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Annual Report 2016

icipe
African Insect Science for Food and Health

Launch of the Young Entrepreneurs in Silk and Honey (YESH) project, Addis Ababa Ethiopia, 4 March 2016: His Excellency Hailemariam Desalegn, Prime Minister of the Federal Democratic Republic of Ethiopia (3rd left), listens as *icipe* scientist Dr Everlyn Nguku (2nd left), explains the Centre's silkworm rearing technology. Looking on is *icipe* Director General, Dr Segenet Kelemu (4th left), Prof. Suresh Raina, former Head, Beneficial and Commercial Insects Programme (1st left) and other *icipe* team members.

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May 2017

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International Centre of Insect Physiology and Ecology
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Cover photo: In 2016, *icipe,* The MasterCard Foundation, and various institutions in Ethiopia launched the Young Entrepreneurs in Silk and Honey (YESH) project, towards creating employment opportunities for 12,500 unemployed and out-of-school youth. Photo: *icipe.*

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Foreword

Supporting youth employment in Africa

Dr Lukas Bertschinger
Chair, *icipe* Governing Council

The 2030 Agenda for Sustainable Development (through the SDGs) and the African Union's Agenda 2063, and the Declaration on Employment and Poverty Alleviation in Africa, send powerful messages regarding eradication of youth unemployment. In alignnment, in 2016, *icipe* made a firm commitment to youth employment in Africa.

Over the past decade, the African economy has been on the rise, registering an annual economic growth rate of more than 5%, which is above the 3.6% global average. But, as many observe, economic growth on its own is not enough for Africa's transformation. This goal can only be achieved through an inclusive and holistic approach to development.

More than 20% of Africa's population, almost 200 million people, is aged between 15–24 years, and the figure is expected to double by 2045. In fact, Africa has the youngest population in the world. Moreover, while young people make up 40% of the continent's workforce, they also comprise 60% of the unemployed. Therefore, the creation of productive employment for the youth is fundamental to economic transformation in Africa. *icipe*'s insect research and development for Africa impacts on youth employment.

In 2016, *icipe* and The MasterCard Foundation launched the Young Entrepreneurs in Silk and Honey (YESH) project. The initiative is aimed towards creating employment opportunities for 12,500 unemployed and out-of-school youth.

The YESH project builds on science-based long-running initiatives by *icipe*, Biovision Foundation for Ecological Development (Switzerland), and the International Fund for Agricultural Development (IFAD) that have demonstrated the potential of honey production and silk farming in transforming the livelihoods of communities, including youth, across Africa.

In addition, as is evident in this report, *icipe*'s research and development activities, which are designed and disseminated in an inclusive impact-oriented manner, present numerous opportunities for young people. For instance, about 25% (30,000) of all push–pull farmers are young people.

Further, *icipe*'s horticultural strategies and technologies, supported by a value chain approach, enhance the quality, quantity, and marketability of yield, locally and globally, thus creating employment potential for young people; for instance, in the cultivation, transport, processing, and marketing of the produce.

The Centre's emerging research in insects for food and feed is also presenting new possibilities of employment for young people. As reported in this publication, in Kenya alone, use of insects in poultry feed at a magnitude of just 5% would create demand for 27,000 to 32,000 metric tonnes of dried insects per year, translating to 14,300 smallscale enterprises.

The commercialisation of *icipe*'s products, which include biopesticides and various natural products obtained from the Centre's bioprospecting activities, also opens up avenues for creating novel public private partnerships for youth employment.

We look forward to your continued partnership, including in our goal of supporting youth employment in Africa.

Preface

2016 and beyond

This Annual Report presents a highly varied list of *icipe*'s accomplishments in 2016, and an outlook of the Centre's plans in 2017 and beyond. While this diversity reflects the breadth of activities, more importantly, it denotes *icipe*'s uncompromising, excellence driven approach, to produce and use insect science for better livelihoods in Africa.

In collaboration with our partners from across the continent and the world, we have continued to research, develop and disseminate products and technologies for human diseases like malaria, yellow fever, Rift Valley fever and dengue. In regard to livestock, studies on tsetse and camel health have progressed significantly, and we are particularly pleased to highlight a re-focus on tick borne diseases.

The highly innovative push-pull technology continues to thrive, improving cereal and livestock productivity for thousands of farmers in the continent. Meanwhile, our integrated pest management (IPM) strategies for pests of fruit and vegetables are unlocking the potential of horticultural farming, enhancing the income, employment and nutritional security of numerous households.

We have continued to expand our commercial and beneficial insects programmes, while also contributing to global knowledge on bee health. In addition, we are disseminating research-led strategies that will enable vulnerable communities thrive despite the impacts of climate change.

icipe is trail blazing the emerging insects for food and feed sector, with breakthroughs in insect rearing protocols, new knowledge on potential edible insects, and socioeconomic and market studies, as well as linkages with the private sector.

All our activities continue to be underscored by capacity building of young researchers and institutional development of various stakeholders, and by social science and impact assessment studies.

I would also like to highlight some of our key future plans. One, in collaboration with partners, we plan to develop a strategy for collective action on invasive pests in Africa, to enable high-level scientific and policy dialogue and strengthened coordination and collaboration among stakeholders. Two, we are preparing a strategy to consolidate and shape our bee health research. Three, we have started to expand the Centre's human health research, for instance on blood flukes (trematode worms) that cause Schistosomiasis, a neglected tropical disease.

As we move forward, we are extremely aware that our success is dependent on our dedicated teams, donors and collaborators, and we look forward to even stronger, mutually beneficial partnerships.

Dr Segenet Kelemu
Director General, *icipe*

In 2016, *icipe* and partners made commendable progress in the goal of enhancing food security and health of communities across Africa, as presented in this Annual Report. We continue to reinforce our efforts towards these goals.

Management and Leadership

icipe **core donors:** Aid for Africa, USA; Federal Ministry for Economic Cooperation and Development (BMZ), Germany; Ministry of Higher Education, Science and Technology, Kenya; Swiss Agency for Development and Cooperation (SDC), Switzerland; Swedish International Development Cooperation Agency (Sida) and UK Aid from the UK Government.

icipe has commenced the 'greening' of its Centre, for instance by enhancing carbon storage as shown in this picture. ▶

Resource mobilisation

In 2016, *icipe* received funding from the following core donors.

- UK Aid from the UK Government
- Swedish International Development Cooperation Agency (Sida)
- Swiss Agency for Development and Cooperation (SDC)
- Federal Ministry for Economic Cooperation and Development (BMZ), Germany
- Government of Kenya

Resource mobilisation

44 Signed multi-year projects

7 New donors

25 Current donors

Some of the major projects to be implemented as a result, are discussed below.

Swedish International Development Cooperation Agency (Sida)

Reached an agreement with *icipe* for the Centre to host the Bioresources Innovations Network for Eastern Africa Development (BioInnovate) programme, Phase II. BioInnovate is an initiative established in 2010 with support from Sida, to strengthen bioscience research and innovation activities in eastern Africa.

Biovision Foundation for Ecological Development, Switzerland

Committed support for the: dissemination and scaling-up of the push–pull technology; integrated vector management of malaria in Kenya and Ethiopia; upscaling, dissemination and capacity building for the prevention of Rift Valley fever (RVF) in northeastern Kenya; and impact assessment studies of *icipe*'s activities.

Ministry for Foreign Affairs of Finland

Ministry for Foreign Affairs of Finland and *icipe* launched the Adaptation for Ecosystem Resilience in Africa (AFERIA) project to support smallholder farmers living around fragile mountain ecosystems in eastern Africa to adapt to the impacts of climate variability and change through research-based interventions. The project will disseminate findings of the CHIESA project (http://chiesa.icipe.org/) implemented by *icipe*, the Ministry for Foreign Affairs of Finland and partners (2011–2015).

Wellcome Trust

icipe is one of the organisations to benefit from the Developing Excellence in Leadership, Training and Science (DELTAS) initiative, within the Training Health Researchers into Vocational Excellence in East Africa (THRiVE-2) programme.

Virginia Tech University, USA

icipe is leading the Maize, Rice, and Chickpea IPM for East Africa project, funded by USAID through **Virginia Tech University, USA**. Partners include: University of Minnesota and USDA-ARS National Biological Control Laboratory (USA); Ethiopian Institute of Agricultural Research (EIAR), Hawassa University, Ambo University, Jimma University, Addis Ababa University and Haramaya University (Ethiopia); Kenya Agricultural and Livestock Research Organization (KALRO) and University of Nairobi (Kenya); Cholima Research Centre-Dakawa, Sokoine University of Agriculture and University of Dar es Salaam (Tanzania).

German Federal Ministry for Economic Cooperation and Development (BMZ)

icipe received 3 grants from German Federal Ministry of Education and Research (BMBF) through BMZ and GIZ (Phase 2), for research on: postharvest losses and value addition in food value chains; increased production and use of push–pull; and horticultural innovations and learning for improved nutrition and livelihoods in East Africa. **BMZ,** through **GIZ**, is also financing EntoNUTRI, a project on the use of insect-based products to enhance food and nutritional security in sub-Saharan Africa.

Partnerships

Research and development partners

Institut de recherche pour le développement (IRD), France
icipe and IRD signed an (MoU) for continued collaborative research on the "Biodiversity, chemical ecology and functioning of monocotyledonous noctuid stemborers in East Africa". IRD researchers will continue to work with *icipe* and will be integrated into the Centre's research programmes.

Keele University, UK
The Centre established a partnership to develop novel technologies for the control of bean flower thrips in cowpea and other legumes, as an alternative to insecticides. The collaboration will advance previous research by *icipe,* Keele University, and Plant Research International, (The Netherlands), which identified special chemicals (pheromones) released by male bean flower thrips that can attract male and female species of the pest.

Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
icipe entered into a partnership with CSIRO for collaborative bee health research using micro-sensing technology and systems. CSIRO is leading a global research effort in this field, by employing microchips as back-packs to measure bee foraging behaviour and environmental traits.

Faculty of Biology and Biotechnology, Ruhr-University, Bochum, Germany
This collaboration focuses on the biology, behaviour, health, and pollination efficiency of social and solitary non-managed African bee pollinators. The researchers will also study the impact of beekeeping and agricultural practices on bee pollinator health, and on disease and pest transfer between social and solitary bees in Africa.

The Harvard T.H. Chan School of Public Health, Harvard University, USA,
signed an agreement with the *icipe* Social Science and Impact Assessment Unit to conduct a randomised trail control experiment to assess impact of the push-pull technology on various welfare outcomes in Uganda.

Partnership for Economic Policy (PEP)
The *icipe* Social Science and Impact Assessment Unit established a collaborative partnership with PEP. As part of this arrangement, the Unit was awarded two research and capacity building fellowships through the Structural Transformation of African Agriculture and Rural Spaces (STAARS) project (https://www.pep-net.org/staars).

Citrus Research International (CRI), South Africa
icipe is collaborating with CRI in joint research towards integrated pest management of citrus pests and diseases, in light of the expanding threat of huanglongbing (HLB) (citrus greening disease), a serious disease of the crop in East Africa.

One Acre Fund (1AF), Kenya
The goal of this partnership is to advance *icipe's* climate-smart push–pull technology in Uganda and Kenya, by addressing key limitations to its scaling up, acceptability, and sustainability. *icipe* and 1AF will develop target-specific dissemination and impact pathways and partnerships, including with the private sector.

Partnerships

Material transfer agreements

International Potato Center (CIP)
icipe signed a material transfer agreement with CIP for the introduction of the parasitoid *Dolichogenidea gelechiidivoris,* to control *Tuta absoluta*, a devastating pest of tomato and other vegetables in Africa.

United States Department of Agriculture – Agricultural Research Service (USDA-ARS)
USDA-ARS signed a material transfer agreement with *icipe* to enable it access *icipe*-reared, Kenyan strains of *Buakea kaueae* and *Busseola nairobica* stemborers, to support studies on their potential as biological control agents of guineagrass, *Panicum maximum*, an invasive species in the USA. USDA-ARS will collect *B. kaueae* and *Busseola nairobica* from Kenya and rear the insects at *icipe* before shipping them to USA for mass rearing.

Regional partnerships for a global agenda

***icipe* Stockholm Convention Regional Centre – Kenya (SCRC – Kenya)**
Since July 2010, *icipe* has served as the Stockholm Convention Regional Centre for capacity building and the transfer of technology (*icipe* SCRC-Kenya), under the Stockholm Convention on Persistent Organic Pollutants (POPs). The Centre entered into a new phase in 2016 for a further four years (2016 – 2019).

World Health Organization Regional Office for Africa (WHO-AFRO)
An agreement was signed for a joint integrated vector management (IVM) training course, held at *icipe* Duduville from 10–23 July 2016 for 20 participants from Ethiopia, Eritrea and Madagascar. Further, *icipe* was invited by WHO-AFRO to lead an evaluation of IVM in six countries that are still using DDT in southern Africa. The Centre also participated in an inception meeting of an initiative funded by UNEP and executed by WHO, as part of the global effort to generate evidence on effectiveness of novel/ potential vector control interventions.

Private sector partners

College of Agricultural Sciences, Pennsylvania State University (Penn State), USA
This cooperation is aimed towards promoting exchanges of faculty members, postgraduate students and postdoctoral researchers, and of scientific materials, publications and information. The researchers will also undertake joint research and educational programmes.

Metals and Engineering Corporation (METEC), Ethiopia
A memorandum of understanding was signed towards the production of *icipe* tsetse repellent dispensers, as part of the Centre's ongoing activities to make the technology accessible to more farmers through public–private partnerships.

icipe's designation as a **Food and Agriculture Organization of the United Nations (FAO) Reference Centre for vectors and vector-borne animal diseases** has been renewed for a further four years, from 1 August 2016 – 31 July 2020. FAO Reference Centres are institutions selected by the Director General of the organisation to provide specific, independent technical or scientific advice on issues related to its mandate. *icipe's* initial designation commenced on 1 August 2012 for a period of four years and ended on 31 July 2016. The current extension is based on the progress and compliance, and the high quality contributions made by *icipe,* to assist FAO in its mission of providing authoritative advice to its Members, and in particular, the developing countries.

Patent applications

***icipe* patent applications filed, or in progress, in 2016.**

Repellent composition for insects and other arthropods (tsetse repellent)	This patent application is co-owned by *icipe* and Kenyatta University, Kenya. The filing of the national phase was done under the Patent Cooperation Treaty (PCT), the African Regional Intellectual Property Organization (ARIPO) and USA.
Antimicrobial agents produced by *Xenorhabdus Griffinae* Starin XN45	Co-owned by *icipe*, Kenya Agricultural and Livestock Research Organization (KALRO), University of Nairobi and Trek Science (all in Kenya), this patent was filed in May 2015. PCT application was filed under the European Patent Office as the Search Office.
Composition and methods of controlling a bee pest	The utility model is wholly owned by *icipe*, and it was filed in Kenya in September 2015, and the validation of the product has been initiated in other African countries that have serious bee pest and disease problems. PCT application was filed under the European Patent Office as the Search Office.
Formulation and method for the control of ectoparasites	This utility model is wholly owned by *icipe*, a provisional application has been filled at the Kenya Industrial Property Institute (KIPI).

Communications

Summary of 2016 vs. 2015 peer reviewed journal articles statistics

2015		2016
143	Total number of peer-reviewed journal articles.	160
52%	Percentage of journal articles co-authored by *icipe* postgraduate students.	33%
46%	Percentage of journals with an impact factor of 2.0 and above.	44%
72%	Percentage of papers published in open access journals, or in journals with an open access model.	84%

International Journal of Tropical Insect Science (IJT)
The first impact factor of IJT, which stood at 0.419 in June 2015 had by June 2016 increased by 23%, to 0.518. To further strengthen the journal's impact, in 2016, the internal *icipe* review committee of IJT was expanded from three to seven members. The original team, which consisted of Drs Baldwyn Torto, Robert Copeland and Sunday Ekesi, has now been joined by Drs Daniel Masiga, Rosemary Sang, Subramanian Sevgan and Jeremy Herren. Additionally, from 2012, IJT is abstracted/indexed in: Science Citation Index Expanded (also known as SciSearch®), Journal Citation Reports/Science Edition, Zoological Record, Biological Abstracts, and BIOSIS Previews. This has boosted the submission rate from 85 manuscripts in 2015 to 124 in 2016 (45.9% increase).

New *icipe* website: In February 2016, *icipe* launched a new website (www.icipe.org) that has been designed with the goal of providing partners, stakeholders and the general public with a comprehensive, user-friendly and efficient platform on the Centre's activities. By December 2016, the site had attracted approximately 50,000 visitors and 250,000 page views. The top 20 countries (ranked in order of visitor numbers) are: Kenya, United States, Nigeria, United Kingdom, Germany, Uganda, Tanzania, Ethiopia, Cameroon, South Africa, India, Ghana, Zimbabwe, Switzerland, Sudan, France, Benin, The Netherlands, Canada and Rwanda.

***icipe* in the media**: *icipe* was mentioned in about 2400 news items, in almost all Kenyan media and across Africa in newspapers and TV stations. Internationally, the BBC, National Geographic, *Nature* journal, SciDev.Net, *The Guardian*, UK, Reuters News Agency, Xinhua News Agency, ARD Germany, The Conversation, and TED Talks covered *icipe*'s research.

Greening of *icipe*

The Greening of *icipe* is a US$ 2.5 million project funded by the Swiss Agency for Development and Cooperation (SDC), with the aim of reducing the Centre's carbon footprint and making its environment more eco-friendly. The initiative includes production of renewable energy through the construction of solar photovoltaic (PV) power plants at *icipe*'s Duduville Campus (Nairobi) and at the Centre's Thomas Odhiambo Campus on the shores of Lake Victoria, energy saving and water conservation measures, and extensive flower and tree planting on its Duduville campus.

In 2016, the installation of solar PV plants was completed. The systems have a combined generating capacity of 1016 kilowatt peak (kWp). The design and construction was undertaken by Solar Century, which was awarded the contract through a rigorous, international selection process.

A semi-aerial view of the *icipe* Headquarters at Duduville. A total of 4130 PV modules have been installed on rooftops on both *icipe* campuses. Photovoltaic modules placed on roofs have various advantages; for instance, better use of available space and natural cooling of the spaces underneath.

The solar battery backup system at the *icipe* Thomas Odhiambo Campus, Mbita, on the shores of Lake Victoria, can supply power during the night for about five hours.

A total of 228 solar photovoltaic (PV) modules have been fixed on carports in both *icipe* campuses.

Technicians from Solar Century installing solar inverters, one of the components of the solar PV plants.

Approximately four acres of the *icipe*'s Duduville campus is now covered with over 30 different types of grasses, trees, plants and flowers, as a way of enhancing carbon storage.

Human Health Theme

Donors: Biovision Foundation for Ecological Development, Switzerland; Bill & Melinda Gates Foundation, USA-Grand Challenges Explorations grant; Federal Ministry for Economic Cooperation and Development (BMZ); Foundation for the National Institutes of Health (FNIH), USA; German Doctors e.V., Germany; German Research Foundation (DFG), Germany; Global Environment Facility (GEF)/United Nations Environment Programme (UNEP); Government of Kenya; Innovative Vector Control Consortium (IVCC), UK; National Institutes of Health (NIH), USA; R. Geigy Foundation, Switzerland; Swedish International Development Cooperation Agency (Sida); The Swedish Research Council, Sweden; Swiss National Science Foundation; Swiss Agency for Development and Cooperation (SDC); UK Aid from the UK Government; National Science Foundation (NSF), USA; Wellcome Trust, UK; World Health Organization-Regional Office for Africa (WHO-AFRO).

Partners: Addis Ababa University (Aklilu Lemma Institute of Pathobiology), Ethiopia; agricultural research institutes, non-governmental organisations, private sector partners, farmers and farmer groups; CEVA, France; Dabaso Tujengane Self Help Group – Watamu Marine Association, Kenya; Duke University, USA; Durham University, UK; Egerton University, Kenya; Helmholtz Centre for Environmental Research (UFZ), Leipzig, Germany; Ifakara Health Institute, Tanzania; International Livestock Research Institute (ILRI); Kenya Medical Research Institute (KEMRI); Kenya Wildlife Service (KWS); KTH Royal Institute of Technology, Sweden; Liverpool School of Tropical Medicine, UK; London School of Hygiene and Tropical Medicine, UK; Millennium Institute, USA; Ministries of Health in Kenya and Ethiopia; Ministry of Agriculture, Livestock and Fisheries, Kenya; Ministry of Public Health and Sanitation (Division of Disease Surveillance and Response), Kenya; Mosquito Control in Nyabondo (MOCON) community group, Nyabondo, Kenya; National Museums of Kenya (Institute of Primate Research); Punguza Mbu na Malaria Malindi (PUMMA) community group, Malindi; Sumitomo Chemical, Japan; Swedish University of Agricultural Sciences (SLU); Swiss Tropical and Public Health Institute, Switzerland; Ultimate Products (Aust) Pty Ltd, Australia; Umeå University, Sweden; Free University of Berlin and Charité—Universitätsmedizin, Berlin, Germany; University of Glasgow, UK; University of Nairobi, Kenya; University of Pretoria, South Africa; Wageningen University, The Netherlands; World Health Organization-Regional Office for Africa (WHO-AFRO).

icipe's aim is to contribute to the health of communities across Africa, to enable them play their rightful role in society and in socioeconomic development. ▶

Malaria IVM research

Development of biolarvicides

Biolarvicides are a key component of *icipe*'s integrated vector management (IVM) for malaria control. The industry best practice larvicide is *Bacillus thuringiensis israelensis* (*Bti)*, which has to be imported into Africa and is not always readily available. *icipe* has made progress in developing four effective plant-derived larvicides for the control of mosquito larvae; which, potentially, are more cost-effective and suitable alternatives to *Bti*. Evaluations of the larvicides on people and insects have shown the biolarvicides to be eco-friendly and safe to handle at the recommended doses and user instructions. Samples of the larvicides have been submitted to the Pesticide Control Products Board, Kenya for independent efficacy and safety testing before registration. Registration of one of the larvicidal products (*icipe*-Med-Plant-11) is in progress in Kenya. The biolarvicides are derived from commonly-occurring plants in Kenya and Ethiopia, and are suitable for sustainable domestic cultivation and income generation for communities.

UZIMAX, a plant-derived larvicide developed by *icipe* for the control of mosquito larvae

Malaria IVM research

Socioeconomic impact assessment

Using *Anopheles* mosquitoes and malaria parasite prevalence as impact indicators, *icipe* conducted an assessment on the use of a comprehensive integrated vector management (IVM) for malaria control package, consisting of long-lasting insecticide treated nets (LLINs), intensive community education and mobilisation, and larviciding with *Bti.*

60% Reduction of *Anopheles* mosquito larval densities in Tolay, Ethiopia

Reduction of *Anopheles* mosquito larval densities in Nyabondo, western Kenya 80%

50% Reduction in malaria prevalence in Tolay, Ethiopia

Fewer malaria cases in Nyabondo

Malaria is more entrenched.

Blocking mosquito entry points (house eaves) using screens. Reducing malaria parasite reservoir in people.

New strategies to optimise IVM in high malaria endemic areas

A socioeconomic assessment was undertaken to determine the impact of malaria on agricultural productivity among smallholder farmers in Tolay Region, Ethiopia.

Malaria was found to reduce agricultural productivity in the farming households.

Differences were observed depending on the sex of the sick member, with the effect being significant when the woman fell sick when compared to when the man fell sick.

Some evidence of malaria-reducing effects of the investment in community IVM interventions was observed.

Generally, use of *Bti* for mosquito larval control was perceived by communities as being effective in reducing malaria in households.

In addition to *icipe*'s IVM strategies (larviciding, community education and mobilisation, and use of LLINs), house screening led to fewer self-reported malaria cases.

Overall, the findings make a case for embedding IVM policies for malaria control in the health and agricultural sectors.

Control strategies for mosquitoes and malaria

Push–pull strategies for malaria vector control

icipe is working on several projects to develop a proof-of-concept that odour-based push–pull systems are feasible in preventing malaria mosquitoes from biting people indoors and outdoors when they are not under insecticide-treated bednets. Several active ingredients released from a range of physical devices, such as active and passive emanators and treated fabric (push devices) and traps (pull devices), are being tested for their ability to push mosquitoes away from homesteads, and to pull them towards odour-baited traps, resulting in a push–pull strategy. Pilot data obtained so far will be used to identify the best entomological measurements that could be used to estimate the impact on the disease outcome and to design further studies; for instance, to determine malaria prevalence and new parasite infections.

icipe's new screen house is used to study mosquito behaviour, and is among the largest semi-field systems in Africa. For example, the Centre is using the facility to test the push–pull and attract-and-kill strategies for mosquito control.

Control strategies for mosquitoes and malaria

Attract-and-kill strategies for *An. gambiae s.l.*

icipe is developing a number of attract-and-kill strategies that aim to lure female malaria-transmitting mosquitoes, either to an attractive trap or to an attractive resting place. Here, the mosquito will either be killed or get contaminated with an insecticide, which the insect will then transfer to its breeding site; and, in effect, kill its offspring.

Studies are ongoing to develop such attract-and-kill traps and resting sites using odour and visual baits, including different light sources. Novel slow-killing adulticides and insect growth regulators that affect adult and larval stages of mosquitoes are being tested in conjunction with trapping devices targeting host-, plant sugar- and oviposition-site seeking mosquitoes.

icipe is exploring the use of light as an attractant to mosquito traps. On the right, an *icipe* technician hangs a UV light trap to collect malaria vectors.

Spirovector project

Endosymbionts for controlling the malaria parasite

Endosymbiotic microbes which are found inside the cells or body of insects have a significant impact on the interactions between their host insects and pathogens (that is, disease causing agents). This is because to promote their own survival, the microbes often assist their host insects in the defence against pathogens. Globally, insect endosymbionts are emerging as a promising alternative in vector-borne diseases management. However, there has been minimal progress in the development of endosymbiont-based strategies to control vector-borne diseases of great importance in Africa.

icipe is conducting studies to explore the potential of endosymbionts in making insects more resistant to pathogens and to prevent the transmission of diseases.

The Centre's researchers have screened populations of numerous vectors throughout Kenya and they have identified several strains of *Spiroplasma*, insect-endosymbiotic bacteria that are known for their ability to protect insects against eukaryotic parasites.

These discoveries are important in the long-term vision to develop endosymbiotic microbes, for instance as a strategy to prevent *Anopheles* mosquitoes from transmitting the malaria parasite.

icipe's research, which is being conducted through the Spirovector project, primarily aims to obtain a better understanding of diverse insect endosymbioses and to explore their potential use to control insect vector-borne diseases.

Notably, *Spiroplasma* strains have been discovered in *Anopheles arabiensis* (major vector of *Plasmodium*), *Glossina fuscipes* (major vector of *Trypanosoma*) and *Culex quinquefasciatus* (major vector of *filarial nematodes*). Currently, the scientists are investigating the *Spiroplasma* strains for their potential as a tool for blocking parasite transmission.

Rift Valley fever

Preventing and controlling Rift Valley fever in Kenya

Yellow fever and dengue

Yellow fever is an acute viral haemorrhagic disease transmitted by infected mosquitoes of the Stegomyia subgenus. The first ever outbreak of yellow fever in Kenya occurred between 1992 and 1995. This outbreak was controlled through mass vaccination in 1993, which was repeated in 2003. Dengue is a mosquito-borne viral disease that has rapidly spread in many regions in recent years. Dengue virus is transmitted by female mosquitoes mainly of the species *Aedes aegypti*.

Epidemiologic assessment of risk of yellow fever and dengue transmission and outbreaks in Kenya

This study aims to determine existence and locality of yellow fever and dengue transmission foci in Northern Kenya at border with endemic countries; assess vector species presence and their vector potential; and to assess the potential for urban *Aedes* vectors to sustain an outbreak in major urban centers in Kenya

The research team has established by serologic surveys, the presence and extent of the two diseases among primates and people in West Pokot, bordering Uganda. This indicates possibilities of transmission through travel and/or movement of infected people and primates. However, the vector population were observed to have low vectorial capacity in transmitting yellow fever. The researchers also noted low risk levels for transmission of yellow fever and dengue in major cities in Kenya, except for Kisumu and Mombasa which were observed to have medium to high risk of the two diseases. was repeated in 2003. Dengue is a mosquito-borne viral disease that has rapidly spread in many regions in recent years. Dengue virus is transmitted by female mosquitoes mainly of the species *Aedes aegypti*.

Trapping tools for vector surveillance of yellow fever and dengue fever

The researchers have identi ed suitable odours and tools for attracting and sampling yellow fever and dengue vectors. An odour bait has been screened for forest dwelling Aedes mosquito species. Chemical profile differences have been established for different primates and humans. Previously established protocol(s) provide a useful framework for developing improved disease surveillance tools.

The health and well-being of communities across Africa is central to *icipe*'s activities. ▶

Predatory arthropods

The research on predatory arthropods is a long-term joint programme between *icipe* and the University of Canterbury, New Zealand, which goes back to 1994, primarily based at the *icipe* Thomas Odhiambo Campus, Mbita. Most of the studies under this programme have been on jumping spiders, including species that target malaria vectors as preferred prey. There is a strong commitment to acquiring a conceptually deeper understanding of what specialisation means in a wider context, including in the context of distinctive cognitive capacities.

Thinking ahead

In 2016, Prof. Robert Jackson, a Visiting Scientist from New Zealand's University of Canterbury and leader of Predatory Arthropods research at *icipe*, along with colleague Dr. Fiona Cross, published landmark findings showing that a wide range of jumping spider species can view a scene that includes prey, plan a circuitous route that will take them to the prey and then execute the planned detour. While taking the detour, the prey is not in view. These findings are the strongest evidence to date of spiders displaying genuine cognition based on representation. Despite the minute size of their brains, these jumping spiders exhibit a capability which is usually associated with much larger animals.

1

2

1. *Portia africana* male.
   Photo credit: Robert Jackson.
2. *Portia africana* female.
   Photo credit: Fiona Cross.

Predatory arthropods

A Festschrift in honour of Professor Robert R. Jackson

In 2016, Professor Robert R. Jackson, a visiting scientist at *icipe* and Professor of Animal Behaviour at the University of Canterbury, New Zealand, was honoured in a Festschrift (a collection of writings celebrating the accomplishments of a scholar) published by *the New Zealand Journal of Zoology*. Prof. Jackson has had a long association with the Journal and has published more than 250 peer-reviewed journal articles, as well as numerous book chapters throughout his career. Written by some of his many colleagues and friends, the Festschrift celebrates Prof. Jackson's productive and successful career in arachnology (the scientific study of spiders and related animals), inspired by his fascination with spiders from an early age.

The articles in the Festschrift reflect the numerous ways in which Prof. Jackson's insights have influenced the work of arachnologists around the world, featuring behavioural studies, as well as descriptions of spiders from New Zealand and further afield. This includes species from the Australian salticid genus *Jacksonoides*, originally named in honour of Prof. Jackson and his outstanding work on Salticidae behaviour. Prof. Jackson's research at *icipe*, while based at the Thomas Odhiambo Campus on the shores of Lake Victoria in western Kenya, began in 1994, and has largely been supported by the Royal Society of New Zealand and the National Geographic Society.

Prof. Robert Jackson

Animal Health Theme

Donors: Biovision Foundation for Ecological Development, Switzerland; Consortium for National Health Research (CNHR), Kenya; UK Aid from the UK Government; European Union; Federal Ministry for Economic Cooperation and Development (BMZ); German Research Foundation (DFG); International Atomic Energy Agency (IAEA); Swedish International Development Cooperation Agency (Sida); National Science Foundation (NSF), USA; United States Agency for International Development's Partnerships for Enhanced Engagement in Research (USAID-PEER) grants program; The Wellcome Trust, UK.

Partners: African Union Inter-African Bureau for Animal Resources (AU-IBAR); county governments of Marsabit and Isiolo, Kenya; Kenya Livestock Producers Association (KLPA); Kenya Tsetse and Trypanosomiasis Eradication Council (KENTTEC), Kenya; Kenya Wildlife Service (KWS); 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; University of Maryland, USA; University of Würzburg, Germany; Tanzania Wildlife Research Institute (TAWIRI); Yale School of Public Health (USA).

In Africa, livestock form a vital resource for populations, with over two-thirds depending on it for their everyday survival. *icipe* develops strategies to secure this vital resource. ▶

Tsetse research

Tsetse genome sequencing

Following the landmark genome sequencing of *Glossina morsitans morsitans*, in 2014, a further five species of tsetse flies were sequenced. To enhance knowledge of how tsetse flies respond to attractive and repellent stimuli, *icipe* researchers identified the genes responsible for chemical sensing in the insects.

In 2016, the Centre published findings showing that tsetse appear to use the same set of genes for odour coding across species occupying different ecological niches. This is a surprising finding, considering that tsetse differ in their responses to animal odours, which results in differential efficacy of odour baits in current use. Overall, there are no major differences in the number or type of genes for sensing chemicals that are present in different species of tsetse, despite the fact that the insects respond differently to chemicals in the environment. These results indicate that a unified approach can be developed to control tsetse. The researchers are now functionally characterising the olfactory receptor genes that they have identified, by testing ecologically relevant host odours to improve the odour bait technology for tsetse vector control, using two tsetse species.

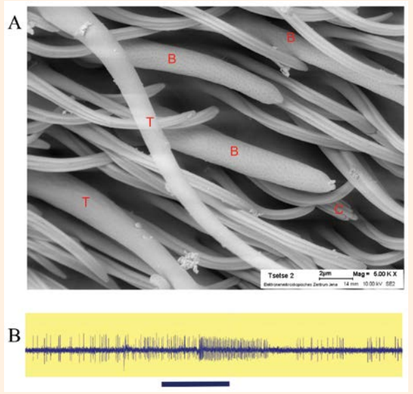


Fig 1. Chemosensory sensilla of tsetse.

(A) Scanning electron micrograph of *G. pallidipes* showing the different olfactory sensilla: B = basiconic, C = ceoloconic, T= thricoid.

(B) Electrophysiological response of a basiconic sensillum to m-cresol in livestock waste (urine) using single sensillum recording (horizontal bar is 500 ms of the stimulation).

Tsetse repellent technology

The upscaling of *icipe*'s innovative tsetse repellent collar technology progressed in 2016. The Centre continued to improve and optimise the technology, by assessing various formulations for cost effectiveness. The Kenya Pest Control and Products Board (PCPB) commissioned an independent evaluation of the repellent technology, prior to final consideration for registration. Further, the researchers continue to investigate additional repellents from wild animals that are attractive to tsetse, such as zebra. Molecular studies are also ongoing to understand the mechanisms of the repellent coding at the olfactory receptor level, which would pave way for further optimisation and development of new compounds (See Figure 1).

Camel health research

The Centre is investigating the prevalence of vector-borne diseases in camels and their vectors; the diverse pathogens harboured by biting flies; and their blood meal sources. These studies are aimed towards understanding disease epidemiology and transmission dynamics and their impact on camel mortality, abortion, and milk production.

The chemical basis of the interaction between biting flies and camels is being investigated, to find behaviour-modifying chemicals that could be used to develop new attractants and repellents. In three research sites, camel trypanosomiasis (surra) has been found to account for 78 –90% of all camel deaths.

In addition, biting flies that are potential vectors of the disease have been identified. The researchers have also identified semiochemicals that can enhance the performance of biting fly traps and are now optimising them as tools for mass trapping of the insects.

icipe's intervention in surra management is particularly significant, based on the importance of the camel in many arid and semi arid regions of Africa.

Emergency response to unexplained camel deaths

Starting in November 2016, in support of the Emerging Pandemic Threats Phase 2 (EPT-2) USAID funded–FAO programme, and led by the Directorate of Veterinary Services, Kenya, *icipe* participated in investigating the deaths of more than 1500 camels in northern Kenya, due to unknown causes. The camel disease symptoms matched those of heartwater, which usually occurs in goats and other small livestock. The Centre's Martin Lüscher Emerging Infectious Diseases (ML-EID) Laboratory identified heartwater, a tick-borne disease caused by a bacterium, *Ehrlichia ruminantium*, in the dead camel samples as well as in the *Amblyomma gemma* ticks, which are known carriers of the disease. This is the first time that *E. ruminantium* has been identified in camels, making it an emerging infectious disease of the animal. *icipe* continues investigations into the strain characteristics of the pathogen.

icipe research has identified a tick-borne disease as the likely cause of the recent camel deaths in northern Kenya, and continues to investigate the characteristics of the pathogen.

Tick-borne disease surveillance

icipe has been conducting tick-borne disease surveillance in Baringo County (Rift Valley) and Homa Bay County (western Kenya). These areas have intense livestock–wildlife interaction, as well as a variety of reptile species that are known to be reservoirs of such ailments. The researchers identified *Ehrlichia ruminantium* in *Amblyomma* and *Rhipicephalus* pools of ticks, sampled from livestock in the two counties.

The disease was also found in *Amblyomma falsomarmoreum* and *A. nuttalli* ticks sampled from tortoises and *A. sparsum* tick sampled in both cattle and tortoises around Lake Baringo. The high prevalence of *E. ruminatium* in ticks associated with tortoises suggests a likely role of tortoises in the incidence and distribution, and other key factors related to the disease in the region.

Among other tick-borne pathogens that may contribute to the disease in livestock, and possibly in people in the region, the *icipe* researchers also report, for the first time, *Ehrlichia chaffeensis*, which is a zoonotic pathogen transmitted by *Amblyomma americanum* and *Coxiella* sp., and *Rickettsia africae* and *Theileria velifera* parasites in *Amblyomma eburneum* ticks in the Shimba Hills National Reserve of Kenya.

Bioacaracide for tick control

icipe's research to develop a bioacaracide to eliminate the use of chemicals in tick control has led to the identification of a novel and potent formulation of an isolate of *Metarhizium anisopliae* fungi (ICIPE 7, commercially known as Tickoff). In field trials, the formulation reduced on-host cattle ticks by 76 to 85%, considerably outperforming a commonly used commercial acaricide, against which many tick species have, in any case, developed resistance. A patent for the formulation is in progress, and local registration of the product has been submitted to the regulatory authority in Kenya.

Tickoff, a bioacaracide for tick control.

Plant Health Theme

A push–pull field consisting of *Brachiaria*, greenleaf desmodium and a maize intercrop. ▶

Donors: 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) and Grand Challenges Canada (GCC); European Union; Federal Ministry for Economic Cooperation and Development (BMZ), Germany; Food and Agriculture Organization of the United Nations (FAO); Government of Kenya; Humidtropics CGIAR Research Programme led by International Institute of Tropical Agriculture (IITA); International Atomic Energy Agency (IAEA), Austria; International Fund for Agricultural Development (IFAD), Italy; Liechtenstein Development Service (LED), Principality of Liechtenstein; McKnight Foundation, USA; National Commission for Science, Technology and Innovation, Kenya; Research Institute of Organic Agriculture (FiBL), Switzerland; Russell IPM Ltd, UK; Swedish International Development Cooperation Agency (Sida); Swiss Agency for Development and Cooperation (SDC); UK Aid from the UK Government.

Partners: Anglican Development Services, Kenya; African Conservation Tillage Network, Malawi and Zambia; Agricultural Research Corporation, Sudan; National Agricultural Research Organisation (NARO, Uganda; Agricultural Transformation Agency, Ethiopia; Biocontrol Research Laboratories, India; Bioversity International; Ethiopian Institute of Agricultural Research (EIAR); University of Bonn, Germany (Center for Development Research - ZEF); Citrus Research International, South Africa; Conservation Farming Unit (CFU), Zambia; Division of Plant Industry, Florida Department of Agriculture and Consumer Services, USA; Embu University, Kenya; Farmer groups and mango growers; Forum for Agricultural Research in Africa (FARA); Hawassa University, Ethiopia; Heifer International – Kenya and Tanzania; Horticultural Research and Training Institute-Tengeru (HORTI Tengeru), Tanzania; HottiServe East Africa Limited; Humboldt-Universität zu Berlin, Germany; Institute for Sustainable Development (ISD), Ethiopia; Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic; 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); 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; Leibniz Universität Hannover, Germany; Lilongwe University of Agriculture & 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 Crops Resources Research Institute (NACRRI), Uganda; National Museums of Kenya; National Potato Council, Kenya; Norwegian Institute for Bioeconomy Research (NIBIO); One Acre Fund, Kenya and Uganda; The New Zealand Institute for Plant & Food Research Ltd, Plant Research International, Wageningen University and Research Centre (WAU), The Netherlands; The Poverty Alleviation Department, Office of the President, Uganda; Real IPM Ltd, Kenya; Research Institute of Organic Agriculture (FiBL), Switzerland; Rothamsted Research, United Kingdom; Royal Museum for Central Africa, Tervuren, Belgium; The Seed Control and Certification Institute of Zambia; Send a Cow; farmers' groups; Sokoine University of Agriculture, Tanzania; Texas A&M University, USA; Tigray Agricultural Research Institute (TARI), Ethiopia; Total LandCare, Malawi and Zambia; Tropical Soil Biology and Fertility (TSBF) Institute of CIAT; University of Hohenheim, Germany; University of Nairobi, Kenya; University of Sousse (Higher Agronomic Institute of Chott-Meriem), Tunisia; University of Tschang, Cameroon; University of Zambia; Wageningen University and Research Centre (WAU), The Netherlands; WeRATE; World Agroforestry Centre (ICRAF).

icipe and partners continue to advance integrated pest management (IPM) packages for exotic and native fruit flies, the key pests of fruits. The IPM packages are aimed at reducing yield losses and the huge expenditure incurred by farmers to purchase pesticides. They are also intended to mitigate the health and environmental risks associated with the use (and misuse) of such chemicals.

Discovery and development of host-marking pheromones for fruit fly control

Fruit flies use host-marking pheromones to mark fruits where they have already laid eggs, thereby pre-empting repeated egg-laying on the same fruit. *icipe* hypothesised that if a product containing these host-marking pheromones is sprayed onto fruits, it could deter and prevent fruit flies from laying eggs on them. In 2016, *icipe* identified host-marking pheromones of three *Ceratitis* fruit fly species: *C. cosyra*, *C. rosa* and *C. fasciventris*. The host-marking pheromone of *C. cosyra* was found to be a tripeptide, while *C. rosa* and *C. fasciventris* share an identical pheromone—an amino acid. Laboratory-based assays have confirmed the broader-spectrum efficacy of the host-marking pheromone of *C. cosyra* in deterring laying by itself and two other related species, *C. rosa* and *C. fasciventris*.

Description of new fruit fly species

icipe helped to describe five new species of fruit flies and to provide the mitochondrial DNA to generate barcodes of the following new pests of cultivated and wild fruits: *Ceratitis (Pterandrus) quilicii* De Meyer, Mwatawala & Virgilio sp. nov.; *C. (Ceratalaspis) pallidula* De Meyer, Mwatawala & Virgilio sp. nov.; *C. (Ceratalaspis) taitaensis* De Meyer & Copeland sp. nov.; *C. (Ceratalaspis) swahilensis* De Meyer & Virgilio sp. nov.; and *C. (Ceratalaspis) flavipennata* De Meyer & Virgilio sp. nov. Using several integrative taxonomy tools, *icipe* also played an important role in resolving the identity of *Ceratitis quilicii*, formerly considered to be the highland population of *Ceratitis rosa*, which is an important pest of commercial fruits. Subtle differences in molecular and morphological characters led to the recognition that these closely related forms were actually separate, sibling species.

New tools for fruit fly control

icipe has identified 16 compounds from blends of host fruit volatiles that can be used to improve the efficiency of existing female-biased attractants, which can be used to improve the efficiency of traps for four fruit fly species: *Bactrocera dorsalis*, *Ceratitis capitata*, *C. rosa*, and *C. cosyra*. Further research is ongoing to synthesise these compounds into a product for wider application in suppressing fruit flies.

Ceratitis quilicii female

Ceratitis quilicii male

Ceratitis taitensis, male

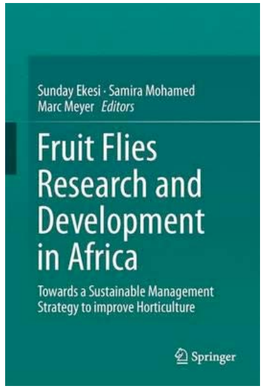
Fruit fly natural enemies

Previous research by *icipe* on the control of the invasive *Bactrocera dorsalis* identified two efficient parasitoid species, *Fopius arisanus* and *Diachasmimorpha longicudata*. The Centre has imported these parasitoids from Hawaii, USA and is supporting their release in several African countries where *B. dorsalis* is a problem. For instance, in 2016, *F. arisanus* and *D. longicaudata* were transferred to national partners in Burkina Faso, Namibia, and Zambia for mass rearing and release. Permits for the release of *F. arisanus* were also secured in Uganda and South Africa. Further, large-scale augmentative releases of *F. arisanus* were conducted in eastern Kenya.

New book on fruit flies in Africa

icipe researchers Dr Sunday Ekesi and Dr Samira Mohamed, in collaboration with Dr Marc de Meyer, Royal Museum of Central Africa, co-edited a new book titled *Fruit Flies Research and Development in Africa: Towards a Sustainable Management Strategy to improve Horticulture*, published by Springer International Publishing, Switzerland, in November, 2016 (link: http://link.springer.com/book/10.1007/978-3- 319-43226-7).

In addition to Dr Ekesi and Dr Mohamed, several *icipe* scientists are among 60 researchers from across the globe, who have authored chapters in the book which has been made possible by the support of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and Federal Ministry for Economic Cooperation and Development (BMZ), Germany.



The publication presents one of the most comprehensive appraisals of fruit fly problems and solutions in Africa, from taxonomy, to bioecology, management and socioeconomic impact assessment.

While several specific reviews have addressed various aspects of the biology, ecology and management of economically important tephritid fruit flies, assessment of African native species has been limited to *Bactrocera oleae* and *Ceratitis capitata* – which are not economically important species in the continent. Indeed, there is currently no other book that explicitly addresses the most significant African fruit flies.

There are also no prior reviews that have focused on the status of the bioecology, economic impact and management of exotic and native fruit flies – including several potentially invasive *Dacus* species attacking vegetables – in Africa.

Therefore, *Fruit Flies Research and Development in Africa: Towards a Sustainable Management Strategy to improve Horticulture* is important, as it fills critical knowledge gaps.

The book is also especially pertinent at a time when the fruit fly landscape is changing rapidly in Africa, due to the arrival of highly destructive alien invasives (*Bactrocera dorsalis*, *B. zonata* and *B. latifrons*).

It also provides a perspective on desirable future control strategies and necessary research, and comes complete with images of native and invasive species of fruit flies and their natural enemies.

The publication is therefore a critical reference material for researchers, academics and students keen to improve horticulture and enhancing food and nutrition security in Africa and beyond.

To purchase a copy of the book, please visit: http://www.springer.com/gp/book/9783319432243

Citrus IPM

Ms Helen Heya (right), a laboratory technologist at the Kenya Plant Health Inspectorate Service (KEPHIS), and Mr Peterson Nderitu, an *icipe* technician, sample citrus pests using an aspirator.

One of the most serious pests of citrus in Africa is the native African citrus triozid, *Trioza erytreae*. In addition to other damage symptoms, *T. erytreae* transmits a devastating phloem-limited bacteria known as *Candidatus* Liberibacter africanus (CLaf), which is responsible for the African form of citrus greening or huanglongbing disease. The disease is most significant in the mid and highland zones, where it causes yield losses between 25–100%, and is in fact, implicated in the collapse of the citrus industry in these regions in Kenya. Due to its severity, the European and Mediterranean Plant Protection Organisation has classified *T. erytreae* as an A1 quarantine pest. In addition, *T. erytreae* has been shown experimentally to transmit the Asian form of citrus greening, *Liberibacter asiaticus*

First DNA barcode reference library for the African citrus triozid, *Trioza erytreae*

Knowledge on the molecular identification and barcodes, which would increase bioecological and morphological understanding of *T. erytreae,* is lacking. *icipe* scientists have constructed, for the first time, a barcode reference library for *T. erytreae* from Kenya and several other countries, as a means of rapid identification of the pest, especially new detections. This ability will shorten the decision-making process for quarantine officers, phytosanitary bodies, and citrus growers.

Citrus IPM

In joint surveys along the Kenyan coast, *icipe* and the Kenya Plant Health Inspectorate Service (KEPHIS), have detected, for the first time, the exotic Asian citrus psyllid, *Diaphorina citri.* The Centre has conducted studies towards understanding its distribution, population dynamics, damage, and molecular ecology.

Knowledge on the Asian citrus psyllid

The Asian citrus psyllid is more devastating than the African citrus triozid, *T. erytreae*, and is more efficient at vectoring the Asian form of citrus greening disease.

The Centre has also established that in East Africa, huanglongbing disease is mainly caused by *Candidatus* Liberibacter africanus (Claf).

In addition, since *Diaphorina citri* is adapted to the lowlands, these regions, which have to-date remained free of huanglongbing, are now at risk.

Further, the researchers have also detected a new subspecies of *Candidatus* Liberibacter africanus subsp. clausenae (Claf-cl) causing citrus greening in the region, in plant tissue and, interestingly, in the tissue of the vectors *T. erytreae* and *D. citri*.

Tuta absoluta (also known as tomato leafminer) is a harmful species of moth. The larvae have a strong preference for tomato, but also attack other crop plants such as eggplant, pepper, potato, and African nightshade (an important indigenous leafy vegetable), which would have detrimental implications on the nutritional security of millions of peoples across the continent.

Tuta absoluta

Tuta absoluta invasion in the target countries

Tuta absoluta was first detected in East Africa in 2016 and is now widespread and well-established, including along the borders with Rwanda and the Democratic Republic of Congo; thus, the pest poses an imminent threat to Africa. Using samples obtained from Mozambique, *icipe* scientists confirmed the presence of *T. absoluta* in Mozambique and Malawi. The invasion pathway of the pest has been established using already-developed microsatellite markers. The Centre also generated prediction maps of the spatial–temporal spread of *T. absoluta* in Africa that indicated that the pest would reach the Republic of South Africa by the end of 2017, which is a prediction that has been confirmed.

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Classical biological control of *Tuta absoluta*

icipe and the International Potato Center (CIP), have identified a larval parasitoid, *Dolichogenidea gelechiidivoris*, an efficient parasitoid in suppressing *T. absoluta* (with up 70% parasitism) in Peru, which is the aboriginal home of both the pest and the parasitoid. The Peruvian government granted an export permit to CIP to transfer the natural enemy to *icipe*. In addition, the Kenya Plant Health Inspectorate Service (KEPHIS) granted *icipe* a permit to import the parasitoid species for rearing and testing at the Centre's quarantine facility and also for subsequent releases in Kenya and beyond.

1. *Tuta absoluta* adult
2. *Dolichogenidea gelechiidivoris* adult

Microbial control

Two isolates of the entomopathogenic fungus, *Metarhizium anisopliae*—ICIPE 18 and ICIPE 20—have been found to be pathogenic to *T. absoluta*. Field cage experiments and open field trials will be undertaken to evaluate the performance of these isolates on *T. absoluta* under natural and semi-natural conditions. *icipe* 20 has higher prospects for commercialisation as a biopesticide for suppression of *T. absoluta*, when used within the framework of a holistic approach. In an effort to identify a virulent virus with the potential for use as a biopesticide for *T. absoluta* suppression, five strains (three from Tunisia, one from Yemen, and one from Kenya) were evaluated for their virulence against this pest. Although all the strains were pathogenic to *T. absoluta,* one of the Tunisian strains showed a higher level of virulence. However, there is need for further testing of this strain under field conditions, before it is recommended for commercialisation as a potential biopesticide.

Biorationals for *Tuta absoluta* control

icipe researchers have tested under laboratory conditions, the essential oils of two widely available herbs from the East African region—African basil (*Ocimum gratissimum*) and camphor basil (*O. kilimandscharicum*)—for their effect on larvae and adults of *T. absoluta*. Although both plant species were found to have insecticidal activity against *T. absoluta*, *O. gratissimum* demonstrated a higher ability to repel and kill both stages of the insect. Studies will be conducted, towards advancing strategies to control the pest.

Tuta absoluta can cause the significant damage shown in the middle of this field.

Vegetable IPM

Capacity building

A total 204 (48% female) of NARS from Kenya, Uganda, and Sudan were trained on identification, monitoring and management of *T. absoluta*. A further 859 (27% female) tomato growers were trained on monitoring and management of the pest.

Resistance to *Tuta absoluta*

icipe researchers have evaluated the response of female *T. absoluta* to cultivated tomato and wild cherry tomato (*Lycopersicon esculentum var. cerasiforme*). Wild tomato was found to be repellent to *T. absoluta* compared to cultivated tomato. In collaboration with the World Vegetable Centre (AVRDC), *icipe* is conducting studies to identify the sources of resistance to *T. absoluta* among the wild relatives of tomato.

Mass trapping

An *icipe* partner, Sudan Agricultural Research Corporation (ARC), has established that mass-trapping using the *T. absoluta* lure, TUA-Optima, leads to a significant reduction of the pest population and to increased tomato yields (by 90%).

An *icipe* researcher conducting training on *Tuta absoluta* control in Sudan.

A heathy tomato field: Tomato is one of the most economically important crops in Africa; but cultivation of the crop is under threat because of *T. absoluta* invasion.

Indigenous vegetables are becoming increasingly important, in efforts to improve the nutritional security of many households across Africa. *icipe* is making a significant contribution to addressing the constraints in production of these valuable crops.

Indigenous vegetables

African nightshade's 'dead-end' strategy

The Centre has discovered that a species of the African nightshade, a widely consumed indigenous vegetable in Africa, has evolved a unique ability to defend itself against one of its major pests, the tomato red spider mite. *icipe*'s findings show a distinctive resistance strategy in the plant, which is based on opposing roles, with the chemicals acting as attractants in the leaves and the trichomes defending the plant against certain behaviours of the attacking pests. In effect, the pest is lured to its 'dead-end'. The Centre will advance this research with the aim of developing integrated pest management strategies to control tomato red spider mite on African nightshade.

Biopesticides and natural enemies

icipe has identified an isolate (ICIPE 62) from *Metarhizium anisopliae* entomopathogenic fungus as an effective biopesticide in an IPM strategy against the cowpea aphid, *Aphis craccivora*. A second isolate from *M. anisopliae,* ICIPE 30, has been shown to be effective against adult leaf webbers. The Centre is working with private sector partners to commercialise these biopesticides. *icipe* has also developed technologies to conserve and augment parasitoids of lepidopteran defoliators. Two parasitoids, *Apanteles hemara* and a new species of *Cotesia*, were found efficient under laboratory conditions against leaf webbers and leaf worms, respectively, and are being considered for conservation and augmentative biological control.

1. A spider mite on culivated African nightshade (notice the trichomes and trichome exudate).

2. In Africa, *Amaranthus* species is an important traditional leafy vegetable. Through its research, *icipe* aims to contribute to increased production of such crops.

Nematode research

The potato cyst nematode (PCN), is a serious pest of potatoes worldwide. These microscopic, soil-dwelling roundworms are destructive, as they feed on the roots of plants, leading to poor root development, stunted plant growth, and reduced tuber yield. The pests are difficult to control due to the longevity of their cysts in the soil and their ability to spread in the soil and in the tubers. Two years ago, PCN was reported in eastern Africa for the first time, signalling potential adverse impacts on food security and livelihoods in a region where potatoes are an important crop for many households.

Since then, *icipe* has been involved in an initiative funded by the Food and Agriculture Organization of the United Nations (FAO), aimed at surveying the countrywide spread of PCN in Kenya, while training government technicians and staff of research institutions to deal with the pest. *icipe*'s preliminary findings indicate that certain crops act as dead end PCN traps, because the PCN nematodes are attracted to the roots of such plants, but they are unable to survive on them. This discovery provides promising leads for PCN management approaches. *icipe* is now conducting studies on the possibility of using African nightshade in a dead end trap crop strategy for PCN in eastern Africa.

In Africa, potato is important, often serving as a backup to cereals. Through its nematode research, *icipe* aims to contribute to increased production of the crop.

Smart maize defence against stemborers

icipe's earlier studies revealed that some maize landraces possess a valuable defence trait that is not present in commercial maize varieties. The trait involves release of odours (semiochemicals) that are attractive to natural enemies of stemborers after they lay eggs on the plant. These odours provide a reliable cue for the natural enemies to locate plants colonised by the pest, and kill their eggs and caterpillars, thus preventing damage on the crops. In 2016, *icipe* researchers identified genetic markers linked to this stemborer resistance trait in the smart maize germplasm. These findings will facilitate use and delivery of the natural stemborer resistance to farmer-preferred maize cultivars with other agronomically desirable traits. In a related study, researchers have identified the structures of chemical compounds (elicitors) that activate the defence response on smart plants from the stemborer egg material associated with attachment to the leaves. One of the elicitor compounds has been synthesised in large quantities at Rothamsted Research, UK for further study. These discoveries will open up opportunities to search for sorghum germplasm that demonstrates this favourable trait, thus expanding the possibility of controlling stemborers in this manner to yet another important cereal crop in Africa.

Push–Pull IPM

Advancing climate-smart push–pull

In relation to the increasingly dry and hot conditions associated with climate change, the Centre has over the past several years developed a climate-smart push–pull technology that involves use of the drought-tolerant repellent and trap crops, greenleaf desmodium (*Desmodium intortum*), and *Brachiaria* cv *Mulato*, as intercrop and border crops, respectively. In 2016, *icipe* evaluated *Brachiaria* accessions in comparison with a local African open pollinated maize cv. 'Nyamula', in relation to egg laying and larval performance of *Chilo partellus* stemborers. The results demonstrate the suitability of *Brachiaria* for *C. partellus* egg-laying, as well as the inability of larvae to survive on the grass. In turn, the findings indicate that *Brachiaria* can be used as a "dead end" trap crop for management of cereal stemborers.

New drought-tolerant *Desmodium* plants

Control of *Striga* in the push–pull technology is a function mediated by root chemicals produced by *Desmodium* spp. The chemical synthesis of some of those chemicals in *C*-glycosylflavone group has continued and mono *C*-arabinosyl-2-hydroxyapigenin and mono *C*-galactosyl-2-hydroxapigenin precursors have been synthesised in small quantities. This will be repeated on a larger scale and with multiple stable isotopes, so that they may be used to determine the biosynthetic pathway for the *C*-glycosylflavones. The biosynthetic pathways of those containing glucose have now been elucidated and published (*Phytochemistry 2016,* 125:73–87).

C-glycosylflavones are the only *Desmodium* spp. plant metabolites found in the root exudates so far that have shown activity against *Striga* when assayed *in vitro*.

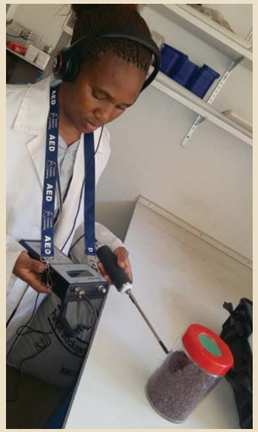
icipe scientist, Dr Amanuel Tamiru collecting volatiles from maize seedlings.

Mitigating postharvest losses

Every year, in sub-Saharan Africa (SSA), significant volumes of food (estimated to amount to the calorific needs of 48 million people) are lost after harvest.

Bean weevil acoustics

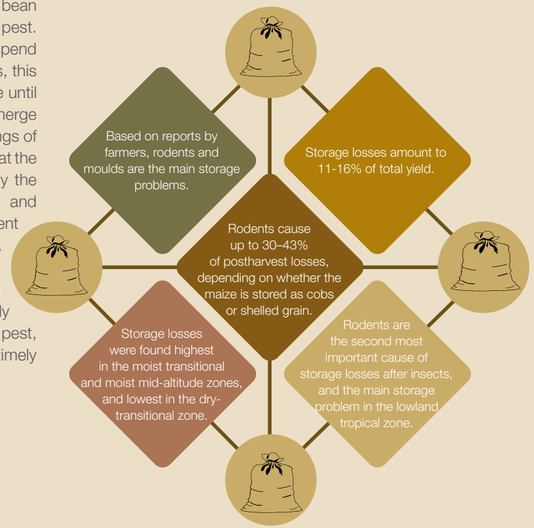
One of the challenges in the quest towards reduction of postharvest losses is the difficulty in detecting the presence of insect pests that damage food in storage. In 2016, *icipe* completed a study towards exploiting the sounds made by insects, to develop early warning systems to control storage pests. The research investigated the acoustics characteristics of the bean weevil, *Acanthoscelides obtectus*, a major legume pest. Because of the cryptic nature of its larvae, which spend most of their developmental stage inside bean seeds, this pest is imperceptible until when the larvae emerge as adults. The findings of this study indicate that the sounds produced by the bean weevil larvae and adults have different temporal patterns. Therefore, the larvae acoustic signals can be exploited for early detection of the pest, thus permitting timely intervention.



icipe is conducting research on insect acoustics, as a way of mitigating postharvest losses.

On-farm maize storage systems and rodent postharvest losses in Kenya

icipe undertook an assessment of the magnitude and contribution of rodents in postharvest losses in on-farm maize storage systems. These findings reveal the need for pest-proof storage technologies and incentives for farmers to invest in them.



Field testing trial of the effectiveness of various hermetic storage technologies against the larger grain borer (*Prostephanus truncatus*) at Katulani, Machakos County.

Environmental Health Theme

Donors: AIRD (French Inter-institution Agency for Research and Development); Biovision Foundation for Ecological Development, Switzerland; European Union (EU); Federal Ministry for Economic Cooperation and Development (BMZ), Germany; International Fund for Agricultural Development (IFAD); JRS Biodiversity Foundation, USA; Ministry for Foreign Affairs of Finland; Ministry of Higher Education, Science and Technology, Kenya; Swedish International Development Cooperation Agency (Sida); SWITCH Africa Green; Swiss Agency for Development and Cooperation (SDC), Switzerland; The MasterCard Foundation; UK Aid from the UK Government; World Trade Organization (WTO) – Enhanced Integrated Framework (EIF).

Partners: African Union Inter-African Bureau for Animal Resources (AU-IBAR); Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), France; German Centre for Integrative Biodiversity Research (iDiv), Germany; Holeta Bee Research Centre, Ethiopia; Institut national de la recherche agronomique (INRA), France; Iziko South Africa Museum, South Africa; Jimma University, Ethiopia; Kenya Agricultural and Livestock Research Organization (KALRO) (National Sericulture Research Centre); Martin-Luther-Universität Halle-Wittenberg, Germany; Ministry of Agriculture, Livestock and Fisheries (Directorate of Livestock Production), Madagascar; Ministry of Agriculture, Ethiopia; Ministry of Agriculture, Fisheries, Environment 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 Animal Resources and Fisheries, Burkina Faso; Ministry of Livestock, Fisheries and Animal Industries, Cameroon; Museum für Naturkunde, Berlin, Germany; National Agriculture and Food Research Organization, Japan; National Beekeeping Station, Kenya; 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; Wageningen University and Research Centre (Resource Ecology group), The Netherlands; Smithsonian Institution, USA; Smithsonian National Museum of Natural History, USA; Sokoine University of Agriculture, Tanzania; Taita Environmental Research and Resource Arc (TERRA), Kenya; Tropical Entomology Research Center, Viterbo, Italy; United States Department of Agriculture, USA; University of California, Davis, USA; University of Dar es Salaam, Tanzania; University of Helsinki, Finland; University of Kansas, USA; Tuscia University, Viterbo, Italy; University of York, UK; Yeungnam University, South Korea.

Silkworm rearing on mulberry leaves is part of *icipe* research.

Understanding colony losses

The significant population decline of bees as a result of colony losses has caused global concern and the syndrome is a priority of governments, development agencies, farmers, and beekeepers. The causes of the colony losses are unknown, although a number of possible reasons have been proffered. *icipe* aims to contribute knowledge on colony losses and on bee health. In collaboration with partners, the Centre is mapping bee health risk factors, while investigating mitigating strategies.

icipe's ongoing surveys have revealed the presence of varroa mites, one of the key pests associated with colony losses in Europe and the USA, in many African countries. In Europe and the USA, colony losses have been attributed to the widespread use of agrochemicals in addition to pest, diseases and habitat destruction. *icipe* surveys of hive products in Kenyan apiaries have detected a range of agrochemicals, including insecticides, herbicides, fungicides, and acaricides at low levels. The Centre is also surveying a wide range of known bee pathogens and pests in several African countries.

By studying African honey bees, *icipe* will contribute to global knowledge on bee health.

Harnessing the benefits of bee microbiota

All living organisms, including plants and animals, carry with them a variety of microorganisms that contribute to their general health and well-being in a range of ways. The microbiota of the bee gut plays an important role in many aspects of bee biology and health, such as digestion. In a newly established project, *icipe* scientists will investigate bee gut microbial diversity and the nature of specific interactions between microbes and bee fitness. It is hoped that this increased understanding of how gut mircobiota influences the health of bees will lay a foundation for microbe-based strategies for improved bee health management.

Dr Juan Paredes, who is leading bee microbiota research at *icipe*, conducts a capacity building training session on the topic.

Apicure®, a new natural product developed by *icipe* for the control of bee diseases.

New plant-based biofumigant for bee health

Developed by *icipe*, the product, Apicure®, has been tested in small-scale field trials in various regions in Kenya, where it has been shown to be effective in killing varroa mites and in repelling small hive beetles in bee colonies. A patent application on the composition and methods of using the product in bee pest control has been filed with the Kenya Industrial Property Institute (KIPI). Similar applications will also be made in other African countries. An international patent application has been filed with the World Intellectual Property Organisation (WIPO). *icipe* is continuing research to characterise the key components of the product, and optimise the production, formulation and application process, followed by validation under semi -field and field conditions.

The Young Entrepreneurs in Silk and Honey (YESH) project

A collaborative initiative between The MasterCard Foundation and *icipe* was launched in March 2016. The YESH project is aimed at enhancing youth employment in Ethiopia, through beekeeping and silk farming enterprises.

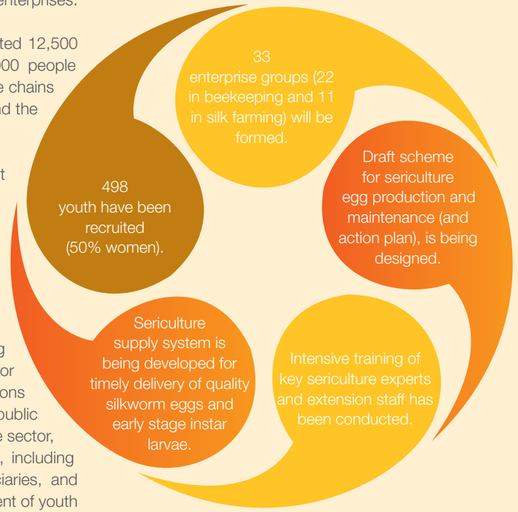
The initiative is expected to benefit an estimated 12,500 unemployed youth, while an additional 25,000 people will be involved in different aspects of the value chains that will be strengthened and developed around the project.

The YESH project represents a significant evolution of *icipe*'s Commercial Insects Programme technology adoption model. In addition to technical skills, beneficiaries will also receive financial and business management training.

The project is supported by overall guidance and facilitation of a national project steering committee chaired by the State Minister for Livestock and Fisheries, with collaborations across regional, zonal and district level public offices, as well as representatives of the private sector, in the planning and implementation of plans, including site selection, recruitment of project beneficiaries, and delivery of essential services in the establishment of youth enterprises in silk and honey.

The project is currently exploring partnerships with related projects and programmes of non-governmental organisations (NGOs) and United Nations agencies.

Accomplishments in 2016



Commercial and beneficial insects

Semiochemicals to control wild silk pests and parasitoids

Limited ecological research conducted on wild silkmoth species exists. As well, knowledge on their population dynamics is minimal. To complete these gaps, *icipe* is documenting and studying the spatial distribution of four wild silkmoth species in Kenya—*Gonometa postica, Anaphe panda, Argema mimosa* and *Epiphora mythimnia.* Results indicate that cocoon losses are due to parasitoids, predators, pests, and diseases. Four hymenopteran and two dipteran parasitoids that attack *G. postica* cocoons have been identified.

The researchers are now conducting studies to explore the potential of volatile cues to control these pests and parasitoids. The volatiles that the plants release when herbivores eat (insects) them are the main focus. The aim is to develop a trapping system that will be used to target specific parasitoids that affect wild silk in the field. Comprehensive studies on the key parasitoids in relation to the environment are being conducted as a prerequisite for devising any management programme to protect silkmoths and boost cocoon production.

Expanding beekeeping in Africa

icipe is introducing improved beekeeping technologies and pollination services in four Indian Ocean island nations off the southeastern seaboard of Africa—Comoros, Madagascar, Mauritius (and Rodrigues), and Seychelles—and in Zanzibar, Tanzania on the eastern coast. The Centre's goal is to provide an alternative source of livelihood, increase crop yields and incomes, and enhance the ability to conserve biodiversity among communities participating in the International Fund for Agricultural Development (IFAD) country programmes.

Since 2016, issues related to bee health and responsible use of pesticides have been included in the beekeeping curriculum of extension officers and beekeepers in Comoros, Zanzibar, Mauritius, Seychelles, and Madagascar. Close to 50 government staff and 100 lead beekeepers in Comoros, Zanzibar, Mauritius, Seychelles and Madagascar have been trained on the identification of varroa mites and the American and European foulbrood diseases, impact of pesticides on honey bee health, and contamination of hive products.

These women beekeepers on Unguja, Zanzibar manage this apiary.

Insect biodiversity research

Discovery of new insect species

In 2016, the *icipe* Biosystematics Unit and colleagues from l'Institut National de la Recherche Agronomique (INRA), France and from three institutions in the United States of America (USA) published findings on research aimed at completing the existing gaps on the knowledge regarding insect biodiversity in Africa. One paper examined species richness and the geographic and host-plant distribution of seed-feeding Megastigminae wasps (Hymenoptera: Torymidae). The researchers from INRA and *icipe*'s Biosystematics Unit described eight new wasp species, all from Kenya, doubling the number previously known from Africa. One of the new species, *Megastigmus icipeensis* Roques & Copeland was collected in a Malaise trap set on the *icipe* Duduville Campus in Nairobi.

The second paper featured findings from collaborative research between *icipe*, the United States Department of Agriculture (USDA), the Smithsonian Institution, USA, and Pennsylvania State University, USA. It presented a comprehensive taxonomic revision of *Dvivarnus*, a small but formidable genus of Scelionidae, a group of parasitoid wasps that exclusively attack eggs of other invertebrates. One of the newly described scelionid species has been named *Dvivarnus mikuki* Talamas & Miko. The species name is derived from the Kiswahili word for spears (*mikuki*), and refers to the prominent spines on the wasp's thorax. Like *M. icipeensis*, the holotype of *D. mikuki* was collected in a Malaise trap set at the *icipe* Duduville Campus.

Both *D. mikuki* and *M. icipeensis* were captured during a two-week training course on insect identification and taxonomy organised by the *icipe* Biosystematics Unit for scholars conducting research within the Centre's African Regional Postgraduate Programme in Insect Science (ARPPIS). The Biosystematics Unit has also published an online book which is free for downloading entitled: A Natural History of the Wild Fruits of Taita Hills, Kenya.

1. *Megastigmus icipeensis* female
2. *Megastigmus icipeensis* male
3. *Dvivarnus mikuki*


1


2


3

AFERIA project

Between 2011 and 2015, the Ministry for Foreign Affairs of Finland and *icipe*, and various partners implemented the Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa project (CHIESA, http://chiesa.icipe.org/).

In 2016, *icipe* and the Ministry for Foreign Affairs of Finland launched a new initiative to disseminate and communicate research findings, insights, and interactions obtained through CHIESA. Known as the Adaptation for Ecosystem Resilience in Africa (AFERIA), the two-year project is aimed at supporting the ability of smallholder farming families living around fragile mountain ecosystems in eastern Africa to adapt to the impacts of climate variability and change through research-based interventions.

AFERIA will facilitate the implementation of improved technologies and methods for climate change adaptation, such as integrated pest management, drip irrigation, and conservation agriculture. In addition, the project will focus on building the capacity of national agricultural research and extension services and smallholder farmers to support the implementation of community-based climate change adaptation action plans.

Through climate change adaptation action plans and technology transfer, the AFERIA Project will disseminate research findings on climate change impacts and implement research-based interventions in different agro-ecological zones, including the Taita Hills and Murang'a County in Kenya, Mount Kilimanjaro region in Tanzania, and the Jimma Highlands of Ethiopia. The Project will cooperate with national and local organisations to reach smallholder farmers, especially women and special needs groups. Among the adaptation technologies to be transferred to communities are drip irrigation, rain water harvesting, conservation agriculture, farm forestry, and insect pest management.

AFERIA will enable *icipe* to extend its scope of expertise in developing and extending environmentally-friendly management tools and strategies, towards improving the livelihoods of smallholder farmers across Africa. AFERIA will also support the achievement of the four focal points of Finland's Development Cooperation Policy of 2016—to improve food security, enhance access to water and energy, and promote sustainable use of natural resources.

Participants of a Training of Trainers (ToTs) course during an integrated pest management session conducted by AFERIA on how to scout for crucifer pests. Findings from the CHIESA project indicate that the damage caused by these pests is increasing with climate change.

Insects for Food and Feed

Donors: Australian Centre for International Agricultural Research (ACIAR) and International Development Research Centre (IDRC) through the Cultivate Africa's Future (CultiAF) programme; BMZ – German Federal Ministry for Economic Cooperation and Development through GIZ; DANIDA; Netherlands Organization for Scientific Research (NWO).

Partners: University of Bonn, Germany (Center for Development Research - ZEF); Egerton University, Kenya; Jaramogi Oginga Odinga University of Science and Technology (JOOUST), Kenya; National Livestock Resources Research Institute (NaLIRRI), Uganda; Kenya Agricultural and Livestock Research Organization (KALRO), Kenya; University of Nairobi, Kenya; Kenya Bureau of Standards; Kenya Marine and Fisheries Research Institute (KMFRI); Lasting Solutions Ltd, Kenya & Uganda; Makerere University, Uganda; National Fisheries Resources Research Institute (NaFIRRI), Uganda; Sanergy Ltd., Kenya; Solidaridad Eastern & Central Africa Expertise Centre, Kenya; Uganda National Bureau of Standards, Uganda; University of Hohenheim, Germany; Wageningen University, The Netherlands; University of Copenhagen, Denmark; University of Bonn, Germany.

Feeding poultry on feed that has been enriched with insects. ▶

Insect rearing

In 2016, 22 insect species were reared at *icipe* under this research programme, 16 for feed and six for food. The most vibrant colony is the black soldier fly, *Hermetia illucens*, with up to 59 kilogrammes of insects produced per week.

Based on nutritive profiling of various insects discussed in a previous section, the Centre designed different feed formulations and tested them on fish and poultry.

Nutritional assessment of potential insects for food and feed

25 — Crude protein content of 25 species has been documented, based on profiling of various insects considered to have potential for food and feed.

More than 90% of the species were found to have higher protein content than beef, fishmeal, sunflower meal and cottonseed meal. ↑

> Mopane worm, the caterpillar of the moth *Gonimbrasia belina*, has up to 73.3% crude protein, compared to 40.3% in fishmeal.

Insects have far higher components of two amino acids, tryptophan and threonine that are commonly purchased by farmers to complement vegetable-based feed, than fishmeal, sunflower meal and cottonseed meal. ↑

↑↑↑ The insects tested were also rich in vitamin, flavonoids, and fatty acids.

No aflatoxin was detected in a total of 13 insect samples analysed. 0

While various bacteria and fungi were found in fresh insects, boiling them at 96ºC for > five minutes or toasting them at 150ºC for 2 or more minutes resulted in no detectable contamination; thus, microbial contamination can be eliminated in insect-based animal feed. ✓

Performance of insect-based feed on fish and poultry production

↑ Performance studies revealed a 37% higher growth rate and a 23% higher weight gain in catfish fingerlings fed with a black soldier fly-based protein feed, in comparison to similar fish reared on conventional fishmeal diet.

Nile tilapia maintained on a black soldier fly-based protein feed were 23% heavier than those fed with conventional feed. >

0 — No differences in weight or feed intake were observed between broiler chickens reared on the conventional and those reared on insect-based feed.

However, replacement of 25 to 100% fishmeal in conventional layer feed with black soldier fly protein meal resulted in up to 53% higher egg production and improved quality compared to conventional feed. ↑

> While egg production in conventionally fed layers dropped below 50% from the 43rd week, those reared on black soldier fly-based feed maintained high levels of egg production (up to 100%), extending even up to the 52nd week.

These findings indicate that poultry farmers could considerably extend their earnings from the same flock if they adopt insect-based poultry feed. ✓

Insect rearing

Rearing the black soldier fly on agro-industrial brewer's waste streams

Efforts to optimise black soldier fly production using affordable locally available raw materials revealed higher body weight of larval, pre-pupa, pupa, and adult black soldier flies. The studies also showed that the insect was able to reproduce when reared on waste materials supplemented with brewer's yeast and molasses, when compared to adding water alone. These results offer great prospects for using readily available raw materials to mass produce black soldier flies.

Joshua Wambua displays a colony of black soldier flies in the *icipe* Animal Rearing and Containment Unit. With proper research, this insect can also be used for organic waste management

Standardisation of diets for mass rearing of crickets and locusts

Rearing procedures for crickets and locusts are based on the use of fresh plant materials, and are dependent on the seasonality of the plant. *icipe*'s aim is to standardise diets using dried leaf or seed powders of maize, cowpea, and soybean. Results of studies conducted by the Centre in regard to rearing the desert locust, *Shistocerca gregaria,* indicate that diets composed of dried cowpea leaf, soybean flour, and carrot powder with vitamins outperformed the conventional rearing protocol, which uses wheat seedlings. Similarly, in crickets, *Gryllus bimaculatus*, a diet of maize stover powder combined with soybean powder or cowpea leaf powder and maize flour was found to be equally effective in the rearing process.

This knowledge will enhance *icipe*'s insects for food and feed production practices, and will also be transferred to private sector partners.

The desert locust, *Shistocerca gregaria.*

New knowledge on saturniid caterpillars

Diversity of saturniids in East Africa and rearing protocols

Saturniid caterpillars are a major group of insects consumed as food in several central and southern African countries, with tremendous market potential. While the most widely known species is the mopane caterpillar, *Gonimbrasia belina,* field surveys revealed at least five saturniid species in the region, including: Cabbage Tree Emperor Moth (*Bunaea alcinoe*), African Emperor Moth (*Gonimbrasia zambesina*), Pine Tree Emperor Moth (*Nudaurelia krucki*), mopane worm (*Gonimbrasia belina),* Speckled Emperor Moth (*Gynanisa maja*) and *Holocerina angulata. icipe* has established stable colonies of *G. zambesina*, *Nudaurelia krucki* and *Holocerina angulata,* and research is ongoing to develop rearing protocols of the other species.

Natural enemies and entomopathogens of saturniids

icipe researchers have revealed, for the first time, the existence of the tachinid flies, *Carcelia* sp. and *Ceromyia* sp. as parasitoids of *B. alcinoe* and *G. belina.* These flies are also braconid larval parasitoids on *G. zambesina.* Egg parasitoids belonging to the family Euplemidae have also been recorded from eggs of *N. krucki*.

A novel strain of entomopathogenic fungus belonging to the species *Bionectria ochroleuca* was isolated for the first time from *B. alcinoe.* Knowledge of this natural enemy and the biocontrol possibilities will be useful in mass production of saturniid caterpillars, thus pre-empting the possibility of challenges such as colony collapse.

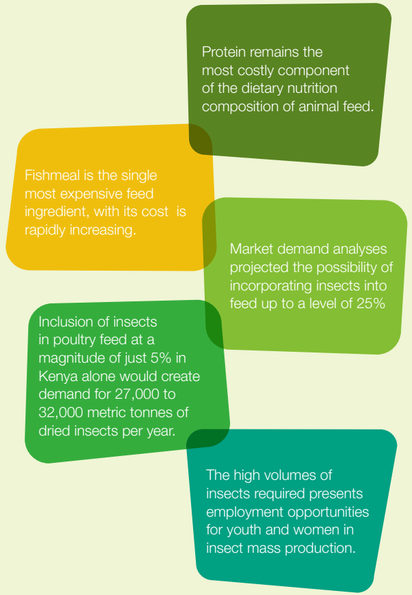
1. Speckled Emperor Moth caterpillar, *Gynanisa maja* feeding on an *Acacia* tree.

2. Braconid larval parasitoid, *Aleiodes trifasciatus* (Enderlein) on African Emperor Moth (*Gonimbrasia zambesina*).

Socio-economic and market studies

Market study on insects for feed

icipe and partners conducted a market study to estimate the costs of poultry and fish feed, and the implications for farmers.



Socio-economic assessments

Studies on community perceptions regarding insects as feed for fish, poultry, and pigs revealed that more than 80% of respondents were aware that insects are a good source of protein in feed, and are willing to purchase insect-based feeds as an alternative to the more expensive fishmeal or plant protein sources. Nearly 35% of the respondents had harvested and used insects from the wild to supplement their diet for poultry. Further, a consumer study revealed that more than 90% of the respondents were willing to buy and consume poultry products reared on insect-based feeds. A major concern highlighted by livestock farmers and traders was the sustainability of insect production systems, in addition to quality and regulation concerns. *icipe* and partners are addressing these concerns in their ongoing research.

Policy and regulations for insects for food and feed

icipe and partners have been collaborating with stakeholders in the livestock and fish production value chain, to create favourable and conducive political and social conditions for the use of insects as feed. The first step was an international conference on legislation and policy, held in March 2016, and led by *icipe* with participants from Africa, Asia, America, and Europe. In November and December 2016, *icipe* was involved in follow-up sessions with stakeholders, in the development of draft standards for insect use for livestock and fish feed in Kenya and Uganda. Plans are underway to present these documents for public review and approval in 2017.

Dr Sunday Ekesi, *icipe* Director of Research and Partnerships, presenting the conference recommendations to the participants.

Capacity Building and Institutional Development

icipe is committed to ensuring gender equality in its capacity building activities. ▶

Donors: Australian Centre for International Agricultural Research (ACIAR) through Cultivate Africa's Future (CultiAF) research partnership; Danish International Development Agency (DANIDA); German Academic Exchange Service (DAAD); German Federal Ministry for Economic Cooperation and Development (BMZ); Government of Kenya; International Development Research Centre (IDRC); Swiss Agency for Development and Cooperation (SDC); Swedish International Development Cooperation Agency (Sida); UK Aid from the UK Government; National Institutes of Health (NIH), USA; Organization for Women in Science for the Developing World (OWSD); African Women in Agricultural Research and Development (AWARD); The World Federation of Scientists, Switzerland; Swiss National Science Foundation, Switzerland; McKnight Foundation, USA; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ); United States Agency for International Aid (USAID); Netherlands Organization for Scientific Research (NWO); European Union (EU); Grand Challenges, Canada; Ministry for Foreign Affairs of Finland; The World Academy of Sciences (TWAS)

Collaborating universities: University of Yaoundé I, Cameroon; Addis Ababa University, Ethiopia; Ambo University, Ethiopia; Jimma University, Ethiopia; University of Cape Coast, Ghana; Dedan Kimathi University of Technology, Kenya; Egerton University, Kenya; Jaramogi Oginda University of Science and Technology, Kenya; Jomo Kenyatta University of Agriculture and Technology, Kenya; Kenyatta University, Kenya; Mount Kenya University, Kenya Nairobi University, Kenya; University of Eldoret, Kenya; University of Ibadan, Nigeria; Dar es Salaam University; Tanzania; Sokoine University of Agriculture, Tanzania; North-West University, South Africa; Stellenbosch University, South Africa; University of Pretoria, South Africa; University of the Witwatersrand, South Africa; Kassel University, Germany; Leibniz Universität Hannover, Germany; University of Bonn, Germany; University of Hannover, Germany;University of Hoheinheim, Germany; University of Wuerzburg, Germany; Norwegian University of Life Sciences, Norway; Wageningen University, Netherlands; Liverpool School of Tropical Medicine, United Kingdom.

Postgraduate and postdoctoral training

icipe offers postgraduate training at masters and doctoral levels, through the African Regional Postgraduate Programme in Insect Science (ARPPIS) and the Dissertation Research Internship Programme (DRIP).

icipe also has a postdoctoral fellowship programme that enables doctoral graduates to undertake research at the Centre, towards developing their research skills and careers, and to allow them to create collaborative research programmes with scientists. In addition, *icipe* facilitates a range of training courses, from basic research, technology development and validation, to community-based adoption of new technologies and approaches.

Ongoing scholars

A total of 138 scholars were in progress in 2016.

PhD fellows: 34 ARPPIS and 34 DRIP;
MSc fellows: 58 DRIP;
Postdoctoral fellows: 12

Country diversity

17 African nations (Benin, Burkina Faso, Cameroon, Ivory Coast, DR Congo, Ethiopia, Ghana, Kenya, Nigeria, Rwanda, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe) and three non-African nations (Germany, The Netherlands, Oman) were represented in the postgraduate and postdoctoral programmes.

Gender equity

43% of all scholars in the postgraduate and postdoctoral programmes in 2016 were women.

Publications

50 (33%) of the 150 peer-reviewed papers published or in press by *icipe* in 2016 were either rst-authored or co-authored by postgraduate and postdoctoral fellows.

Theses defence and graduations

36 (Nine ARPPIS PhD scholars, six DRIP PhD scholars and 21 DRIP MSc scholars), defended their theses or graduated in 2016.

Training and development courses

Each year *icipe* holds training courses, workshops and other training events for research students and scientists, research and development collaborators, farmers and extension workers, and other stakeholders.

Training covers a range of research and development activities, spanning the continuum from basic strategic research to technology development and validation, to community-based adoption of new technologies.

37 training courses and workshops were organised through *icipe* projects, CB&ID and partners.

2033 participants, including researchers, community workers, and entrepreneurs benefitted.

20 the number of African countries from which participants were drawn.

28,000 (58% of them women) farmers, pupils/students, and extension workers and other stakeholders were trained through the push–pull programme.

6 the number of African countries from which participants of the push–pull trainings were drawn.

The push–pull programme hosted two interns from the USA, Holly Enowski and Isaac (Rico) Mirti, under the World Food Prize Borlaug-Ruan Summer Internship Program (July–August 2016). During their tenure at *icipe*, Holly and Isaac conducted research within the push–pull integrated pest management technology programme.

Social Science and Impact Assessment Unit

Donors: Australian Centre for International Agricultural Research (ACIAR) & International Development Research Centre (IDRC) through the CultiAF programme; Biovision Foundation for Ecological Development, Switzerland; UK Aid from the UK Government; European Union; German Federal Ministry of Economic Cooperation and Development (BMZ). Partnership for Economic Policy (PEP); Swedish International Development Cooperation Agency; Swiss Agency for Development and Cooperation

Collaborators: Biocontrol Research Laboratories (BCRL), Bangalore, India; CIRAD, France; Egerton University, Kenya; Horticulture Research and Training Institute, Tanzania; Kenya Agricultural and Livestock Research Organisation (KALRO); Kenya Bureau of Standards; Kenya Plant Health Inspectorate Service (KEPHIS); Kenyatta University, Kenya; Mikocheni Agricultural Research Institute, Tanzania; Ministry of Agriculture, Food Security & Cooperative, Tanzania; Moi University, Kenya; Real IPM Ltd, Kenya; Sanergy Ltd., Kenya; Texas A&M University, USA; Citrus Research International, South Africa; University of Bonn (Center for Development Research (ZEF), and Medical Center), Germany; University of Nairobi, Kenya; World Vegetable Center (AVRDC).

The *icipe* Social Science and Impact Assessment (SSIA) Unit evaluates the Centre's impact towards enhancing food security while securing the health of communities and the environment. ▶

Benefits of an integrated *icipe* 4H interventions approach

Case study findings

Using a case study of Oromia Region, Ethiopia, *icipe* researchers assessed the economic benefits of using a holistic 4Hs (Human Health, Animal Health, Plant Health and Environmental Health) approach in the Centre's research and development activities. The findings are presented below.

On average, the implementation of just one *icipe* 4H intervention increases a household's net annual income by 49%, relative to a baseline scenario.

However, when all *icipe*'s 4H components are applied, household net annual income can go up by an additional 126%, compared to a single 4H intervention.

The advantages of multiple interventions are higher when assessed from a baseline scenario, with a 237% net income average increase observed.

The *icipe* interventions can also raise the price of farmland by as much as 100%, when just a single intervention is used.

Examples of ongoing *icipe* 4H interventions in Ethiopia (l–r): Malaria integrated vector management; increase in milk productiviity through tsetse control; enhanced maize yield through the push–pull technology; and production of honey through modern beekeeping technologies.

Push–pull impact assessments

Economic impacts of the push–pull technology in western Kenya

This study was conducted using a combination of economic surplus and econometric approaches, with the following findings:

The push–pull technology has the potential to lead to an additional total income (economic surplus) of US$ 60–139 million in western Kenya, under the current technology adoption level.

The adoption of push–pull technology has reduced the number of poor people by 1.4–3.1% under the current technology adoption level.

The key drivers for the adoption of the push–pull technology are information on the technology, quality of extension service, plot tenure, family size, cropping patterns, dairy animal ownership, and availability of complementary inputs (such as credit).

Impact of women empowerment on agricultural productivity in Kenya

For this study, the researchers constructed the Women Empowerment in Agricultural Index (WEAI) following the standard methodology developed by the United States Agency for International Development (USAID) and its partners, and explored the index's impact on agricultural productivity.

The findings showed that women's empowerment in agriculture has significantly increased maize yield in western Kenya.

For instance, an increase in women's empowerment against the WEAI by 1% led to a 27% increase in maize yield.

All 6 indicators of empowerment (i.e. leadership, production decisions, asset ownership, credit access, income decisions, and workload) have significant effect on maize yield.

However, the greatest yield effects are observed from improvements in production, income, and asset and credit indicators.

The effect of empowerment is significant on maize plots managed by women, but insignificant on maize plots managed by men, or by both spouses.

Gender and adoption of push–pull technology in Kenya

This study assessed the differences in adoption of the push–pull technology between plots managed by women, those managed by men, or plots jointly managed by men and women. It also evaluated how households combine push–pull technology with other sustainable intensification practices, including grain–legume intercropping, rotations, fertiliser, improved maize seeds, manure, and soil and water conservation measures.

Findings suggest that the push–pull technology is gender neutral, as there are no differences in its adoption between men and women. Furthermore, farmers using the push–pull technology could combine other agricultural inputs, such as fertiliser, improved maize seed, and manure. However, the results show that the technology is less likely to be practised in a plot where the farmers practice legume–maize intercropping and rotations. These results will be useful to the push–pull IPM as *icipe* continues to advance the technology.

Assessment of thrips IPM research

Potential economic benefits of research and outreach of IPM of western flower thrips

An economic benefits assessments of *icipe*'s research and outreach for integrated pest management (IPM) of western flower thrips in Kenya was conducted.

The findings estimated the net present value of the thrips IPM research and outreach at US$2.2 million, implying that the project would be profitable and improve income distribution.

The internal rate of return (IRR) was estimated at 23% with a benefit–cost ratio (BCR) of 1:2.46, suggesting that returns on investing in the IPM technology would more than double compared to most private-sector investments whose rates of return range between 8–10%.

These results show that, potentially, the benefits of the project could exceed the investment costs.

New collaborations

The *icipe* Social Science and Impact Assessment (SSIA) Unit has established a number of new partnerships. In December 2016, SSIA started collaborating with the Partnership for Economic Policy (PEP). As a result, SSIA was awarded two research and capacity building fellowships through the Structural Transformation of African Agriculture and Rural Spaces (STAARS) project. Further, the Unit established linkages with Harvard T.H. Chan School of Public Health, USA and Wageningen University and Research Centre (WUR), The Netherlands, to build the Unit's capacity to conduct randomised control trials. SSIA also collaborated with international institutions such as Cirad, France and University of Bonn Medical Centre, Germany, in resource mobilisation.

Annex I
2016 awards and recognitions

◀ Outstanding employee of the year: Elijah Asami (Mail Clerk).

2016 awards and recognitions

2016 *icipe* internal staff awards

Outstanding employee of the year: Elijah Asami (Mail Clerk), who oversees *icipe*'s mail room, was recognised for his distinction in ensuring efficient and effective management and movement of all the Centre's documentation and mail to local and international destinations.

Outstanding support staff of the year: Seth Kamidi Mulusa (Senior Accountant – Projects), was awarded for his commitment to delivering high quality financial reports that meet internal and external requirements as pertains to *icipe* staff, donors, collaborators and other relevant stakeholders.

Outstanding professional staff of the year 2016: Sunday Ekesi (at the time, Head, Plant Health, and Leader, Fruit fly IPM programme), was recognised for his exemplary scientific output, technology development, resource mobilisation, capacity building and leadership.

Outstanding publication of the year 2016: Villinger J., Mbaya M.K., Ouso D.O., Kipanga *P.N.*, Lutomiah J. and Masiga D.K. (2016) Arbovirus and insect-specific virus discovery in Kenya by novel six genera multiplex high-resolution melting analysis. *Molecular Ecology Resources*. This paper, authored by researchers working in the *icipe* Martin Lüscher Emerging Infectious Diseases Laboratory and collaborators, reported the development of an economical, high-throughput, nearly pan-arbovirus, low-cost detection assay, for the rapid surveillance, discovery and identification of arthropod borne viruses (arboviruses).

Outstanding partner of the year 2016: Rothamsted Research, UK, was recognised for longstanding partnership with *icipe*, which, among other outcomes, has led to the development of the highly innovative and successful push-pull technology, currently being used by over 130,000 farmers in Africa.

2016 Governing Council student awards

Best published paper category: The top award went to Rosaline Wanjiru Macharia (ARPPIS PhD), for her publication in *PLoS Neglected Tropical Diseases*, based on her discovery that different species of tsetse flies use the same set of genes to find their hosts. The second prize went to Matilda Wangeci Gikonyo (DRIP MSc), for a paper on the common blossom thrips, *Frankliniella schultzei* Trybom, a pest that affects a huge variety of crops in many African countries. Mercy Mumbi Murigu (DRIP MSc) won the third prize for a paper on the effectiveness of fungal isolates developed by *icipe* against the *Rhipicephalus decoloratus* tick species.

Best poster category: Pamela Ochungo (ARPPIS PhD) won the top prize for her poster titled: Landscape setup and honey bee colony integrity: a case study of Mwingi, eastern Kenya. Beritah Mutune (DRIP MSc) was awarded the second prize for her poster: Fungal endophytes as promising tools for the management of bean stem maggot *Ophiomyia phaseoli* on beans. Nelly Ndungu (ARPPIS PhD) received the third prize for her poster titled Transcriptome comparison between newly emerged queen and worker bees of stingless bee, *Hypotrigona gribodoi.*

External awards

Bill Hansson (Vice Chair, *icipe* Governing Council and Jena Max Planck Director and Vice President of the Max Planck Society), received the International Ellis Island Medal of Honor, for his contributions to international scientific cooperation and as a global leader in neuroscience research. The Ellis Island Medals of Honor, which were established in 1986 by the National Ethnic Coalition of Organizations (NECO), are officially recognized by the United States Senate and House of Representatives; each year the recipients are listed in the Congressional Records.

Segenet Kelemu (Director General, *icipe*), was elected a Fellow of The World Academy of Sciences (TWAS) at the 26th General Meeting of TWAS held in Vienna, Austria, in recognition of her outstanding contribution to science and its promotion in the developing world. Dr Kelemu received an honorary doctorate from Tel Aviv University (TAU), Israel's largest and most comprehensive institution of higher learning, and one of the top 100 universities internationally. She was among five individuals from across the globe who received the distinguished award this year, which has over the past 50 years been conferred by TAU to remarkable figures in recognition of their professional and philanthropic contributions to society. Dr Kelemu also accepted an invitation from the United Nations Under Secretary General to serve as a member of the Governing Council of the United Nations University (UNU), an autonomous UN organisation that conducts research, postgraduate training and the dissemination of knowledge. Further, in April 2016, Dr. Kelemu was part of the eminent judging panel of the Rolex Awards for Enterprise, which honours individuals who have, or are, developing ground-breaking initiatives that have the potential to improve life on the planet. The Rolex Awards support inspiring individuals with innovative projects that advance human knowledge or well-being. The 2016 series of the Rolex Awards marked the 40th anniversary of this global philanthropic program that has given support to 130 pioneers working on highly original projects worldwide.

Dr Kelemu was also appointed a member of the National Science and Technology Council of Rwanda, the governing body of the country's National Commission of Science and Technology (NCST). The core mandateof NCST is to provide strategic advice to the Government of Rwanda on all matters pertaining to the development of science, technology, innovation and research as drivers for rapid national socio-economic transformation and growth, in line with the Rwanda Vision 2020. Dr Kelemu was also invited to speak at the Women's Forum Mauritius, held between 20 – 21 June 2016 under the patronage of Her Excellency Dr Ameenah Gurib-Fakim, President of Mauritius. The programme for the Women's Forum Mauritius, a direct follow-up of COP-21, focuses on climate change and health, energy, agriculture and biodiversity, as well as frugal green innovation, for Africa and for small island developing states.

Sunday Ekesi (at the time Head, Plant Health Theme and Leader, Africa Fruit Fly Programme, and currently Director of Research and Partnerships), gave a plenary keynote at the 3rd International Symposium of the Tephritid Workers of Europe, Africa and the Middle East (TEAM), on Fruit Fly Research and Development for Subsistence, Small and Large Scale Commercial Fruit Production in Africa.

Baldwyn Torto (Head, *icipe* Behavioural and Chemical Ecology Unit), was appointed to the Editorial Board, and as an ambassador of *Pest Management Science* journal. Prof. Torto was also invited by the Editor-in-Chief of the prestigious and leading American Chemical Society journal, to join the Editorial Advisory Board of the *Journal of Agricultural and Food Chemistry,* for a two-year term commencing January 2017.

In July 2016, Prof. Torto was among 10 new Fellows elected by the Governing Board of the Entomological Society of America (ESA) in 2016. He was also selected to serve as a member of the African Academy of Sciences (AAS) Commission on Sciences Education, one of four commissions established by AAS to build capacity and set the agenda for science in Africa.

In addition, Prof. Torto was a review panelist of the African Union Commission, Kwame Nkrumah Awards Program Rules of Procedure, 5 – 6 December 2016. He was appointed Extraordinary Professor, by the University of Pretoria, South Africa. He also became a Member, Board of Trustees, JRS Biodiversity Foundation, an independent grantmaking foundation based in Seattle, Washington, USA, which aims to increase the access to and use of biodiversity information in sub-Saharan Africa.

In April 2016, Prof. Torto was one of the speakers at the Biovision World Life Science Forum, in the Medicine and Humanities Plenary Session, held in Lyon, France. Further, Prof Torto was a keynote speaker at the Chemical Symposium, held at the University of Pretoria, South Africa, between 31 October and 2 November 2016. Dr Torto was also a keynote speaker at the 13th Arbovirus Surveillance and Mosquito Control Workshop in Florida, USA.

Subramanian Sevgan (Senior Scientist, Plant Health Theme), was nominated as a member of the Editorial Board of Springerplus journals.

Robert Jackson (Professor, University of Canterbury, New Zealand and Visiting Scientist, *icipe*) was honoured in Festschrift (a collection of writings celebrating the accomplishments of a scholar) published by *the New Zealand Journal of Zoology*.

Clifford Mutero (Integrated Vector Management for Malaria programme) and colleagues won the Best Overall Publication, in the Qualitative/ Education/ Health Systems Research category from the University of Pretoria, Faculty of Health Sciences

2016 awards and recognitions

for their paper: Mutero C.M., Kramer R.A., Paul C., Lesser A., Miranda M.L., Mboera L.E.G., Kiptui R., Kabatereine N. and Ameneshewa B. (2014) Factors influencing malaria control policy - making in Kenya, Uganda and Tanzania. *Malaria Journal*, 13:305

Tobias Landmann (Head, Geo-Information Unit), gave a talk on land cover harmonisation issues and efforts in Africa at the Group of Earth Observation (GEO) Global Earth Observation System of Systems (GEOSS) Africa (AfriGEOSS) Symposium in Zimbabwe in April 2016.

Amanuel Tamiru (Push-pull Programme), received an Early Career Scientist (ECS) award from the CGIAR Independent Science and Partnership Council (ISPC) to participate in the ISPC Science Forum held in April 2016, under the banner: Agricultural research for rural prosperity: rethinking the pathways.

Beatrice Muriithi (Postdoctoral Fellow, Social Science and Impact Assessments Unit), was selected to participate in a special research and capacity building fellowship with particular focus on gender issue in the Structural Transformation of African Agriculture and Rural Spaces (STAARS) initiative offered by the Partnership for Economic Policy (PEP).

Damaris Matoke, a postdoctoral fellow in the Martin Lüscher Emerging Infectious Diseases Laboratory, conducting research on the environmental determinants of sand fly and leishmaniasis distribution, was named best presenter (biotechnology category) during a conference convened by the Kenya Medical Research Institute.

George Obiero (former DAAD ARPPIS scholar and currently Lecturer, Technical University, Kenya), was awarded an Alexander von Humboldt (AVH) Georg Forster Research Fellowship.

Xavier Cheseto (former ARPPIS scholar), was offered a Rothamsted International Fellowship Award to conduct research on the enantioselective synthesis of plant-based semiochemical kairomones of tropical insect disease vectors at Rothamsted Research, UK.

Rosaline Macharia (former DAAD PhD scholar, Molecular Biology and Bioinformatics Unit), received the best oral presentation during the Young Investigators conference convened by the Kenya Medical Research Institute in February 2016.

Richard Kyalo (DRIP PhD scholar), et al., presented a paper titled: Mapping maize lethal necrosis severity in Kenya using multi- spectral high to moderate resolution satellite imagery, to map the severity of maize lethal necrosis (MLN) in Kenya, which was selected as the most innovative out of more than 1500 oral paper presentations made at the 2016 European Space Agency (ESA) Living Planet Symposium held on 9 – 13 May 2016, in Praque, Czech Republic.

Annette Busula (DRIP PhD), was awarded a GBP400 prize for the best student presentation at the British Society of Parasitology Spring Meeting, Imperial College London, from 11 – 13 Apr 2016.

Peter Njenga (DRIP MSc), received a DAAD scholarship to undertake PhD studies at the University of Freiburg in Germany, in Prof. K. Aktories's group at the Institute of Toxicology and Pharmacology.

Sheila Agha (ARPPIS PhD), received a travel grant by the Swedish International Development Cooperation Agency (Sida) to participate in the Development Research Conference in Stockholm, Sweden, from 22 – 24 August 2016.

Yvan Ritter (ARPPIS PhD), received a travel grant from Feed the Future Sustainable Intensification Innovation Lab, African Soil Information Service and CIAT, to participate in a training workshop on Spatial Data Analysis and Modeling for Agricultural Development, held in Arusha, Tanzania (14 – 20 August 2016).

Vincent Nyasembe (ARPPIS PhD), received a travel award from the International Society of Chemical Ecology Meeting to attend its meeting in Igauazo, Brazil from 4–8 July 2016.

Teresiah Njihia (ARPPIS PhD), won the first prize (a book prize of USD 150) in the oral presentations category at the 16th Horticultural Association of Kenya workshop held from 28 November – 2 December 2016.

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icipe
African Insect Science for Food and Health

Annual Report 2016

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* is mandated to conduct research and develop methods for pest control that are effective, selective, non-polluting, non-resistance inducing, and affordable to resource-limited rural and urban communities. *icipe*'s mandate further extends to the conservation and utilisation of Africa's rich insect biodiversity.

icipe focuses on sustainable development, including human health, as the basis for development, and the environment, as the foundation for sustainability. Working through a holistic and integrated approach through the 4H paradigm – Human, Animal, Plant and Environmental Health – *icipe* aims at improving the overall well-being of communities in tropical Africa by addressing the interlinked problems of poverty, poor health, low agricultural productivity, and degradation of the environment.

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