi-field conditions, to create a strain and dosage for several biting arthropods. The *M. anisopliae* strain ICIPE 7, which is currently commercially being developed for tick control under the trade name Tickoff®, was found effective against malaria mosquitoes, ticks and tsetse flies.

Schistosomiasis

Schistosomiasis is a severe neglected tropical disease caused by *Schistosoma*, a genus of trematodes (parasitic flatworms, commonly known as blood flukes), which are released by freshwater snails. Recent studies by *icipe* focused on the connection between chemicals of emerging concern in freshwater environments and the intermediate host-snails of *Schistosoma*. Several compounds were detected for the first time in Kenyan waters, with four being found in 80 percent of all water bodies sampled.

The results show that pesticide pollution is a major driver in increased occurrence of host snails; and thus, the risk of schistosomiasis transmission. Indeed, snails were found to be more tolerant to pesticides than any other tested macroinvertebrates; and, therefore, more dominant in pesticide polluted environments. The study also tested an affordable and rapid bioindicator to monitor pesticide pollution in water bodies.

Tungiasis

Tungiasis is a parasitic skin disease caused by penetration of female sand fleas into the skin. Previous research by *icipe* has shown house floors to be transmission hotspots of tungiasis. While sealed floors can provide sustainable solution to tungiasis, they are unaffordable to many affected families. *icipe,* in collaboration with research partners, and community-based and non-governmental organisations has tested affordable, improved floors.

Findings indicate that household prevalence of tungiasis reduced by more than 50 percent. The infection intensity of people associated with abundance of off-host stages inside houses also went down. Some participating community members have adopted new flooring solutions. *icipe* intends to work with stakeholders towards further advocacy. However, the effectiveness of such an intervention will only be possible with necessary behaviour change, and formative research towards this goal is ongoing.

ANIMAL HEALTH THEME

The *icipe* Animal Health Theme aims to develop integrated strategies and tools for control of animal disease vectors, to enhance livestock health and productivity. Research activities are geared towards detailed understanding of vector behaviour, population ecology, vector–host and vector–parasite interactions. The Centre primarily conducts studies on tsetse flies (vectors of animal and human trypanosomosis); and ticks; and biting flies, in relation to camel health.

Donors: Biovision Foundation for Ecological Development, Switzerland; European Union; Federal Ministry for Economic Cooperation and Development (BMZ); German Research Foundation (DFG); International Atomic Energy Agency (IAEA); UK's Foreign, Commonwealth & Development Office (FCDO); Max Planck Institutes, Germany; National Science Foundation (NSF), USA; Swedish International Development Cooperation Agency (Sida); 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.

2020 IN BRIEF

Vectors, pathogens, livestock and wildlife

Increasing risk of African tick bite fever (ATBF) and other spotted fever at the human–livestock–wildlife interface; new dengue vectors; tsetse flies preference for buffalo; and endosymbiont associated with higher trypanosome rates, reported.

Movement of vectors and pathogens between community lands and protected areas confirmed; Crimean-Congo haemorrhagic fever virus found in *Rhipicephalus* ticks; *Rickettsia africae* pathogen, responsible for ATBF, found in livestock ticks.

Camel odour coded

leading to new knowledge on interaction between camels and *Stomoxys calcitrans*, blood-sucking flies; more rigorous approach to identify potent attractants for the flies; advances in *icipe*'s efforts to build a body of neuroethology knowledge.

Camel blood-borne pathogens

Three most common diseases detected; three species of livestock keds in northern Kenya identified; pathogens detected in their bloodmeals; and rapid, low cost, and sensitive diagnostic assay for detecting trypanosomes developed.

Tsetse fly management

Tsetse odour repellency discovered; and studies on tsetse vision ecology advanced.

Amidst the COVID-19 pandemic, thanks to community owned resource persons (CORPs) in Kwale County along the Kenyan coast, tsetse control activities have been uninterrupted. The CORPs set up and monitor traps, and also transmit data electronically to us.

Tsetse Fly Management

In its early years, *icipe* discovered compounds in waterbuck that repel tsetse flies, leading to the development of the Centre's successful tsetse repellent collar technology for livestock.

The Centre has now built on these groundbreaking findings by identifying the cellular and molecular mechanisms that the fly uses to detect and code odours.

The studies have focused on the sensory neurons and odorant receptors in tsetse antennae.

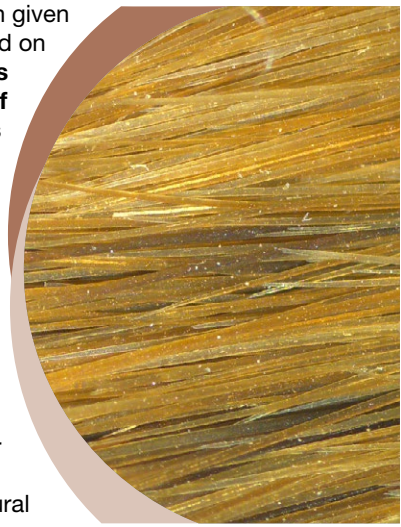
Discovery of tsetse odour repellency

The sensors used for the interaction between the fly and the source of the repulsive odour, and ultimately the decision to avoid it, have been revealed.

This new knowledge could contribute to the refinement of repellents as a strategy for tsetse fly management.

Tsetse vision ecology

Tsetse and biting flies use combinations of visual and olfactory cues to locate and select their hosts. While there has been emphasis on manipulating the insect's olfactory cues to design trapping systems, little attention has been given to developing control tools based on vision. **New *icipe* research aims to inspire a novel generation of tsetse management strategies through understanding of the insect's vision ecology. Our aim is to deviate from the traditional approach of randomly evaluating colours as perceived by the human eye, instead taking a fly's eye view approach.**



Micrograph (at 250 times) of cattle skin showing the complex colouration of what would appear to the human eye to be an even colour.

We have documented the colour spectra of several livestock. We are now exploring the use of neural network models or deep learning algorithms to simulate the perception of colour by the insects. This process has made it possible to predict colours that are attractive to tsetse. **Using this knowledge and fabric engineering, we have developed prototype attractive panels that could attract and kill disease vectors, which we are evaluating in the field.**

Vectors, Pathogens, Livestock and Wildlife

Ticks and tick-borne diseases at the Human–livestock–wildlife interface
Surveys in the Maasai Mara National Reserve, Kenya, on the diversity of questing ticks, their bloodmeal hosts, and tick-borne pathogens, recovered a diversity of pathogens, including the zoonotic *Rickettsia africae* and unclassified *Rickettsia* spp. **This information demonstrates a risk of African tick-bite fever and other spotted-fever group of rickettsioses to people, wildlife and domestic animals, as well as amplified transmission of tick-borne zoonoses and livestock diseases.**

Integrated control of tsetse and tick-borne livestock diseases
icipe studies identified multiple bacterial and protozoal pathogens in ticks and livestock in Human–livestock–wildlife interface areas in Kenya, and in some farmed areas in Ethiopia. In addition to the known tsetse-borne trypanosomosis, cattle were found to be co-infected by up to 13 ticks-borne pathogen combinations. One previously unclassified *Anaplasma* species was associated with increased risk of disease severity in cattle. **This knowledge provides evidence of movement of vectors and pathogens between community land and protected areas, and highlights the need for integrated disease vector management.**

Pathogens, endosymbionts and blood-meal sources of mosquitoes, and tsetse flies at the human–wildlife interface
Further studies in the Maasai Mara National Reserve found sylvatic dengue and Sindbis virus circulating in mosquitoes, representing potential new dengue vectors. Tsetse flies were found to feed mainly on buffalo and hippopotamus despite the abundance of wildebeest and zebra in the area, during the 'Great Wildebeest Migration'. The endosymbiont *Sodalis glossinidiusis* was noted to be associated with higher trypanosome infection rates in wild tsetse flies.

Vector-borne pathogens in livestock markets, slaughterhouses, and health clinics
Our research established the presence of Crimean-Congo haemorrhagic fever virus, which is associated with high mortality in infected people, in *Rhipicephalus* ticks. High rates of *R. africae* pathogen, which is responsible for African tick-bite fever, were found in livestock ticks. Sindbis virus was found in mosquitoes in western Kenya.

Camel Health Research

The three most common diseases detected are anaplasmosis, caused by *Candidatus* Anaplasma camelii; ehrlichiosis by *Candidatus* Ehrlichia regneryi; and trypanosomosis, caused by *Trypanosoma vivax* and *T. evansi.*

We identified three species of livestock keds in northern Kenya: *Hippobosca camelina, H. variegata,* and *H. longipennis*.

Pathogens detected in their bloodmeals include *Trypanosoma*, *Ehrlichia*, *Anaplasma*, and *Theileria* spp. and zoonotic pathogens, such as *Brucella* spp., *Clostridium perfringens,* and *Bartonella schoenbuchensis*.

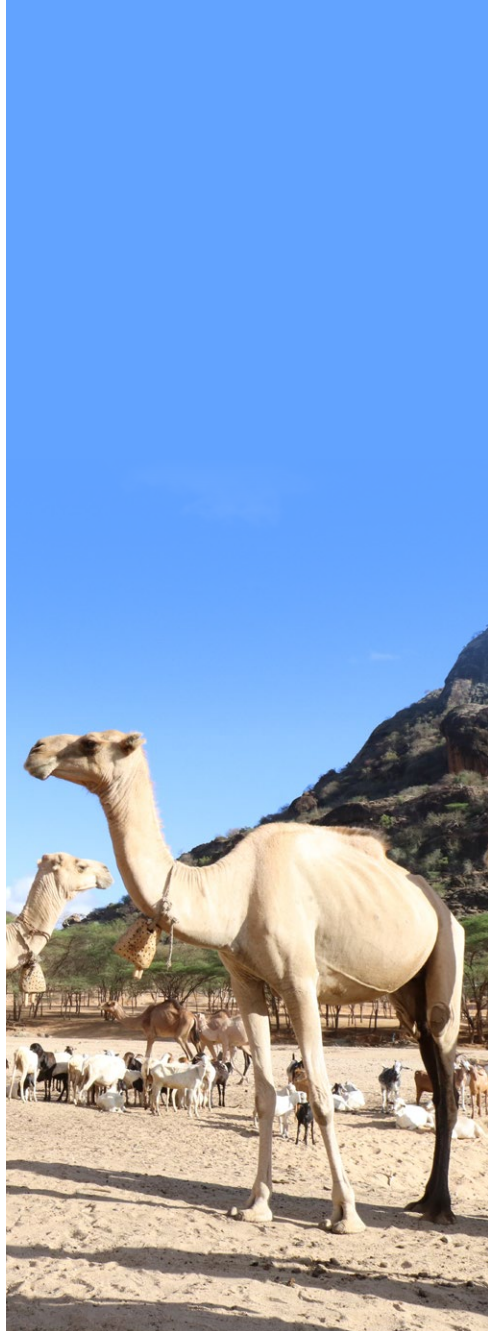
Blood-borne pathogens

in one-humped camels (*Camelus dromedarius*) and their transmission by *Hippobosca camelina* (camel ked or camel fly)

More than 90 percent of camels were found to be naturally infected with the emergent *Anaplasma* sp., whereas *Ehrlichia* sp. was present in about 20 percent of camels. Both are first records in Kenya.

A rapid, low-cost, and sensitive diagnostic assay for detecting trypanosomes, was developed. The tool will enhance capacity for the study of vectors and pathogens in camels.

The results show that camel keds could be used for xenomonitoring, as a surveillance strategy for camel diseases.



New knowledge has been generated on the interaction between camels and *Stomoxys calcitrans*, blood-sucking flies that transmit various pathogens to the animals.

We investigated the coding of odours that are present in the four main sources in the camel: breath, body (skin), urine, and dung.

Our studies also found odours that activate most neurons and elicit strong behavioural response in the flies.

Camel odour coding

These findings form a more rigorous approach to identify odours that are potent attractants for the flies.

The research advances *icipe*'s efforts to build a body of neuroethology knowledge, as a foundation for the development of environmentally friendly, species-specific control strategies for pest and disease vectors.

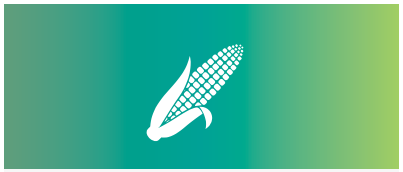
PLANT HEALTH THEME

The Plant Health Theme undertakes innovative basic and applied research, with the underlying principle of developing control options for crop pests. The overall aim is to reduce the use of pesticides and subsequent impacts on the health of people, animals and the environment, and the inevitable resistance that comes from extended use of such products. The Theme's research is based on the discovery and strategic use of biopesticides, semiochemicals, and other naturally-occurring compounds that can be employed to disrupt the pests' life cycles, and control them through the use of natural enemies.

Donors: African Union; French Agricultural Research Centre for International Development (CIRAD); Biotechnology and Biological Sciences Research Council (BBSRC), UK, through Rothamsted Research and Keele University (both in the UK); Biovision Foundation for Ecological Development, Switzerland; Canadian Government through International Development Research Centre (IDRC); European Union; Federal Ministry for Economic Cooperation and Development (BMZ), Germany; Food and Agriculture Organization of the United Nations (FAO); French National Research Institute for Sustainable Development (IRD); Government of Kenya; International Atomic Energy Agency (IAEA), Austria; International Fund for Agricultural Development (IFAD); Norwegian Agency for Development Cooperation (Norad); Research Institute of Organic Agriculture (FiBL), Switzerland; Royal Society, UK; Swedish International Development Cooperation Agency (Sida); Swiss Agency for Development and Cooperation (SDC); UK's Foreign, Commonwealth and Development Office (FCDO), 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.

2020 IN BRIEF



Push–pull technology

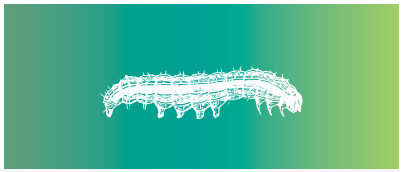
Effectiveness against aflatoxin and fumonisin contamination confirmed; third generation push–pull developed; further efforts to UPSCALE dissemination.

Advocacy for agroecology

Push–pull seed management and production bolstered.

Rice, Chickpea and Maize IPM

Capacity building in push–pulll agronomy; benefits for households using the technology; chickpea agronomy improved.



Fall armyworm

Biopesticides developed and natural enemies released, boosting synergistic control package that also includes *icipe* push–pull technology, to control different stages of the pest.

Tuta absoluta

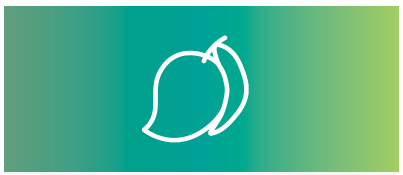
Milestone for tomato production in Africa, as natural enemies released; effective biopesticides identified.

Whiteflies and leafminers

Effective biopesticides identified; efforts for commercialisation started; and capacity building of farmers to use biopesticides increased.

Nematodes

Antagonistic plants identified; new knowledge on PCN spread generated; advances in strategies to control PCN; premier research on enset published.



Fruit pests

Protocol for disinfestation of *Bactrocera dorsalis* from Tommy Atkins mango; new knowledge on natural enemies; progress in fruit fly control in Zanzibar.

New invasive pests

Plans to control white mango scale. First report of *Drosophila suzukii*, pest of berries, in Kenya; delimiting survey conducted; and plans for further research.

Locust control

National support to strengthen surveillance, capabilities of stakeholders, and awareness. Prediction of breeding sites and basic research to enhance control.

Push–Pull Technology

The push–pull technology has been confirmed to reduce ear rot fungi that cause pre-harvest mycotoxin contamination of maize. Mycotoxins, mainly aflatoxin and fumonisin, have adverse effects on human health. Push–pull prevents ear rots by reducing stemborer and fall armyworm damage on maize cobs and ultimately limiting mycotoxins. Root extracts of two push–pull intercrops, *Desmodium intortum* and *D. uncinatum,* also significantly reduce spore germination and radicle growth of the aflatoxin and fumonisin-producing fungi, *Aspergillus flavus* and *Fusarium verticillioides* found in maize and the soil.

icipe and Leibniz University Hannover, Germany, are co-leading a newly launched five-year project titled: Upscaling the benefits of push–pull technology for sustainable agricultural intensification in East Africa (UPSCALE). In collaboration with 17 partners in Africa and Europe, *icipe* is scaling up understanding and spatial applicability of push–pull; expanding the technology from cereal to other crops and cultivation systems; and determining the factors influencing success of the technology across scales.

Against the background of the COVID-19 pandemic, vital monitoring of pest populations and crop damage continued through use of Open Data Kit (ODK) web tools. Using a database of farmers and their GPS locations, farmer teachers armed with programmed Andriod devices, pre-loaded with preformatted data templates, collected and relayed field data, photographic and video images of pest occurrence and damage.

A new, version of the push–pull technology (pictured) has been developed.

The adapted version retains the basic principles of the technology: suitable chemistry to attract and repel stemborers, fall armyworm control, and attraction of natural predators of the pests; *Striga* suppression; proficiency in improving soil fertility, soil moisture retention and organic matter; and added value, for example in provision of high-quality fodder.

The selected farmer-preferred, and drought-tolerant, companion plants are *Desmodium incanum*, an excellent seed yielder and *Brachiaria* variety *xaraes*, which is resistant to red spider mites and produces a higher amount of fodder.

Advocacy for Agroecology

The project aims to create a model for agroecology through the push–pull technology. In 2020, we made the achievements listed below:

30

private seed collectors, producers and local government partners were trained on forage seed production and management.

55

farmers, development partners and stakeholders were trained on *Desmodium* seed collection.

30

participants from research organisations, private and individual seed collectors, extension services, and local government partners, took part in field days and exchange visits on forage seed development to boost the crop and livestock production systems.

Rice, Chickpea and Maize IPM

icipe has been part of a five-year (2015–2020) project funded by USAID through the Feed the Future Integrated Pest Management Innovation Lab at Virginia Tech, USA, that aims to enable smallholder farmers in Ethiopia, Kenya and Tanzania to implement proven, robust and locally adapted IPM options. Major achievements in 2020 include:

267

(149 male and 118 female) participants representing providers of extension services, seed producers and local government partners received training on the agronomy of push–pull companion crops, planting and field management.

Farmers using the push–pull technology testified to reduced stemborer infestation and damage on maize; lower expenses, labour and time in sourcing livestock feed; increased dairy cow keeping; and improved incomes.

122

(48 females and 74 males) participated in field days during four crop stages (early stage, before flowering, flowering and at harvesting).

93

(10 female and 83 male) participants were trained on chickpea agronomy, weed and diseases management, set up and maintenance of raised beds.

Chickpea is a nutrition-rich, climate-resilient legume that has significant economic potential in Africa. The full benefits of the crop could be tapped through various interventions, for example those led by *icipe* and partners.

Fall Armyworm Management

icipe has developed a range of biopesticides, providing farmers in Africa with effective and environmentally friendly alternatives for the management of the invasive and destructive fall armyworm. This milestone has been accomplished with the support of development partners, government and regulatory authorities, as well as private sector actors in East Africa.

Biopesticides

The Centre tested the effectiveness of some of its biopesticides that had been commercialised for the control of diverse pests in partnership with Real IPM Ltd, a Kenya-based biocontrol company. Two of these, Mazao Achieve® (ICIPE 78) and Mazao Tickoff® (ICIPE 7), were found to be effective against immature stages of the fall armyworm. ***icipe* and partners have undertaken label extension of these biopesticides, which have now been branded as Achieve OD® and Detain®, respectively and are being upscaled for fall armyworm control.**

In addition, *icipe* has identified new and potent fungal strains: ICIPE 20, ICIPE 41, ICIPE 655 and ICIPE 621; that are effective against various life stages of the fall armyworm. Based on scientific evidence, regulatory authorities in Kenya, Tanzania and Uganda have permitted the testing of the strains in the field. The trials are being conducted in alignment to the harmonised regional guidelines of the East African Community, and in partnership with regulatory agencies and private sector partners.

The *icipe* biopesticides are powerful arsenals against the notorious fall armyworm. In addition, the process towards their development strengthens regional collaboration, and also serves as a model, for harmonisation and commercialisation of agricultural products and technologies.

Natural enemies

Although the fall armyworm is an alien invasive pest, *icipe* research has revealed three wasps that are widely distributed in Africa: *Telenomus remus*, *Trichogramma chilonis* and *Cotesia icipe*; that can parasitise and kill the pest.

Over the past several years, the Centre has evaluated the performance of the parasitoids on various life stages of the fall armyworm, and ways to mass produce these natural enemies for release in the pest's hotspots. The goal is for the parasitoids to work synergistically by attacking different developmental stages (eggs and larvae), of the pest, in compatibility with other eco-friendly management strategies, like the *icipe* push–pulll technology and biopesticides.

In the last quarter of 2020, *icipe* and partners in Kenya conducted the first mass releases of the fall armyworm natural enemies. So far over 140,000 wasps each of *T. remus* and *T. chilonis* that parasitise fall armyworm eggs, and 5000 wasps of *C. icipe* that parasitise early larval stages of the pest have been released in five counties in Kenya.

The initial post-release field assessments revealed that parasitism rates of fall armyworm in the field increased by 55 percent, 50 percent and 38 percent, for *T. chilonis*, *T. remus* and *C. icipe*, respectively. ***icipe* and partners intend to mass release these beneficial insects in other major maize-growing zones across Kenya, before expanding to other eastern and southern African countries.**

T. chilonis

T. remus

C. icipe

Smart Maize

icipe and partners have discovered that certain 'smart' maize varieties are able to defend themselves against stemborers by summoning natural enemies of the pest. The researchers have also determined the genetic markers in such plants that are associated with this “call for help”, presenting strong possibilities for developing maize varieties that are resistant to the pests.

The study analysed the genetic makeup of 146 different types of maize plants comprising farmer-selected varieties, known as landraces, as well as plants from formal breeding programmes – inbred lines and commercial hybrids.

The results reveal that when stemborers lay eggs on some maize cultivars, a defence reaction is triggered in the plants, which then release odours that attract wasps that are capable of parasitising the stemborers, or in other words natural enemies of the pests.

An interesting finding is that the plants recruit both egg and larval parasitic wasps. As such, the natural enemies parasitise and kill the stemborer eggs before they hatch into larvae, as well as any larvae that may emerge, thus pre-empting damage on the crop. **Beyond promoting stemborer resistance in maize cultivars, the knowledge is a valuable resource for future research on the interactions between plants, pests and beneficial insects.**

Stemborer Diversity

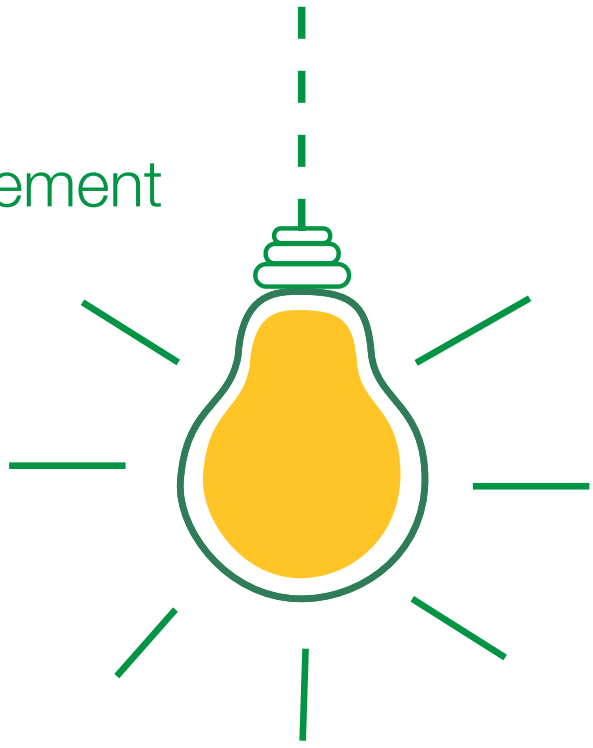
Since 2001, IRD and *icipe* have conducted extensive research on the diversity of lepidopteran stemborers, some of which are important pests of maize, and their interactions with their natural enemies (mainly parasitoids). A large database has been created, providing knowledge on the ecological and evolutionary processes at the origin of the tritrophic interactions of grasses–insect pests–parasitoids. Also, the collaboration has revealed certain entomological risks resulting from the anthropogenic impacts on natural environments.

The research also indicates that the fall armyworm has unbalanced or modified the resident interactions between lepidopteran maize stemborers and their natural enemies. Laboratory studies show that the introduction of this new invasive species could have a negative impact on the resident parasitoids regulating stemborers, by diverting them from their initial targets.

Using their database complemented by other sources, the researchers have developed dynamic models to monitor the evolution of these interactions during and after the introduction of this new invasive species into the system. **Although the model predicts the coexistence of the fall armyworm with the stemborer species, the invasive pest, alongside the exotic stemborer *Chilo partellus*, dominates over other indigenous species.**

Fruit Pests Management

After developing a protocol for non-chemical, postharvest disinfestation of the invasive fruit fly *Bactrocera dorsalis* from Apple mango, the main export variety in East Africa, *icipe* has now developed a similar process for the Tommy Atkins variety. **This is encouraging progress towards enabling exporters regain access to lucrative overseas export markets.**



icipe has advanced knowledge to guide effective release of *Diachasmimorpha longicaudata*, a wasp introduced by the Centre from Hawaii, USA, for the management of various fruit fly species in Africa. The results show that the natural enemy controls the invasive fruit fly species *Bactrocera dorsalis* on mango. The wasp is equally efficient in controlling *Ceratitis cosyra*, a native fruit fly species, on mango and on guava. **This finding is important because, while guava is not a high value crop in Africa, it forms a reservoir for *C. cosyra* during the mango off-season.**

In 2010, the white mango scale, *Aulacaspis tubercularis*, was reported for the first time in Ethiopia, in the western part of the country where it has now become the most important threat of the crop. Originating in Asia, the pest can also attack citrus, papaya, avocado, ginger, cinnamon and pumpkin. In 2020, *icipe* commenced efforts to mitigate the damage by the white mango scale in Ethiopia, as well as imminent threat of invasion by the pest to other African countries. **The Centre aims to import a parasitoid known as *Aphytis chionaspis*, an efficient co-evolved natural enemy of the white mango scale, for evaluation and subsequent releases in Ethiopia.**

Jointly with the Swedish University of Agricultural Sciences, Kenya Plant Health Inspectorate Service and national agricultural research systems in Kenya, *icipe* detected and reported for the first time, the presence of the spotted wing drosophila, *Drosophila suzukii,* a devastating pest of berries. The Centre also undertook a delimiting survey to establish the extent of its spread. ***icipe* intends to collaborate with various partners to conduct detailed basic and applied research on the pest.**

Since 2018, *icipe* has made significant progress in addressing fruit fly challenges in Zanzibar. The researchers have identified *B. dorsalis* to be the major species attacking mango. However, the host range of the pest also extends to oranges, guava, soursop, papaya, rubber vine fruit, passion, Terminalia almond, and Madras thorn. The *icip*e integrated pest management packages have led to reduction in fruit fly infestation levels. This is reflected in annual trap catches in the project sites, which have gone down from a high of 25,000 fruit flies in 2018, to around 8000 at the beginning of 2020.

Tuta absoluta Management

Wasp release

In a landmark move for tomato production in Africa, *icipe* has released a parasitic wasp, *Dolichogenidea gelechiidivoris,* that will naturally control the invasive and destructive *Tuta absoluta*, a tomato leafminer that was detected for the first time in Africa in 2008 and has since spread across the continent.

The initial field releases of the natural enemy, *D. gelechiidivoris,* were undertaken in Kirinyaga County, central Kenya, which is the largest producer of tomatoes in the country. The wasp is expected to spread rapidly, in search of infested plant materials. *icipe* and collaborators will continuously monitor its progress in terms of establishment and suppression of *T. absoluta*, as well as overall improvement of tomato yield. **Subsequent releases are planned in major tomato-growing regions in Kenya, as well as in Ethiopia and Uganda.**

The wasp released by *icipe*, *D. gelechiidivoris*, has been imported by the Centre from Peru, the native home of *T. absoluta*. This is the first time it is being introduced outside its origin.

Biopesticides

icipe has established that the Centre's commercially available biopesticides, *Metarhizium anisopliae* ICIPE 69 and *M. anisopliae* ICIPE 20, have potential in protecting tomato and nightshade plants against *T. absoluta*.

We have also identified new fungal endophytes, *Beauveria bassiana* ICIPE 706, *Trichoderma asperellum* M2RT4, and *Hypocrea lixii* F3ST1, that could also be effective against the pest. An interesting aspect is that this protection would occur in a symbiotic interaction; where the plant helps the endophyte to develop, and in return the endophyte stimulates the host plant to produce toxins that protect the plant against insect pests and diseases.

Vegetable IPM

Whiteflies and leafminers

We have identified several fungal endophytes that are virulent against whiteflies. They include *Hypocrea lixii F3ST1* and *Trichoderma asperellum* M2RT4, which we have recently discovered. The *M. anisopliae* ICIPE 69 is also a potent entomopathogenic fungus against the pest, and to be compatible with a known plant-based attractant, trans-2-hexen-1-al. This is an important finding that will enable the development of an attract-and-kill strategy for the pest.

icipe is in discussions with a private sector partner for the commercialisation of *H. lixii* F3ST1 and *Beauveria bassiana* G1LU3, for the management of *Liriomyza* leafminer flies, bean stem maggot, thrips, rust and halo blight on French beans in Kenya.

Closely related to aphids and mealybugs, whiteflies 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, reducing the vigour and at times killing their host plant. The impact of direct feeding and honeydew excreta affects crop yield and product's aesthetic. Indirect damage by whitefly includes transmission of disease-causing viruses in plants.

A pilot biopesticide production facility has been established at *icipe* to train small-scale farmers on mass-production of biopesticides.

Liriomyza trifolii is a leafmining insect that has a vast host range, including vegetables and ornamental crops in several economically important plant families. Females cause punctures for oviposition and feeding, resulting in a stippled appearance on foliage. The most important damage is the mining of leaves by larvae, which can cause leaves to drop, and also reduces photosynthesis and growth in the plant.

Research on Nematodes

Antagonistic plants

Recent studies by *icipe* have confirmed the capability of certain plants from the Asteraceae family to manage root knot nematodes. We investigated four astereceous plants: *Artemisia annua* (also known as sweet wormwood); *Bidens pilosa* (black-jack); *Tagetes minuta* (khaki-weed); and *Chrysanthemum cinerarieafolium* (pyrethrum), against the infective juveniles of *Meloidogyne incognita* nematodes.

The nematodes avoided the root volatiles of the four plants when tested either alone or in combination with a susceptible tomato cultivar. The studies also identified the most important compounds in the four plants in control of nematodes.

The researchers have conducted further evaluations of *B. pilosa* (pictured) on its ability to suppress parasitism of *M. incognita* in two susceptible crops: tomato and African nightshade. The findings indicate that the plant significantly reduces the number of nematode galls and egg masses in the crops, and it also inhibits hatching of nematode eggs.

The most active parts of *B. pilosa* root exudates have been identified, as well as various organic acids and compounds in the plant, which are being investigated further for their role in nematode behaviour, as a basis for the control of these pests.

Photo: D.Coyne

Suicidal hatch of PCN

The potato cyst nematode (PCN, *Globodera rostochiensis*), is an invasive pest that was first reported in Kenya in 2015. Studies by *icipe* and partners have shown that PCN is causing up to 80 percent yield loss in potato in the East African region.

Our research has revealed that it may be possible to manage PCN by inducing 'suicidal hatching' of the pests using naturally-occurring chemicals in crop roots. PCN eggs will hatch only in the presence of suitable host plants of the Solanaceae family; and only when triggered by chemical signals produced by roots of the host plant. Our findings show that most juvenile PCN that hatched in response to certain chemical signals in host plants, known as steroidal glycoalkaloids (SGAs) and steroidal alkaloids (SAs), remained encysted.

In other words, they did not leave the cyst to invade crop roots but remained encapsulated in the cyst.

Blends of the compounds obtained from crude material of such plants may be used to treat potato fields as organic soil amendments. This approach would be environmentally attractive and better than using nematicides, which can be hazardous, and due to their dependence on single compounds, are prone to pest resistance.

PCN spread, diversity and control tools

In 2020, *icipe* and IITA made the first report of PCN in Uganda. The research showed that the PCN populations in Uganda cluster with the Kenyan *G. rostochiensis* isolates but are less closely related to Rwandan populations or other *Globodera* species. These findings highlight the need to conduct a comprehensive epidemiologic survey for developing a regional PCN-management strategy.

We are in the process of developing a PCN diagnostic tool that would enable detection of the pests directly from soil. Such a tool would provide a rapid detection ability for farmers. Currently, several lines of selected potato varieties are being assessed in-field for suitability to local conditions, productivity and acceptability by farmers. Various varieties are also being screened for this purpose to determine resistance against the nematode pest.

Nematodes and enset

An orphan crop little known outside of Ethiopia, enset (pictured), is a drought-tolerant staple that underpins much of the food supply in south and southwestern parts of the country. *icipe* and IITA have generated knowledge on the threat posed by plant parasitic nematodes to the production of enset. This research represents the most up-to-date and extensive assessment of nematodes associated with enset and how these pests are correlated with altitude (temperature); and consequently, how climate change may impact these pests and enset production.

A significant source of nematode dissemination appears to be through farmer planting material, which was found to be regularly infected with *Pratylenchus goodeyi* nematodes. In addition, resistance against this key nematode pest was determined in some of the local landraces, providing a potential source of nematode management.

Capacity building

Four students in the Nematology Research Group undertook summer scholarships offered by the Global Burden of Crop Loss initiative. Their research will contribute to the management of PCN through: the development of an appropriate tool to determine yield losses related to the pest; knowledge on the control potential of non-solanaceous crops; use of fungal isolates; and design of a model for plant-parasitic interactions.

The annual Basic Crash Course Nematology (BCCN), a one-week course organised annually by *icipe*, IITA, and International MSc in Agro- and Environmental Nematology, University of Gent, Belgium, was held in December 2020. The course provides grounding in methods to quantify, qualify and process plant-parasitic nematodes in crops, with an introduction to beneficial nematodes, indicators of soil health, and nematodes for biocontrol of insects (entomopathogenic).

Photo: S. Araya

Locust Control

Since late 2019, several eastern African countries, especially Ethiopia, Kenya and Somalia, have been devastated by catastrophic locust swarms, with adverse implications for livelihoods, food security, environment and socio-economic development. *icipe* has contributed to controlling this menace in a range of ways as outlined in the following sections.

National support

icipe is part of a multi-agency locust control team assembled by the Ministry of Agriculture, Livestock and Fisheries, Kenya. The Centre brings to the alliance extensive experience and capacity in biology, ecology, management, and beneficial use of locusts. **Specifically, our efforts have strengthened ground surveillance of locusts; bolstered the capabilities of stakeholders (government agencies, research partners and communities); and contributed to awareness creation regarding the hazard.**

Discovery of locust breeding sites

We accessed 9134 desert locust occurrence records and applied a machine-learning algorithm to predict potential breeding sites of the insect in East Africa using key bioclimatic (temperature and rainfall) and edaphic (sand and moisture contents) factors.

Demonstrated that vast areas of Kenya and Sudan, north eastern regions of Uganda, and south eastern and northern regions of South Sudan, are at high risk of providing conducive breeding environments for the desert locust.

Highlighted the need to target and strengthen ground surveillance in these high-risk areas, so as to manage the pest in a timely, cost-effective, and environmentally-friendly manner.

Basic research and control

The Centre has intensified studies on locust biology, taxonomy and identification, to accelerate control efforts, as well as integration of the insect in food and feed, and its use as a source of high quality oil. The Centre has also identified biopesticides for locust control that have been found to be effective under laboratory conditions.

A Calliphoridae fly, commonly known as carrion or blow flies, pollinating avocado flowers.

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 focus includes: bee research; beneficial and commercial insects; bioprospecting, particularly for plants for biopesticides and medicinal products; and habitat management, which supports 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; Swiss National Science Foundation (SNSF); International Fund for Agricultural Development (IFAD); JRS Biodiversity Foundation, USA; Swedish International Development Cooperation Agency (Sida); Swiss Agency for Development and Cooperation (SDC), Switzerland; Mastercard Foundation; UK's Foreign, Commonwealth & Development Office (FCDO); World Trade Organization (WTO) – Enhanced Integrated Framework (EIF); Norwegian Agency for Development Cooperation (Norad).

A comprehensive list of partners is included in the annexes.

2020 IN BRIEF

Bee research
Varroa mites and absconding bees; stingless bees found to be better pollinators; and characterisation of bee gut microbiota.

Young Entrepreneurs in Silk and Honey (YESH)
Results consolidation; and continued good performance by youth beekeepers in producing honey, refined beeswax, silk cocoons and yarn.

More Young Entrepreneurs in Silk and Honey (MOYESH)
Partner youth and new staff recruited; partnering banks selected; and local extension staff deployed. Youth, and local extension teams trained in entrepreneurship, life skills, and improved beekeeping practices.

Sericulture research
Knowledge on proteins and other plant phytochemicals in domestic silkworms, and wild silkmoths; studies on possible uses of silk sericin protein; ways for degumming silk using enzymes; and use of castor plant for rearing silkworms.

Bioprospecting
Socio-economic impact assessments conducted on community-based enterprises.

SWITCH Africa Green
Integrating sustainable consumption and production practices within *icipe*-supported community-based conservation enterprises.

Bee Research

Absconding bees

Varroa destructor, parasitic mites that attack, feed on, and transmit viruses to honey bees, have had a devastating impact on colonies in Europe and America. Previous *icipe* studies have shown that honey bees in Africa are less vulnerable to *Varroa* mites than subspecies of European origin.

In the past, researchers have hypothesised that absconding of colonies is the main mechanism that bees use to safeguard themselves from the damage caused by *Varroa* mites. We have recently investigated the impact of *V. destructor* on colony size, absconding and productivity, in colonies of the African honey bees, *Apis mellifera scutellata* in Kenya. We measured several characteristics related to the mite populations and associated resources, such as food.

The results show lower infestation of *V. destructor* and its effects on *A. m. scutellata* colonies than when the mite was first reported in the country. This indicates that the local honey bee populations are developing tolerance or resistance mechanisms to *Varroa* mites.

However, the most important finding of our study is that *V. destructor* does not cause bees to abscond their colonies. Rather, the phenomenon occurs due to unavailability of pollen. This scenario highlights bee nutrition as a critical, emerging issue in Africa, especially with increasing transformations of land use, and associated changes in natural vegetation.

Bee gut microbiota

***icipe* has made the first characterisation of the stingless bee gut microbiota, based on eight species found in Africa. Globally, the study is one of the few of its kind, and it represents seminal findings for the domestication and resilience enhancement of stingless bees.** The most dominant bacterial groups found in the stingless bee guts are of *Lactobacillus, Bifidobacter*, and *Acetobacter* genera, which account for more than 50 percent of the total gut microbiota.

A second study on the honey bees, *Apis mellifera*, demonstrated the beneficial effect of *Lactobacillus kunkeei*, a bacterial gut symbiont, on bee protection against opportunistic pathogens. We aim to explore how to spread this symbiont at hive level.

Better pollinators

Stingless bees (such as *Hypotrigona gribodoi*, *Meliponula bocandei*, *Meliponula lendliana* and *Plebeina hildebrandti*) are more efficient pollinators of sweet melon than the African honey bee, *A. m. scutellata*. *Meliponula bocandei* (pictured) is the most effective cucumber pollinator out of all species tested.

Better fruit quality of cucumber when using honey bees as pollinator can only be obtained from multiple visits of a flower. But through stingless bees, higher fruit quality and seed quantity are achieved from a single flower visit, due to their longer probing time compared to honey bees.

YESH Project

The Young Entrepreneurs in Silk and Honey (YESH) project was implemented in Ethiopia by *icipe*, Mastercard Foundation and several public and private sector partner institutions, starting from 2016. The YESH project has spawned jobs for 12,500 young men and women in the country through honey and silk enterprises. The initiative also established functional marketplaces for honey and beeswax, and served as a platform for *icipe* to lead the development of a National Sericulture Development Strategy, at the request of the Ministry of Agriculture of the Federal Democratic Republic of Ethiopia.

During its fifth year, the YESH project focused on result consolidation. After a major honey and beeswax harvest of 17 metric tonnes, the youth beekeeper enterprises produced a further 14.6 metric tonnes of honey and 1.5 metric tonnes of refined beeswax. The sericulture enterprises produced over one metric tonne of eri silk cocoons and 20 kilogrammes of yarn.

MOYESH Project

The More Young Entrepreneurs in Silk and Honey (MOYESH) project was launched in 2019 by *icipe* in partnership with Mastercard Foundation and Ethiopia Jobs Creation Commission (JCC). The five-year initiative aims to see 100,000 young men and women in Ethiopia secure dignified and fulfilling work along honey and silk value chains. MOYESH is being implemented in Amhara, Oromia, Tigray, and Southern Nations, Nationalities, and Peoples (SNNP) regions of Ethiopia, with the goal of scaling up technologies and good practices to other parts of the country.

16,926
partner youth (59 percent female) were recruited across the four Regions and organised into 1263 business enterprises.

71
new staff were recruited to support implementation of MOYESH.

15,276
youth (59 percent female) obtained entrepreneurship and life skills training delivered by 579 trained local extension staff.

450
trained local extension staff (22 percent female), 13,885 youth (60.5 percent female) were provided with practical training in improved beekeeping practices.

4
banks were selected to partner with the programme in areas of financial inclusion.

137
trained local extension staff were deployed to deliver village-level practical training in sericulture to 2487 youth (59 percent female).

Sericulture Research

We have conducted studies to compare proteins and other plant phytochemicals found in domestic silkworms, eri (*Samia ricini*), *Bombyx mori* and wild silkmoths. Findings indicate high percentages of phenols and flavonoids in the eri and *B. mori* silkworms than in the wild silkworms. The presence of these phytochemicals indicates the potential use of silkworms as a source of antioxidants. The study also revealed high nutritional value of proteins and carbohydrates in both the domesticated and wild silkworms, presenting their possible integration as food for people and livestock.

Research conducted in the Democratic Republic of the Congo shows that castor *(Ricinus communis* L*)*, a plant that is abundant in the country, can be used for rearing the eri silkworm, *Philosamia cynthia ricini*.

Our ongoing studies include investigation of ways for degumming silk using enzymes. The goal is to minimise the use of chemicals in the process to reduce the adverse impact on the environment. We are also researching better ecologically sustainable ways to rear silkworms. Further, we are exploring the potential application of sericin, a natural protein produced by silkworms.

Eri silkworm rearing techniques, eggs supply and procurement have been enhanced within the YESH and MOYESH projects. The sericulture grainage produced 1.8 million eggs of the domesticated silk moth *Bombyx mori*, which were supplied to partners in Uganda. In addition, 200 kilogrammes of wet *B. mori* cocoons were produced in the *icipe* silk rearing section, as well as 80 metres of fabric. Over 100 silk products, including scarves and ties, were produced.

Applied Bioprospecting Programme

Since the early 2000s, *icipe* has partnered with local communities living adjacent to biodiversity-rich areas to discover, develop and commercialise natural products for pest and vector management. The central vision is to support the conservation of the biodiversity and environment, while opening up new avenues for income generation.

Participating communities around Kakamega forest (pictured), Kenya; East Usambara mountains, Tanzania; and Mpigi district, Uganda, were supported to cultivate various indigenous medicinal plants, traditionally harvested from natural ecosystems like forests, in their farms.

Between 2016 and 2020, together with our partners, we implemented SWITCH Africa Green, an initiative aimed towards integrating sustainable consumption and production practices within the *icipe* community-based conservation enterprises, especially around Kakamega forest in Kenya. The goal was to support the transition of the enterprises towards a green economy by improving efficiency in the processes; reducing raw material inputs; recycling; product quality assurance and labelling; reducing environmental pollution; development, diversification and marketing of green products; health and safety; and social responsibility and equity.

In 2020, socio-economic impact assessments of such initiatives were conducted, showing:

Key factors for participation in community-based enterprises are age, distance from forest and markets, benefits from the forest and experience in farming.

Approximate average increase in income ranges from USD 800 to USD 1800 per hectare, per year.

The findings will inform policy formulation to encourage local community participation in the medicinal plants cultivation and enterprises.

10 Micro, Small & Medium Enterprises, composed of 400 households were formed.

627 community members adopted SCP practices.

70 youth (44 male and 26 female) were engaged in new economic opportunities.

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) and International Development Research Centre (IDRC) through the Cultivate Africa's Future (CultiAF) programme; Bioinnovate Africa; BLE – German Federal Agency for Food and Agriculture; German Federal Ministry for Economic Cooperation and Development through GIZ; Danida; Netherlands Organization for Scientific Research (NWO); Rockefeller Foundation; Norwegian Agency for Development Cooperation (Norad); UK's Foreign, Commonwealth and Development Office (FCDO); Scientific Cooperation Grant Initiative for Eastern Africa; Biotechnology and Biological Sciences Research Council, UK Research and Innovation (UKRI); World Bank.

2020 IN BRIEF

Food Planet Prize
icipe awarded prestigious and largest accolade of its kind in the world.

Insect oils
Evidence on the nutritional superiority of insect oils; desert locust and long-horned grasshopper identified as ideal candidates for mass rearing for oil production; African entrepreneurs could tap into booming global cooking oil market.

Mainstreaming *nsenene*
Model developed to predict potential regions in Africa where the long-horned grasshopper could become permanently established in future.

Most consumed insects
in Kenya; and species most popular for rearing identified.

Cricket species
are an excellent source of macronutrients; and cricket-derived chitosan is a promising agent for suppressing clinically pathogenic bacteria.

Black soldier fly frass fertiliser
discovered to be an environmentally safe, more affordable and sustainable option for increased maize growing; and low-cost technology for production developed.

Insects for Food, Feed and Other Uses Programme

Food Planet Prize

In 2020, *icipe* was awarded the prestigious USD 1 million Curt Bergfors Foundation Food Planet Prize, in recognition of the Centre's pioneering research and activities on insects for food, feed and other uses. *icipe* shared the prize with Sanergy, a Kenya/United States-based organisation.

Currently the largest accolade of its kind in the world, the Food Planet Prize acknowledges ground-breaking initiatives that offer solutions to tackle the Food Planet Challenge — the need to keep a rapidly growing world population alive and well-nourished — without destroying the Earth.

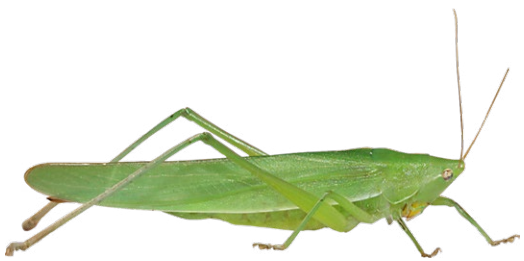
Insect oils

Recent *icipe* studies have provided evidence on the nutritional superiority of insect oils, strengthening the case for the incorporation of insects and their additives into food and animal feed.

We compared oils from two grasshopper species that are commonly consumed in Africa: the desert locust (*Schistocerca gregaria),* and the long-horned grasshopper (*Ruspolia differens),* also known as *nsenene,* and those obtained from olives and sesame.

In comparison to plant oils, insect oils are richer in omega-3 fatty acids, antioxidants and vitamin E. In general, the values of the fatty acids in insect oils compare favourably with those known to be necessary for important physiological functions in people, including defence against pathogens, prevention of heart diseases, and with anticancer and anti-inflammatory agents.

This study aligns with an earlier discovery by *icipe* that consumption of the desert locust could be good for people's hearts. Our findings show that the insect contains a rich composition of compounds known as phytosterols that have cholesterol-lowering properties, thereby reducing the risk of heart disease.



The current results make the desert locust (right) and *nsenene* (left) ideal candidates for mass rearing for oil production, and provide an avenue for entrepreneurs in Africa to tap into the lucrative and booming global cooking oil market, expected to reach USD 130.30 billion by 2024.

Nutritional benefits of insects

A model developed by *icipe* will enable prediction of potential regions in Africa where the long-horned grasshopper, *R. differens* (pictured top-left) could become permanently established in future. The newly generated tool will enable environmental conservation and sustainable harvesting of the insect, counter to the currently seasonal and unreliable mode. It also complements wild harvesting technologies and mass rearing protocols developed by *icipe* for the grasshoppers. **This knowledge could contribute to elevating *nsenene* from a periodic snack, to its rightful role as a sustainable addition to food and nutritional security, and income generation in Africa.**

We have established that two cricket species, *Scapsipedus icipe* (pictured top-right) and *Gryllus bimaculatus* (pictured bottom-right) are an excellent source of iron, zinc and folic acid for people. Further, we have formulated cereal-based products incorporating these two crickets, and confirmed them to have higher protein contents than similar commercial products in the East African market.

Studies in Kenya show that termites, grasshoppers, saturniids, crickets, compost grubs and lake flies, in that order, are the most frequently consumed insects. Over 73 percent of the people interviewed in a survey were willing to rear saturniid caterpillars (pictured bottom-left), primarily for income.

Our studies show that cricket-derived chitosan is a potential and promising agent for suppressing clinically pathogenic bacteria. These findings open novel routes for the application of the product in the food processing industries, for improved gut health in people and animals.

Black soldier fly frass fertiliser

Recent studies by *icipe* have demonstrated the potential of black soldier fly frass fertiliser as an environmentally safe, more affordable and sustainable option for increased maize production.

The first research shows that while various commercial organic and inorganic fertilisers have influence on maize plant height, chlorophyll concentrations and macronutrients uptake, black soldier fly frass fertiliser has additional and considerable impact on nitrogen use efficiency and overall crop yield. In a second study, we found that topsoils in plots treated with black soldier fly frass fertiliser have more nitrogen, resulting in higher uptake of this essential mineral by crops, resulting in better yield.

Further, economic analysis shows that individuals involved in black soldier fly farming could increase their net income 5 – 15 folds by producing frass fertiliser. Maize grown on plots treated with frass fertiliser would raise net incomes by 29–44 percent higher than that grown on plots amended with commercial organic fertiliser.

We have developed a low-cost technology for recycling agro-industrial waste using black soldier flies, to produce high-quality frass organic fertiliser. Among other attributes, the technology shortens the compost maturation period, and helps generate a product that increases seed germination, which implies that the compost generated is free of phytotoxic substances.

Our ongoing studies aim to determine mid- and long-term effects of black soldier fly frass fertiliser on soil health and crop protection, especially against pests like nematodes, across different agroecological zones and cropping systems.

SOCIAL SCIENCE AND IMPACT ASSESSMENT UNIT

The *icipe* Social Science and Impact Assessment (SSIA) Unit focuses on understanding the drivers of technology adoption, impact assessment, and gender analysis. The Unit also has the responsibility for implementing *icipe* Centre-wide Monitoring & Evaluation (M&E), and gender strategies.

Donors: University of Bern, Switzerland; Impaxio GmbH, Switzerland; World Bank; German Research Foundation (DFG); International Development Research Centre (IDRC), Canada; Australian Centre for International Agricultural Research (ACIAR); Biovision Foundation for Ecological Development, Switzerland; European Union (EU); German Federal Ministry for Economic Cooperation and Development (BMZ); German Research Foundation (DGF); Mastercard Foundation (MCF); Norwegian Agency for Development Cooperation (Norad); Swedish International Development Cooperation Agency (Sida); Swiss Agency for Development and Cooperation (SDC); United States Agency for International Development (USAID); UK's Foreign, Commonwealth & Development Office (FCDO); Wageningen University and Research Centre, The Netherlands; National Research Fund (NRF), Kenya; BioInnovate Africa Programme; Rockefeller Foundation; Tel Aviv University, Israel.

2020 IN BRIEF

Food security and COVID-19 pandemic
Benefits of improved on-farm storage technology and training.

Tsetse repellent technology
Economic benefit; and estimated benefit–cost ratio.

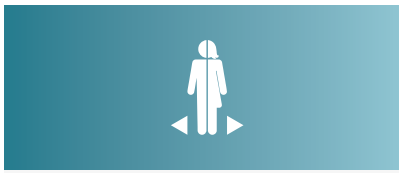
Fall armyworm in Ethiopia
Maize production losses; amount of food-insecure people that could have been fed; expenses in purchasing control chemicals.

Push–pull technology and fall armyworm
Reduction in maize production loss; mitigation of environmental damage.

UZIMAX
Evidence of high adoption potential; need for inclusive policies.

Farmers' perceptions and preferences
for insect-based chicken feeds; key variables for decision to purchase; and needed interventions.

Beekeeping
Increases in household per capita income; benefits of bee colonies for pollination; potential impact on agricultural investment and food security.



Gender-based differences
in PhD performance in Africa.

Social Science and Impact Assessment Unit

A study was conducted in western Kenya to examine the effects of improved on-farm storage on household food security within 30 days of COVID-19 restrictions.

9 percent increase in food insecurity was recorded in households with improved on-farm storage technology and training.

20 percent increase in food insecurity was reported in control households.

Assessments of economic benefits of the tsetse repellent collar technology, which protects livestock from tsetse flies resulting in improved meat, milk and crop productivity, undertaken in 18 African countries, show:

Adoption of the technology in 5 to 50 percent of the animal population generates an economic benefit of USD 78–869 million per annum.

The estimated benefit–cost ratio is USD 9:1.

The fall armyworm is reported to have arrived in Ethiopia in February 2017, and it has now spread to the country's six major maize-growing regional states. *icipe* studies on the pest's impact from 2017 to 2019 indicate:

Total maize production losses of 0.67 million tonnes (0.22 million tonnes per annum). This is equivalent to USD 200 million, which is 0.08 percent of the country's gross domestic product (GDP).

It has cost the country USD 4 million to purchase chemicals in an often futile attempt to control the pest.

Containing the fall armyworm could have fed four million food-insecure people in Ethiopia.

The push–pull technology has mitigated fall armyworm damage in Ethiopia with:

33 percent reduction in maize production loss.

Alleviation of environmental damage that would have been occasioned by the use of chemicals to control the pest.

UZIMAX is a novel plant-based biopesticide developed by *icipe* to control malaria vectors. Studies on Willingness to Pay for UZIMAX show:

High adoption potential of the technology.

Need for inclusive policies to: enhance collective action, mobilise resources, empower men and women and stimulate investment in eco-friendly technologies for malaria prevention.

For the past 15 years, *icipe* and partners have implemented a series of science-led beekeeping initiatives in Ethiopia. Recent assessments show that:

Beekeeping farming increased household per capita income by USD 175.

Availability of bee colonies increases production value of pollination-dependent crops.

Promoting beekeeping can unlock constraints of agricultural investment and enhance food security.

Studies on farmers' perceptions and preferences for insect-based chicken feeds show:

Key variables for decision to purchase are:
Performance, social acceptability of insects in feed, feed versatility, and marketability of livestock products reared on insect-based feed.
Influencing factors of farmers perceptions are:
Awareness creation, group membership, off-farm income, wealth status, and education.

Needed interventions:
Experimental demonstrations, awareness campaigns, and social networks that increase farmers' technical knowledge and growth performance of livestock fed on insect-based chicken feeds.

A study conducted to understand gender-based PhD performance in 17 African countries showed that:

Compared to their male counterparts, women had one paper less accepted for publication during their studies.
Women took half a year longer to complete their training.
Getting married during the PhD journey reduced women's publication productivity but increased men's.
Becoming a parent during the training was a key contributor to women taking longer to complete their PhDs.
Having a female supervisor and attending an institution with gender policies enabled women's timely PhD completion.

Recommendations:
Family-friendly policies and facilities that support women's roles as spouses and mothers;
Fostering broader linkages and networks for women in STEM, including ensuring mentoring and supervisory support that is tailored to their specific needs and circumstances.

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: European Union; Bertha Foundation; United States Agency for International Development (USAID).

2020 IN BRIEF

Training
Materials brochures produced and translated into local languages; technology learning sites established; lead and follower farmers, and extension service providers trained; and partnerships with media formed.

Digital approaches
In view of COVID -19 pandemic, communities of practice formed; and online extension tools established.

Fall armyworm management
Support for efficacy trials for biopesticides; field release of natural enemies; community-based fall armyworm monitoring and forecasting advanced.

New partnerships and collaborations
with the private sector, national research institutions and non-governmental organisations.

Samples of some of the training materials developed and disseminated in 2020.

Technology Transfer Unit

8 million people
reached indirectly through radio programmes and print media in partnership with Biovision Africa Trust.

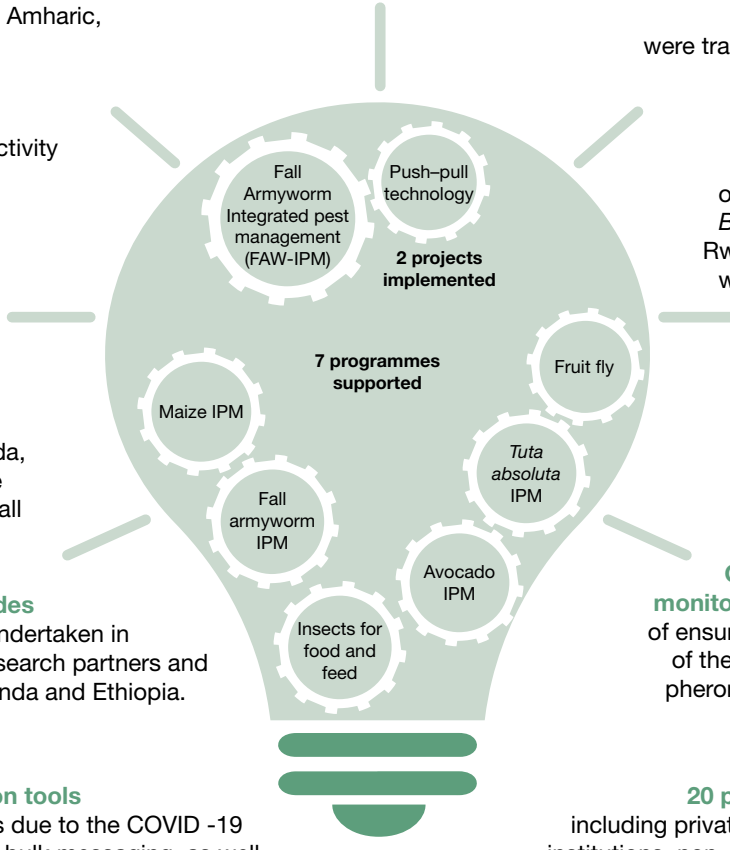
11 sets of materials
including manuals, videos, factsheets and brochures produced and translated into Amharic, Kiswahili and Kinyarwanda.

15,000 follower farmers
were trained on effective management of the fall armyworm.

Communities of practice
were also formed, ensuring interconnectivity among stakeholders.

Seed production
of push–pull intercrops, (*Desmodium* and *Brachiaria*), continued in Kenya, Ethiopia, Rwanda and Tanzania, through partnerships with private sector partners, and informal community-based efforts.

2811 (1582 male, 1229 female)
lead farmers and extension service providers in Kenya, Uganda, Ethiopia, Tanzania and Zimbabwe were trained.



Support for field release of natural enemies
of fall armyworm, *Cotesia icipe*, *Telenomus remus* and *Trichogramma chilonis,* in three counties in Kenya.

11 technology learning sites
were established (4 in Kenya, 3 in Uganda, 2 in Tanzania and 2 in Ethiopia), where demonstrations and farmer training on fall armyworm IPM were hosted.

Community-based fall armyworm monitoring and forecasting advanced as a way of ensuring early warning and timely management of the pest through training and installation of pheromone traps in Ethiopia, Malawi, Rwanda, Uganda and Zambia.

Efficacy trials for biopesticides
to manage the fall armyworm, were undertaken in collaboration with Real IPM Ltd, national research partners and technology disseminators in Kenya, Uganda and Ethiopia.

Digital and online extension tools
were established in response to restrictions due to the COVID -19 pandemic. They include virtual training and bulk messaging, as well as value chain-specific WhatsApp groups.

20 partners and collaborators
including private sector companies, national research institutions, non-governmental organisations, community-based and faith-based organisations, worked with TTU.

Eristalinus, genus of hoverflies, are efficient pollinators while their maggots are predatory on various insects.

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: Bill & Melinda Gates Foundation; BioInnovate Africa Programme; German Federal Ministry for Economic Cooperation and Development (BMZ); European Union; International Development Research Centre (IDRC), Canada.

A comprehensive list of partners is included in the annexes.

2020 IN BRIEF

Maps generated

to delineate field study sites and show locations of field data.

Models generated

to show suitable habitats of various insect pests, parasitoid and weed species.

System thinking, and system dynamics model

on interactions between pests and their natural enemies developed.

Research Data Management and Archiving policy

developed and approved.

Satellite-based models

for characterising landscape structure generated.

Implementation of several projects

led or guided by the Unit.

Systems and infrastructure

for data management workflow initiated.

Data repository system

developed.

Data Management Modelling and Geo-information Unit

130

maps were generated for projects across the Centre's 4Hs Themes to delineate study sites and show locations of field data.

Sophisticated and novel **satellite-based models** for characterising landscape structure were generated to guide the implementation of integrated pollinator and pest management (IPPM) technologies in Kenya and Tanzania.

55

models were generated at global, regional and local scales, under diverse climate scenarios, to show the suitable habitats of various insect pests, parasitoid and weed species. Examples include the fall armyworm and its parasitoids, desert locust, mealybug and *Striga* weed.

The Unit **led the implementation** of the Scaling-up Climate-Smart Pest Management Approaches for Enhancing Maize and Tomato Productivity in Eastern Africa (SCLAMP-EA) project; and the modelling and predicting of crop-induced losses to insect pests under a warming climate.

An innovative **system thinking, and system dynamics model** was conceptualised, developed and implemented to understand the interactions between pests and their natural enemies.

The Unit guided the implementation of project activities using **geospatial and remote sensing modelling** approaches in Malawi and Zimbabwe, focusing on alien invasive fruit flies.

A **Research Data Management and Archiving (RDMA) policy** was developed and approved by the *icipe* Governing Council for implementation. A series of familiarisation trainings were conducted for the Centre's R&D teams.

Systems and infrastructure for **data management workflow** were initiated. REDCap and Open Data Kit (ODK) central systems for digital data collections were configured. These infrastructures are being piloted. The Centre's data repository system was developed.

Cheilomenes lunata, a coccinellid predator of aphids, psyllids and mealybugs.

CAPACITY BUILDING AND INSTITUTIONAL DEVELOPMENT PROGRAMME

Building capacity of people and institutions to respond to arthropod-related development needs in Africa is a major commitment of *icipe*, a goal that is achieved through: high-level training at postgraduate and postdoctoral levels; institutional development by nurturing and strengthening African research and development organisations and institutions; dissemination of technologies to national agricultural and health research and extension systems.

Donors: Scholarships and fellowships are provided by: German Academic Exchange Service (DAAD); Gandhi Smarak Nidhi Fund; Welcome Trust; THRiVE-2 Fellowships.

Further support for scholars, through *icipe* project funds from:
African Union; WHO-AFRO; Agence Nationale de la Recherche (ANR), and HORTINET CI funded by PreSed/CI; African Development Bank, through Technologies for African Agricultural Transformation (TAAT); Australian Centre for International Agricultural Research (ACIAR); Biovision Foundation for Ecological Development, Switzerland; CABI; 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 National Research Institute for Sustainable Development (IRD); French Development Agency (AFD); German Ministry of Economic Cooperation and Development (BMZ) through Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ); German Research Foundation (DFG); International Atomic Energy Agency ; International Development Research Centre (IDRC); JRS Biodiversity Foundation; Kenya Medical Research Institute-Wellcome Trust Programme under the Viral Epidemiology and Control group; Fogarty International centre - NIH, USA; Kungliga Tekniska Hogskolan (KTH) Liechtenstein Development Service (LED); Coop Sustainability Fund National Institutes of Health, USA; Newton Fund; Norwegian Agency for Development Cooperation (Norad); Rockefeller Foundation; Swedish International Development Cooperation Agency (Sida) through BioInnovate Africa Programme; Swedish Research Council; United States Department of Agriculture-Agricultural Research Service USDA-ARS; Volkswagen Foundation; World Health Organization (WHO).

***icipe* core donors:** Swiss Agency for Development and Cooperation (SDC), Switzerland; Swedish International Development Cooperation Agency (Sida), Sweden; UK's Foreign, Commonwealth & Development Office (FCDO); Ministry of Education, State Department of University Education, Kenya; and Government of the Federal Democratic Republic of Ethiopia.

2020 IN BRIEF

Postgraduate, postdoctorate and research internships

Statistics on ongoing scholars, fellows and interns; percentage of women; graduations and thesis defences; research presentations; peer-reviewed publications; African nationalities representation.

Strengthening doctoral supervision

Early career scientists undergo training.

Training

Institutional development; and dissemination of technologies conducted for students, researchers, national programme partners, and farmers.

EANBiT Network

First cohort completed fellowships; third cohort recruited; MoU signed with new partner; Bioinformatics Hub of Kenya established; virtual Bioinformatics Residential Training held.

In addition to scholars undertaking PhD or MSc research under the Centre's programmes, *icipe* also hosts students on internships and attachments as part of their degree requirements. Pictured: Annet Karimi Luka (Kenya), who was placed in the Environmental Health Theme in 2020.

Capacity Building and Institutional Development Programme

Our focus

240

PhD and MSc scholars, postdoctoral fellows and interns were conducting research at *icipe* in 2020.

33

scholars defended their thesis or graduated in 2020. They include 13 ARPPIS PhD; 4 DRIP PhD; and 16 DRIP MSc scholars.

10

research presentations were made by *icipe* scholars at national, regional and international conferences and workshops.

69

percent of all peer-reviewed publications by *icipe* were first-authored or co-authored by postgraduate and postdoctoral fellows.

48

percent of the ARPPIS and DRIP postgraduate scholars and research interns are women.

20

African nationalites were represented in the programmes (including RSIF): Benin, Burkina Faso, Côte d'Ivoire, Cameroon, Chad, Democratic Republic of the Congo, Ethiopia, Ghana, Kenya, Malawi, Nigeria, Rwanda, Senegal, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe

All figures indicated are for 1 January – 30 December 2020

Strengthening doctoral supervision

10 of *icipe*'s early career scientists participated in an eight-week online training course for supervisors of doctoral candidates at African universities, given by the Centre for Research on Evaluation, Science and Technology (CREST), an academic centre of Stellenbosch University in South Africa.

Training

Each year, *icipe* holds courses, workshops and other training events for research students and scientists, R&D collaborators, farmers and extension workers, and other stakeholders. Training covers a range of activities, spanning the continuum from basic strategic research to technology development and validation, to community-based adoption of new technologies. Below is a summary of training activities in 2020.

98
training events held.

21
African nationalities represented in the training events.

43,566
participants involved.

56
percent of all participants in the training events were women.

Participants included students, researchers, national programme partners, farmers.

The focus of the training was on knowledge intensive areas of *icipe* technologies and products, and research and research-related skills.

EANBiT network

The Eastern Africa Network for Bioinformatics Training (EANBiT) is a collaboration of three universities and four research institutes in Kenya, Tanzania and Uganda, established to develop a critical mass of practitioners who can generate and use bioinformatics approaches to biosciences. Coordinated by *icipe* and supported by the Fogarty International Center of the National Institutes of Health, USA, under the H3Africa Programme, EANBiT completed its third year in 2020, with the accomplishments detailed below.

Twelve MSc bioinformatics fellows were recruited in 2020, bringing the total number of fellows under the network to 32.

Eight fellows are registered in Pwani University, Kenya, and four in Makerere University, Uganda.

A memorandum of understanding was signed between *icipe* and Muhimbili University of Health and Allied Sciences, Tanzania, for the establishment of the third EANBiT MSc Bioinformatics programme in Tanzania.

The first EANBiT cohort, consisting of 11 fellows, completed their fellowships. One fellow has advanced to a PhD programme funded by the Wellcome Trust registered at the University of Leicester, UK. A second fellow will take up a position as a Computational Biologist in the UK.

The first EANBiT cohort led the establishment of the Bioinformatics Hub of Kenya, a vibrant capacity building network and a key avenue for mentorship and sharing news.

A virtual Bioinformatics Residential Training was conducted from 6 July – 28 August 2020 bringing together 40 participants from Kenya, Uganda, Tanzania and Eswatini.

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.

Donors: Swedish International Development Cooperation Agency (Sida), Sweden.

A comprehensive list of partners is included in the annexes.

2020 IN BRIEF

Supporting policy for bioeconomy

Regional Strategy developed; Eastern Africa Conference on Bioeconomy organised; and Bioeconomy Observatory portal launched.

Global impact

Participation in the Global Bioeconomy Summit, amplifying the region's voice, and that of the continent, in shaping the global bioeconomy agenda.

Women and bioeconomy

Fellowship scheme continues, and Alumnae Network formed.

Commercial acceleration

of nine projects, including product launch, pilot commercial operations and investor readiness.

Through the BioInnovate Africa Women Fellowship scheme, Marthe Niyibigira (Rwanda), currently an MSc student at Makerere University, Uganda, conducted research within the *icipe* Insects for Food and Feed programme from November 2019 – December 2020. Marthe tested chitosan extracted from various edible insect species, as an alternative, more cost-effective and natural preservative for food products. She also investigated consumer acceptability of flavoured insect-based food products. Marthe's research was a first in the extraction of chitin and chitosan from several insects, including grasshoppers, desert locusts and crickets. This experience positions her in the context of the emerging insect-based food products across eastern Africa and beyond.

Supporting Policy for Bioeconomy in Africa

BioInnovate Africa is supporting the vision of a bioeconomy in Africa in several ways, including facilitating the creation of an enabling policy environment. Working jointly with the East African Science and Technology Commission (EASTECO), and other partners, the Programme has led to the development of a Regional Bioeconomy Strategy. Moreover, in October 2020, BioInnovate Africa and partners organised the first Eastern African Bioeconomy Conference, bringing together 400 regional, continental and global participants, including high-level policymakers, academia, scientists, innovators, funders, investors, business professionals and the media.

The Conference deliberated reforms and policy incentives necessary to foster a sustainable bioeconomy in eastern Africa, as a vital component to achieving the 2030 Agenda for Sustainable Development and the East African Development Strategy 2050. Also, the forum backed the eastern Africa Regional Bioeconomy Strategy and provided guidance towards its implementation and adoption by respective countries. An eastern Africa Bioeconomy Observatory portal was launched to serve as a knowledge repository, and to enable monitoring of advances in bioeconomy in the region. **The progress made by BioInnovate Africa and partners in the eastern African region could pivot the advancement of a bioeconomy across the continent.**

Global impact: In growing recognition of BioInnovate Africa's international importance, the Programme and EASTECO were the official eastern Africa representatives at the third Global Bioeconomy Summit (GBS) 2020, held from 16 – 20 November 2020. Julius Ecuru, Manager, BioInnovate Africa, who serves on the International Advisory Council of GBS, was a speaker in the plenary session of the event. This high-level participation amplified the region's voice, and indeed that of the continent, in shaping the global bioeconomy agenda. **The key message was that a sustainable bioeconomy should be underpinned by innovation. Therefore, it is vital to invest in the development of sustainable industries, as a way of creating employment and increasing household incomes.**

Women and bioeconomy: Efforts to enhance participation of women scientists in the African bioeconomy continue through the Programme's Fellowship scheme. Currently, 12 women scientists are undertaking fellowships within projects supported by BioInnovate Africa in Burundi, Kenya, Uganda, Rwanda, Tanzania and Ethiopia. The BioInnovate Africa Fellows Alumnae Network (BA-FAN), an affinity-based community of women scientists that will enable networking and collaboration on biological-based research and innovation activities in eastern Africa, has also been launched.

Business acceleration

In 2020, BioInnovate Africa commenced acceleration of nine of its funded projects, towards commercialisation, including product launch, pilot commercial operations and investor readiness.

Product	Innovation	Market	Partners
Novel sorghum and millet products	Use of extrusion technology to produce nutritionally-enriched sorghum and millet products that retain nutritional traits and improve digestibility.	The target customer segments are: elementary and school-going children; health-conscious middle-class consumers; and mothers of infants.	Almi Foods Manufacturing PLC Hawassa, Ethiopia Joraku Enterprises Ltd., Tanzania Synamon Food Systems Ltd., Uganda
Aroma honey toffees	Healthier sweets that contain 75 percent honey and 25 percent dairy products, groundnuts, coconut, and spices, and no processed sugar.	Health-conscious sweets consumers, mainly middle- and upper-income consumers and event organisers.	Aroma Honey Toffee Ltd Two bee farmer groups in Rwanda and Kenya
Black soldier fly larvae meal	Commercial scale production of black soldier fly meal, organic fertiliser and defatted oil, incorporating waste processing and recycling.	Small- to medium-scale poultry and livestock farmers.	BioBuu Ltd, Mombasa County government, hotels, feed producers, poultry and fish farmers, among others, all in Kenya
Integrated technologies for agro/biowaste conversion	Biological treatment of wastewater, to produce clean water, biogas and biofertilisers.	The treated water could be reused by industry and farmers for irrigation, or safely discharged into the environment.	Bioconversion Technology Africa Company Ltd and BIOCON Uganda Ltd
Hakika Organic Fertilizer	Conversion of biodegradable waste from food markets, households, and restaurants mixed with special nitrogen plant species, using temperature and humidity sensors to control the rate of decomposition, ensuring quality and product consistency, nutrient-rich organic fertiliser.	Horticultural farmers and commercial flower growers in Tanzania and Uganda	Guavay Company Ltd, Tanzania, Tursam Investments Ltd, Uganda

Product	Innovation	Market	Partners
Striga weed-resistant maize and finger millet varieties	Six new crop varieties that inhibit *Striga* germination, and also have higher grain yield compared to susceptible genotypes.	Maize and finger millet farmers in Kenya and Uganda	Maseno University Seed Unit, Kenya Agri Seedco Ltd, Kenya Qualibasic Seed Company International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) National Semi Arid Resources Research Institute, Uganda
Viazi Vitamu Mobile App	The tool supports real-time mapping of sweet potato farmers, vine multipliers and other stakeholders, to make accessible genetically pure, physiologically sound, pest and disease-free sweet potato seed.	Sweet potato farmers across Africa	Mimea International Limited, Kenya, Senai Farm Supplies Limited, Uganda, Tanzania Agricultural Research Institute (TARI) – Mikocheni
Nutrient-rich substrate blocks for mushroom cultivation	The products, which are obtained from tropical crop residues, reduce initial costs, and they have less lengthy and laborious processes in mushroom production.	Mushroom farmers across Africa	OKOA Mushroom Supplies Enterprises Limited, Tanzania, private mushroom growers in Morogoro, Tanzania, through a one-stop-centre
Bio-Alkanol gel	A clean fuel made from a mixture of fruit-derived waste and other bio-based binders and additives, as an alternative for firewood and kerosene in rural and peri-urban households. The gel reduces carbon emissions by about 80 percent, and it is also more affordable and efficient.	Primarily households in rural and peri-urban households in the Lake Victoria basin, Kenya, with the aim of expansion to communities in Tanzania and Uganda	Ecogel Enterprise Ltd, Kenya, Tropical Pesticides Research Institute, Tanzania, National Agricultural Research Organization, Uganda

Solenosthedium liligerum, commonly known as jewel bugs due to their often brilliant coloration.

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, RSIF supports PhD scholarships, as well as research and innovation grants 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.

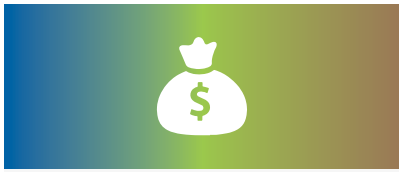
Donors (as of February 2021)
Governments of Benin, Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Rwanda and Senegal.

Further investments have been provided by 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; Kenyatta University, Kenya; Sokoine University of Agriculture, Tanzania; Nelson Mandela African Institution of Science and Technology, Tanzania; Université Félix Houphouët-Boigny, Côte d'Ivoire; Université Gaston Berger, Senegal; University of Ghana; University of Nairobi, Kenya; University of Port Harcourt, Nigeria; University of Rwanda.

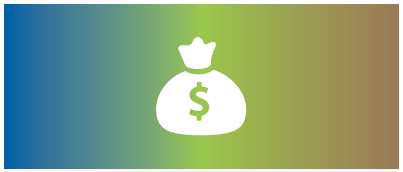
International Partner Institutions (IPIs): Ghent University, Belgium; IMT Mines Albi, France; Institutes of Green-bio Science & Technology, Seoul National University, South Korea; International Livestock Research Institute (ILRI); Karlsruhe Institute of Technology, Germany; Korea Institute of Energy Research, South Korea; Korea Institute of Science and Technology, South Korea; Korea Research Institute of Chemical Technology, South Korea; Maastricht University, The Netherlands; Mohammed VI Polytechnic University (UM6P), Morocco; Seoul National University Global Research & Development and Business Center, South Korea; University of Greenwich, Natural Resources Institute, UK; Virginia Tech College of Agriculture and Life Sciences, USA; Worcester Polytechnic Institute, USA.

2020 IN BRIEF



7 African governments

investing in RSIF as of February 2021.



3 development partners

investing in RSIF as of February 2021.

11 African Host Universities

14 International Partner Institutions

5 thematic areas

Information and Communications Technologies (ICT), including data science and artificial intelligence; food security and agribusiness; minerals, mining and materials engineering; energy including renewables; and climate change.

82 PhD scholars

in progress in 2020.

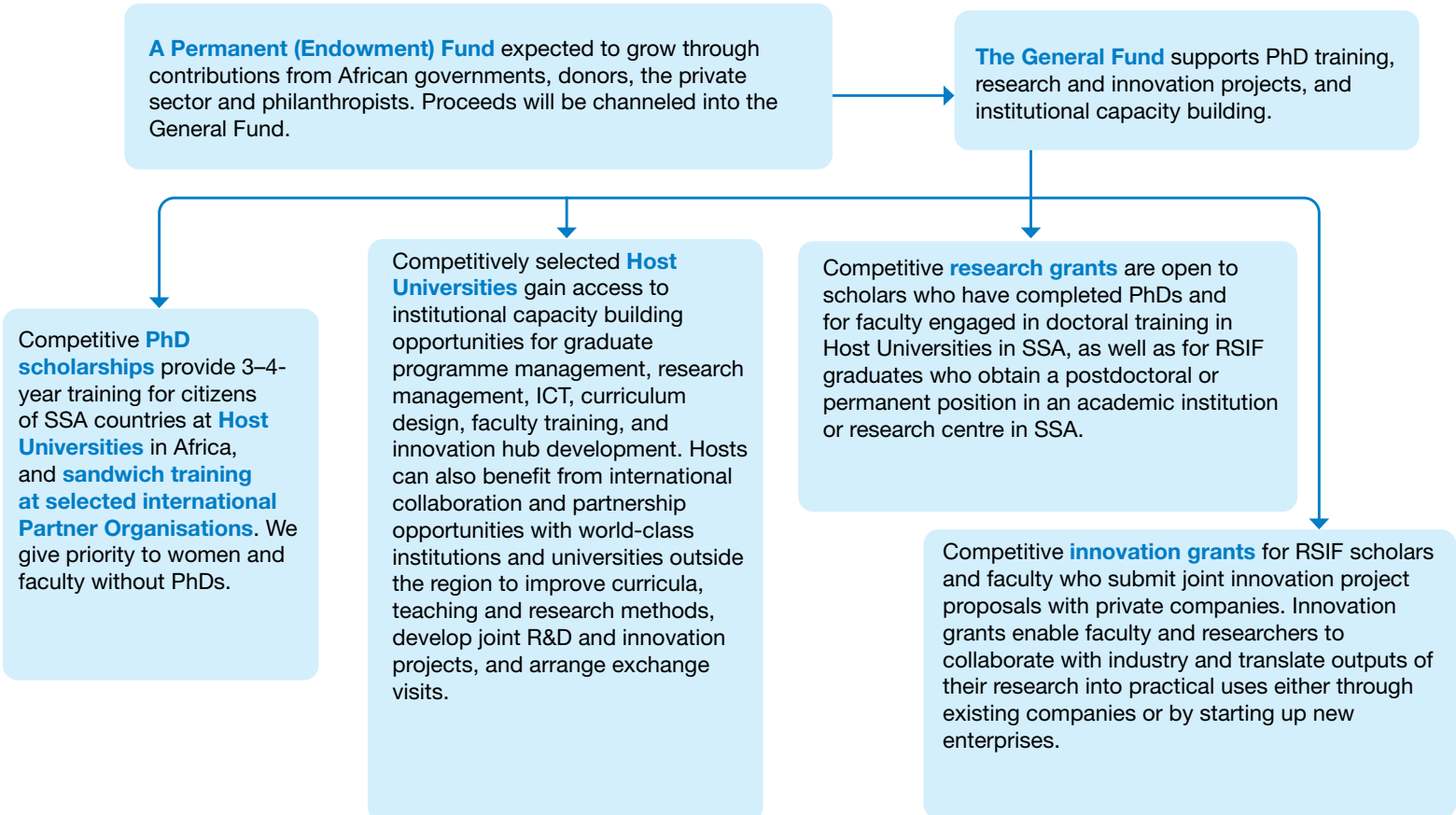
40.3

percent of cohort II scholars selected in 2020 (27 of 67) are women. 37 percent of all RSIF PhD scholars are women (30 of 82).

14 research and innovation grants

awarded in 2020.

RSIF Design


A Permanent (Endowment) Fund expected to grow through contributions from African governments, donors, the private sector and philanthropists. Proceeds will be channeled into the General Fund.
The General Fund supports PhD training, research and innovation projects, and institutional capacity building.
Competitive PhD scholarships provide 3–4-year training for citizens of SSA countries at Host Universities in Africa, and sandwich training at selected international Partner Organisations. We give priority to women and faculty without PhDs.
Competitively selected Host Universities gain access to institutional capacity building opportunities for graduate programme management, research management, ICT, curriculum design, faculty training, and innovation hub development. Hosts can also benefit from international collaboration and partnership opportunities with world-class institutions and universities outside the region to improve curricula, teaching and research methods, develop joint R&D and innovation projects, and arrange exchange visits.
Competitive research grants are open to scholars who have completed PhDs and for faculty engaged in doctoral training in Host Universities in SSA, as well as for RSIF graduates who obtain a postdoctoral or permanent position in an academic institution or research centre in SSA.
Competitive innovation grants for RSIF scholars and faculty who submit joint innovation project proposals with private companies. Innovation grants enable faculty and researchers to collaborate with industry and translate outputs of their research into practical uses either through existing companies or by starting up new enterprises.

RSIF focuses on strengthening institutional capacity of African universities towards high quality and sustainable doctoral training, as well as research and innovation, to generate transformative technologies in Africa. This strategy will lead to increased, and more qualified PhD faculty capacity, who are able to undertake world class and impactful research and innovation, and to mentor and nurture doctoral students.

RSIF provides fully-funded scholarships that are tenable in 11 African Host Universities (AHUs), in partnership with international partner institutions (IPIs). The second cohort of RSIF PhD scholars, selected in 2020, are undertaking a range of studies across the five PASET thematic areas, as summarised below.

Internet of Things (IoT), big data, smart devices among others, for automatic comment sorting by an artificial moderator; IoT data classifier; Monitoring of air pollution; Indoor healthcare monitoring; Digital healthcare service delivery; Fraud prevention in electricity consumption; Terror threats prediction; Agriculture pests monitoring.

Newcastle disease in traditional livestock systems in Côte d'Ivoire; Control of African trypanosomosis in Côte d'Ivoire and Tanzania; Sheep and goats respiratory diseases in Tanzania; Rift Valley fever virus in Rwanda; Migratory birds and ESKAPE pathogens in relation to goat and poultry health in Kenya; Duck breeds and meats quality in Benin; Diagnostic tool for maize lethal necrosis disease; Anticancer, antimicrobial and antioxidant potential in Chadian medicinal plants; Various social impact and value chain studies, including on-farm households, gender, non-traditional export firms, rice sector, mushroom production, private sector investments in the cocoa sector, vulnerability of smallholders, and sustainable farm enterprises in Ghana; Sustainable rural development through agriculture in Nigeria; Postharvest practices and mycotoxin contamination in Rwanda.

Drought prediction models in northern Nigeria; Ecosystem service and biodiversity response in northern Ethiopia; Land suitability and soil classification in Sudan; Impacts of future emissions in Rwanda; Solutions for sustainable control of causes like fungi, bacteria and pests as well as diseases on mango, cashew, and potato in several countries in Africa.

Nanoparticles for solar heterogeneous photocatalysis applications; Heavy metal removal in water using activated carbon from *Moringa oleifera*; Effect of earth-to-air heat exchanger in buildings in Congo; Biochar to enhance methane production and denitrification process in wastewater treatment; Nanofibres for wastewater treatment; Dye-sensitised solar cells and removal of heavy metals from water; Electrode materials derived from chicken feathers.

Improved technologies and strategies for oil production in Nigeria and the Sahel; Advanced solar technologies like perovskite solar cells, optimised magnetorheological nanofluids for heat transfer in solar thermal concentrators and energy storage systems; Dye-sensitised solar cells; Affordable decent smart green buildings; Geothermal energy system integration; Automated biogas system (mini factory) from the hyacinth plant in Kenya.

Research and innovation grants

Research projects

Bayero University, Kano (Nigeria)
Climate Change
Do-it-for-yourself adaptation: New pathways for community flood risk communication

Nelson Mandela African Institution of Science and Technology (Tanzania)
Minerals, Mining and Materials Engineering
Solar-assisted heat pump dryer with energy storage for drying biomaterials

Nelson Mandela African Institution of Science and Technology (Tanzania)
Minerals, Mining and Materials Engineering
Fluoride removal from drinking water using capacitive deionisation

University of Ghana
Food Security and Agribusiness
Building resilient agribusiness practitioners through design thinking approach

University of Nairobi (Kenya)
Energy Including Renewables
Research and development of photovoltaics based on lead-free perovskite solar cell technology

University of Rwanda
ICT Including Big Data and Artificial Intelligence
Real time assessment of the indoor air pollution in sub-Saharan households (case study: Rwanda rural and urban areas)

Cooperability projects

Université Félix Houphouët-Boigny (Côte d'Ivoire)
Climate Change
Sustainable and innovative yam production in Côte d'Ivoire through postharvest pest control

University of Rwanda
ICT Including AI and Big Data
Smart bee hiving technology

Institutional capacity building projects

The African University of Science and Technology (AUST) Nigeria
Strengthen and expand the innovation capacity of AUST through AUSTInspire and create a functional industry advisory board

Bayero University, Kano (Nigeria)
Initiatives for sustainable food security innovations in the drylands

Sokoine University of Agriculture (Tanzania)
Innovative biosystems for self-sufficiency in molecular biology reagents in Africa

University of Ghana
Institutional framework to enhance the agri-innovation ecosystem within the university

University of Nairobi (Kenya)
Capacity building for university–industry business technology transfer

University of Port Harcourt (Nigeria)
Strengthening institutional infrastructure for an innovation ecosystem

African Babul Blue (*Azanus jesous*) a small butterfly found in Africa.

2020, 2019 and 2018 Financial Statements

Statement of Financial Position

DESCRIPTION	2020 "USD 000"	2019 USD "000"	2018 USD "000"
Non-Current Assets	9,087	9,830	9,536
Current Assets	41,664	42,656	44,519
Total Assets	50,751	52,486	54,055
Current Liabilities	26,176	28,560	31,426
Long-term Liabilities	528	527	387
Total Liabilities	26,704	29,087	31,813
Total Assets less Total Liabilities	**24,047**	**23,399**	**22,242**
Financed By:			
Capital Fund and Reserves	**24,047**	**23,399**	**22,242**

Statement of Comprehensive Income & Activities

DESCRIPTION	2020 "USD 000"	2019 "USD 000"	2018 USD "000"
Income			
Unrestricted Grants	4,977	4,320	4,544
Restricted Grants	25,128	24,959	17,960
Other	2,107	2,441	2,571
Total Income	**32,212**	**31,720**	**25,075**
Appropriation			
Research	27,630	26,501	20,628
Institutional	4,070	4,704	4,169
Transfer to Reserves	**512**	**515**	**278**
Total Appropriations	**32,212**	**31,720**	**25,075**

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

Annexes

Annex A: Awards

Centre-wide recognitions

icipe was awarded the prestigious, USD 1 million Curt Bergfors Foundation Food Planet Prize in recognition of the Centre's pioneering research and development (R&D) activities on insects for food, feed and other uses. Link: http://www.*icipe*.org/news/*icipe*-wins-food-planet-prize

Recognition of *icipe* as a Food and Agriculture Organisation of the United Nations (FAO) Reference Centre for vectors and vectorborne animal diseases from 2020 – 2024 (initially appointed for the period 2012 – 2016; and 2016 – 2020).
Recognition of *icipe* as a Stockholm Convention Regional Centre from 2020 – 2023 (initially designated for the period 2011 – 2015, with a further formal endorsement for 2016 – 2019).

Segenet Kelemu, Director General & CEO

- Received the Ellis Island Medal of Honor, New York (2020). This Medal recognises individuals who have made it their mission to share with those less fortunate, their wealth of knowledge, indomitable courage, boundless compassion, unique talents and selfless generosity.
- She was also appointed as a member of the newly created Council of Economic Advisors to the Government of Ethiopia, announced by the Office of the country's Prime Minister.
- Recognised in an article by UN Women titled: "Devoted to discovery: seven women scientists who have shaped our world", https://medium.com/@UN_Women/devoted-to-discovery-seven-women-scientists-who-have-shaped-our-world-a1b9893ccbe1
- In February 2020, she was among five African women scientists selected and featured by the International Climate Change Development Initiative: https://medium.com/climatewed/celebrate-international-day-of-women-and-girls-in-science-profile-of-five-women-in-stem-e548fefae3
- She was appointed as an International Fellow of the Academy's General section by the Royal Swedish Academy of Agriculture and Forestry (2020).
- She was awarded the prestigious TWAS Regional Award by The World Academy of Sciences Sub-Saharan Africa Regional Partner (TWAS-SAREP) for "your significant contributions and for your key roles in the establishment of lively scientific institutions and also for expanding the activities of established institution(s) in the developing world." The selection committee further stated: "you are a transformational leader and manager dedicated to science and development issues.

Prof. Dr Bill Hansson, Chair, *icipe* Governing Council has been awarded the Cross of Merit of the Federal Republic of Germany, 1st Class (Bundesverdienstkreuz 1. Klasse), by the German President Franz Walter Steinmeier.

Baldwyn Torto, Principal Scientist and Head of the Behavioural and Chemical Ecology Unit

- Recipient of the Entomological Society of America (ESA) Nan-Yao Su Award for Innovation and Creativity in Entomology. Each year this award is given to an ESA member who is able to demonstrate through his or her projects or accomplishments an ability to identify problems and develop creative, alternative solutions that significantly impact entomology. https://www.entsoc.org/esa-names-winners-2020-professional-and-student-awards.
- Baldwyn Torto and David Tchouassi (Scientist, Behavioural and Chemical Ecology Unit), have been appointed co-Specialty Editors (Vector Biology) of the newly launched *Frontiers in Tropical Diseases* journal.

Menale Kassie, Head, *icipe* Social Science and Impact Assessment Unit was awarded the TWAS Siwei Cheng Award in Economic Sciences. He has been recognised for advancing our understanding of the process and impacts of multiple-technology adoption in complex social and agricultural environments in sub-Saharan Africa.

Emeritus Professor **Robert Jackson** FRSNZ, University of Canterbury and visiting scientist of *icipe*, was the 2020 recipient of the Charles Fleming Senior Scientist Award. Prof. Jackson was awarded US$10,000 to study the spider's innate aptitude for numbers, and whether numbers are abstract products of our minds and nothing more; or abstract 'natural kinds' existing external to our mental processes.

Workneh Ayalew, Project Coordinator, MOre Opportunities for Young Entrepreneurs in Silk and Honey (MOYESH) Programme was:

- Appointed as a member of the Job Advisory Council of the Ethiopia Jobs Creation Commission from February 2020 for a term of 2 years
- Nominated by the Minister for Agriculture to serve on the Advisory Expert Team on the Ethiopia Agriculture Sector 10 years Strategic Development Plan.

Judy Nyaboke Nyaribo, Nehemiah Ongeso Mosioma, Margaret Nyaboke Nyang'au and Harrison Njoroge Mburu, students in the Nematology Research Group, were awarded GBP 2500 each (totalling GBP 10,000) under the Global Burden of Crop Loss summer studentship programme led by CABI, to undertake a short research project on topics related to the Global Burden of Crop Loss.

icipe Staff Awards

Outstanding Employee of the Year Award
Nebiyu Solomon, Programme and Administration Manager *icipe* Ethiopia Office
Outstanding Principal Scientist of the Year Award
Samira Mohamed, Senior Scientist, Plant Health Theme
Outstanding Support Staff of the Year Award
Emily Kimathi, Data Management, Modelling and Geo-Information (DMMG) Unit
Outstanding Team of the Year Award
icipe@50 Committee
Outstanding Partner of the Year (2020)
Swiss Agency for Development Cooperation (SDC), for long-standing relationship since 1972. Beyond core funding, SDC has also funded other activities, including: the "greening of *icipe*" initiative; renovations and upgrades of R&D facilities; periodic reviews; development of the Centre's Vision and Strategy; and the *icipe*@50 celebrations.

icipe Governing Council Student Awards Winners

Best published science paper

Winner
Emily Kajuju Kimathi (MSc, Kenya)
Paper: Kimathi E., Tonnang H.E.Z., Subramanian S., Cressman K., Abdel-Rahman E.M., Tesfayohannes M., Niassy S., Torto B., Dubois T., Tanga C.M., Kassie M., Ekesi S., Mwangi D. and Kelemu S. (2020) Prediction of breeding regions for the desert locust *Schistocerca gregaria* in East Africa. *Scientific Reports* 10, 11937. https://doi.org/11910.11038/s41598-11020-68895-11932. IF 3.998

First runner up
Juliet Akoth Ochola (MSc, Kenya)
Registered in: Kenyatta University, Kenya
Paper: Ochola J., Cortada L., Ng'ang'a M., Hassanali A., Coyne D. and Torto B. (2020) Mediation of potato–potato cyst nematode, *Globodera rostochiensis* interaction by specific root exudate compounds. *Frontiers in Plant Science* 11, 649. https://doi:610.3389/fpls.2020.00649]https:// doi:610.3389/fpls.2020.00649 IF 4.407

Second runner up
Akbar Ganatra (PhD, Kenya)
Registered in: Egerton University, Kenya
Paper: Becker J.M., Ganatra A.A., Kandie F., Mühlbauer L., Ahlheim J., Brack W., Torto B., Agola E.L., McOdimba F., Hollert H., Fillinger U. and Liess M. (2020) Pesticide pollution in freshwater paves the way for schistosomiasis transmission. *Scientific Reports* 10, 3650. https://doi.org/3610.1038/s41598-41020-60654-41597. IF 3.998

Best science poster

Winner
Mary Wanjiku Chege (MSc, Kenya)
Registered at: Jomo Kenyatta University of Agriculture and Technology (JKUAT)
Poster title: Gut symbionts reduce immune response activation and protect the honey bee, *Apis mellifera*, against opportunistic pathogens
Supervisors: Juan Paredes (*icipe*); Johnson Kinyua (JKUAT)

First runner up
Francis Sengendo (MSc, Uganda)
Registered at: Makerere University, Uganda
Poster title: Improving efficiency and profitability of light trap for harvesting edible grasshoppers *Ruspolia differens* in Uganda
Supervisors: James Egonyu and Subramanian Sevgan (*icipe*); Chemurot Moses (Makerere University)

Second runner up
Kevin Kidambasi Ogola (MSc, Kenya)
Registered at: Jomo Kenyatta University of Agriculture and Technology (JKUAT)
Poster title: Xenodiagnosis potential and vectorial competence of camel ked (*Hippobosca camelina*) in disease transmission.
Supervisors: Joel Bargul (*icipe*/JKUAT); Jandouwe Villinger (*icipe*)

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

ARPPIS	African Regional Postgraduate Programme in Insect Science
ASALs	arid and semi-arid lands in Kenya
ATBF	African tick bite fever
AUST	African University of Science and Technology, Nigeria
BA-FAN	BioInnovate Africa Fellows Alumnae Network
BCCN	Basic Crash Course Nematology
BIOCON	Bioconversion Technology Uganda
BioInnovate	Bioresources Innovations Network for Eastern Africa Development Programme
CAAS	Chinese Academy of Agricultural Sciences, China
CORPs	community owned resource persons
CREST	Centre for Research on Evaluation, Science and Technology, Stellenbosch University, South Africa
DRIP	Dissertation Research Internship Programme
EANBiT	Eastern Africa Network for Bioinformatics Training
EASTECO	East African Science and Technology Commission
ESKAPE	*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter* species
FAO	Food and Agriculture Organisation of the United Nations
FCDO	UK's Foreign, Commonwealth & Development Office
GBS	Global Bioeconomy Summit 2020
GPS	Global Positioning System
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and Communications Technologies
IITA	International Institute of Tropical Agriculture
IoT	Internet of Things
IPM	integrated pest management
IPPM	integrated pollinator and pest management
IRD	Institute of Research for Development
ISPOT	Integrated Sustainable Production of Tomatoes project
IVM	integrated vector management
LLINs	long-lasting insecticide-treated nets
M&E	monitoring & evaluation
MOYESH	More Young Entrepreneurs in Silk and Honey Programme
MUHAS	Muhimbili University of Health and Allied Sciences, Tanzania
OACPS	Organisation of African, Caribbean and Pacific States
ODK	Open Data Kit
PASET	Partnership for Skills in Applied Sciences, Engineering and Technology
PCN	potato cyst nematode
R&D	research and development
RDMA	Research Data Management and Archiving policy
RSIF	Regional Scholarship and Innovation Fund
SCLAMP-EA	Enhanced Maize and Tomato Systems Productivity in Eastern Africa
SDC	Swiss Agency for Development and Cooperation, Switzerland
SDGs	Sustainable Development Goals
Sida	Swedish International Development Cooperation Agency, Sweden
SNNP	Southern Nations, Nationalities, and Peoples' region
SSA	sub-Saharan Africa
SSIA	Social Science and Impact Assessment Unit
STI	science, technology and innovation
TARI	Tanzania Agricultural Research Institute, Mikocheni
TARI	Tigray Agricultural Research Institute, Ethiopia
TTU	Technology Transfer Unit
TWAS	The World Academy of Sciences
UNCTAD	United Nations Conference on Trade and Development
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Programme
UPSCALE	Upscaling the benefits of push–pull technology for sustainable agricultural intensification in East Africa
USAID	United States Agency for International Development
WHO	World Health Organization
YESH	Young Entrepreneurs in Silk and Honey

For more details about *icipe* and its activities, contact:

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www.icipe.org

Field stations and country offices

***icipe* Thomas Odhiambo Campus**
Mbita Point (on the shores of Lake Victoria),
western Kenya
Tel: +254 (57) 205 3000; +254 719 052 000

***icipe* Ethiopia Country Office**
ILRI Campus, Gurd Shola
PO Box 5689
Addis Ababa, Ethiopia
Tel: +251(0) 116 172 592/94

***icipe* Uganda Country Office**
1-3 Speke Memorial Road
Bukaya, Jinja
Uganda
+256 778 524 647

Picasso bug, *Sphaerocoris annulus*, known for its exquisite markings on the scutellum, is widely found in Africa.

Annual Report
2020

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.

www.icipe@icipe.org

Support icipe: www.icipe.org/support-icipe

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THE CURT BERGFORS FOOD PLANET PRIZE WINNER 2020

An FAO Reference Centre

OIE Collaborating Centre for Bee Health in Africa

STOCKHOLM CONVENTION
A Stockholm Convention Regional Centre