ISSN 2309-3838

Annual Report 2014

African Insect Science for Food and Health

icipe

Native African stingless bees present a great opportunity for honey production and crop pollination, without the risk of being stung. *icipe* is researching ways for the successful domestication of these valuable resources.

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African Insect Science for Food and Health

International Centre of Insect Physiology and Ecology (*icipe*)

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May 2015

ISSN 2309-3838

ISBN 978-9966-063-07-6

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May 2015

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Cover photo: The overall goal of *icipe*'s research is to improve the livelihoods of communities in Africa. This picture shows a happy mother and daughter, beneficiaries of the centre's integrated vector management for malaria project in Mwea, Kenya. *Photo: icipe.*

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Foreword

Prof. Dr Bill S. Hansson
Chairman of the Governing Council of *icipe*

Message from the Chair, *icipe* Governing Council

When he founded *icipe* over 40 years ago, Prof. Thomas Risley Odhiambo presented a series of compelling arguments for the Centre, including the urgent need for scientific research, to develop environmentally safe strategies to increase agricultural production, and to address prevalent tropical and vector-borne diseases in Africa.

He also noted that the then postcolonial continent had minimal human, financial and infrastructural capacity to effectively tackle the challenges at hand. Prof. Odhiambo, therefore, proposed that Africa's best long term solution towards conducting effective research was to concentrate efforts in a few centres of excellence. This proposal led to the establishment of the International Centre of Insect Physiology and Ecology (*icipe*).

As the Centre entered its fourth leadership at the end of 2013, with the appointment of Dr Segenet Kelemu as Director General, Prof. Odhiambo's message is as compelling as it was when he articulated it. The pressure to increase agricultural production continues, enhanced by issues such as population growth, urbanisation, climate change, diminishing land and water resources, over- and under-nutrition and persistent poverty. Diseases such as malaria and trypanosomiasis are still a huge burden, while others, such as yellow fever, Rift Valley fever and dengue, are re-emerging.

As a result, scientific research is being called upon even more, to provide ways to cope with these challenges. And yet, inadequate scientific capacity and limited infrastructure, including laboratories and other brick-and-mortar facilities that are critical for conducting effective research, persist in Africa.

As demonstrated in this report, *icipe*'s evolution as a centre of excellence has remained true to the vision of its founder while staying alive to emerging issues. The steps taken in 2014 are grounded in the *icipe* 2013 – 2020 Vision Strategy. They are also guided by the Centre's new leadership, whose goal is to secure and enhance *icipe*'s great legacy. In the past one year, *icipe* has re-demonstrated its commitment to high-quality, community-focused scientific research.

The Centre has also placed much emphasis on building its human, financial and infrastructural resources. By end of 2014, the Centre had a staff of 370, majority of them from Africa, alongside collaborations that bring together researchers and partners from over 200 regional and international institutions. *icipe's* expenditure stood at USD 35 M, a figure that is expected to rise to USD 41.5 M in 2015. The accomplishments in 2014 show *icipe*'s increased ability to innovate, contribute to scientific leadership in Africa and augment the global knowledge hub.

Preface

Dr Segenet Kelemu
Director General, *icipe*

Message from the *icipe* Director General

This annual report presents *icipe*'s achievements in 2014, which was also my first year as the Director General of the Centre. It has been my honour to head such a unique institution, one that conducts world-class research while still remaining grounded in its mandate of science-led sustainable development in Africa.

This publication is organised around five sections. The first, **New Leadership**, is a personal reflection, highlighting my overall approach to the leadership of *icipe*, the management changes that we have implemented so far, key resource mobilisation outcomes, advances in collaborations and partnerships and a brief overview of the Centre's immediate plans. In addition to activities related directly to research, the Centre will embark on a 'greening' initiative, aimed at minimising the carbon footprint by generating renewable energy, and through innovative strategies to harvest and use water.

The second section is titled **Research Excellence**, and as the heading suggests, it underscores *icipe*'s continued commitment to outstanding science, technology and innovation, in accordance to its distinctive mission. We demonstrate this distinction around three outcomes: the Centre's increased numbers of peer-reviewed articles; advances across its range of Themes and projects, and global recognition of our scientists.

In the third section, **Infrastructure Upgrade**, we focus on two key developments at *icipe*: The newly inaugurated African Reference Laboratory for Bee Health, and the acquisition of a variety of cutting-edge chemistry instrumentation. We discuss the Centre's motivation for upgrading its infrastructure, the implications of these upgrades on *icipe*'s own ability to innovate and overall, on Africa's research ecosystem.

Under the fourth section, **New Research Directions**, the report outlines the evolution of the *icipe* research portfolio in the past one year, driven by the Centre's mission of responding to emerging challenges in new, innovative ways. Primarily, this section highlights studies being conducted around the 'insects for food and feed' topic, which has captured the imagination of the global scientific community, donors and general public, as a viable way of meeting the growing demand for animal protein without significant increase in greenhouse gas production. The section also features *icipe's* novel research on the development of insect endosymbiont-based strategies for the control of vector-borne diseases in Africa.

The fifth and final section, **Research Impact**, discusses some significant successes of *icipe* technologies and strategies in changing the lives of communities using them across Africa. They include the push–pull technology, the African fruit fly integrated pest management packages and a variety of biopesticides.

As these five sections illustrate, 2014 was a year of tremendous growth for *icipe*. We are aware of two things: That the achievements discussed in this report would not have been possible without the commitment of the Centre's various teams, donors and collaborators; and that our journey has, in many ways only just begun. With your support, we will continue to forge forward.

New Leadership

Muhaka icipe, a new, enigmatic wasp genus and species hitherto unknown to science, discovered as part of inventory surveys of Kenyan insects conducted by *icipe* and collaborators in the coastal forests of eastern Africa.

Dr Segenet Kelemu's First Year as *icipe* Director General

On 1 November 2013, ***Dr Segenet Kelemu*** *became the fourth Director General of icipe. In the interview below, she discusses her vision for the Centre, and the progress made towards this goal during her first year in office.*

Q. What has been your overall approach to the leadership of *icipe*?

A. From the onset, I found *icipe* to be an institution that has a well-defined mission, with clear strengths focussed on conducting world class, yet impact oriented science. Through this unique mandate, *icipe* not only contributes to, but also takes advantage of advances in global science, to address the urgent developmental challenges faced by communities in Africa in a sustainable manner. Central to this mission is the building of the continent's indigenous capacity and leadership to produce and use science.

My goal has been to build on the structures laid by my predecessors, to ensure that *icipe*'s great legacy is secured and enhanced. Towards this vision, I have endeavoured to understand and assess the situation at the Centre, in order to make the necessary adjustments aimed at developing appropriate governance systems. The intention is to improve day-to-day operations, underpinned by a culture of transparency, equity and accountability that also allows the flexibility required for scientific innovation. A further aspiration is to strengthen the Centre's human, financial and infrastructural resource base, while ensuring that both are used as efficiently as possible. Overall, we hope to put in place systems that foster, promote and reward scientific excellence, and those that will allow the Centre to quantify its impact.

Dr Segenet Kelemu
Director General, *icipe*

To obtain an in depth understanding of *icipe* – from its research and development (R&D) activities, through to finance, administration and management operations – I have undertaken intensive consultations with staff teams at various levels at the *icipe* headquarters in Duduville, at the Thomas Risley Odhiambo (TRO) Campus, Mbita, and in the Ethiopia country office. I have also consulted many of the Centre's key partners and stakeholders. Our activities are guided by the *icipe* 2013 – 2020 *Vision and Strategy* document, the Centre's long-term blueprint, which we completed in 2014. We have also kept in mind the recommendations made in the *icipe*'s 2008 – 2012 *External Review.* In addition, the detailed progress reports that we prepare twice a year for *icipe*'s Governing Council not only allow us to reflect internally on existing and emerging issues at the Centre, but also facilitate feedback from them.

Q. In regard to leadership, what changes have been implemented so far at *icipe*?

A. We have embarked on a process of strategic recruitment to strengthen our existing team that will, in the short term, fill skills and capacity gaps, and in the long term, enable the Centre to put in place a succession plan. This approach will ensure that the Centre has the capabilities it requires to achieve its goals now and into the future.

In accordance, some key changes have been made in the senior leadership team, starting with the creation of a new role of Director of Research and Partnerships (DRP), and the appointment of Dr Chris Prideaux in this position.

The European Union continues to be a key funder of *icipe*, including providing support for the validation and upscaling of the Centre's tsetse control technologies. In this picture, Ambassador Lodewijk Briët, Head of EU's Delegation in Kenya, observes a cow wearing a tsetse repellent collar, during a visit to one of the beneficiary farmers, in Shimba Hills, coastal Kenya.

In addition, the Centre has a new head of capacity building, Dr Robert Skilton, while Mr Gatigwa Kimana has been appointed the new Director of Finance and Administration. The three appointees bring with them extensive experience, which will no doubt reinforce *icipe*'s path to a successful future.

Q. What have been the key resource mobilisation outcomes?

A. The overall approach has been to nurture relationships with *icipe*'s existing donors, while forging partnerships with new ones. As a result, the Centre has strengthened its financial resource base, and it is budgeting a total income of approximately USD41.5M for 2015, up from USD39M in 2014. These figures are based in part, on continued support from the *icipe*'s core donors, including: Aid for Africa, the Government of France (in-kind support), the Government of Kenya, the Swedish International Development Cooperation Agency (Sida), the Swiss Agency for Development and Cooperation (SDC) and UK Aid, and attributed funding from the German Federal Enterprise for International Cooperation (GIZ) on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). *icipe* has also continued to receive significant funding for its restricted R&D and capacity building activities from diverse donors, with a comprehensive list provided on http://www.icipe.org/index.php/index.php?option=com_content&view=article&id=23&Itemid=37. Below, I highlight a few examples of restricted funding and aligned projects, in 2014. Later in this report (**New Research Directions**, page 18 – 23), we note new funding that has helped *icipe* to start novel research on Insects for Food and Feed, and on insect endosymbiont-based strategies in Africa.

The European Union continues to be a key partner, and in December 2014 it confirmed a Euro 12M grant to *icipe* through the Integrated Biological Control Applied Research Programme (IBCARP). Four projects will be implemented, including the targeted dissemination of the *icipe*'s climate resilient push–pull, a technology that simultaneously addresses the key constraints of cereal production, which are the parasitic striga weed, stemborers and poor soil fertility. The Centre's proven integrated pest management (IPM) strategies for fruit flies will also be upscaled. Working with the private sector, *icipe* will enhance mass production and rollout of its innovative tsetse repellent collar technology. In addition, *icipe* will initiate research with the aim of developing low cost, low environmental impact control technologies for camel diseases, in particular surra.

icipe maintains a strong partnership with Biovision Foundation, Switzerland, with funding currently amounting to an approximate USD2M per year being used for disseminating knowledge, activities on integrated vector management (IVM) for mosquito and malaria, and in strengthening commercial insects activities. In 2014, BMZ, a long term project partner of the Centre, provided Euro 1.2M to *icipe* and partners in Kenya, Tanzania, South Africa, Germany and USA, to address the significant insect pests and diseases constraining the production of citrus fruits in Kenya and Tanzania. Titled, Strengthening Citrus Production Systems through the Introduction of IPM Measures for Pests and Diseases in Kenya and Tanzania (SCIPM), it will be implemented in collaboration with smallholder citrus farmers, and private sector stakeholders.

icipe was also awarded USD2.4M, through a three-year project supported by Enhanced Integrated Framework Trust Fund (EIF TF, through the United Nations Office for Project Services – UNOPS). This funding will be used to develop strategies for reducing the incidence of bee diseases and pests, to increase honey production, improve crop yields through better pollination services, and harmonise procedures and legislation relating to bee health in four island nations in Africa: Madagascar, Rodrigues, Seychelles and Zanzibar.

In 2014, *icipe* also acquired 11 other new major project-specific donors, including: The Australian Centre for International Agricultural Research (ACIAR); Austraining International; Food & Business Global Challenges Programme; Geigy Foundation; National Institutes of Health, USA; Stiftung Foundation; Swiss National Science Foundation; Wellcome Trust; and Volkswagen Technology Strategy Board (now called Innovate UK).

Q. How has *icipe* advanced on collaborations and partnerships?

A. Strategic partnerships have always been a key foundation of *icipe*'s success, as they augment the impact of the Centre's work, from project conception, research process, through to commercialisation and adoption.

In the context of research, in the past year, *icipe* has recommitted itself to a number of existing partnerships. For instance, the Centre has signed new collaborative agreements with two French institutions with which it has had a longstanding partnership: the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) and the Institut de Recherche pour le Développement (IRD). The new arrangements aim to broaden the relationship, to create better skills synergies and linkages with *icipe* programmes and to integrate the scientists from the two institutions into the Centre's research activities more effectively.

icipe has also extended its MoU with Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya, and signed a set of others covering a broad range of activities with new collaborators, including Gollis University, Somaliland and the Institut National de Recherché Biomédicale (INRB), Kinshasa, Democratic Republic of Congo. In December 2014, *icipe* signed an MoU with the Alexander von Humboldt (AvH) Foundation, Germany, which sets out collaborative arrangements in promoting scientific excellence, academia and capacity building to boost Africa's development and strengthen the AvH network in Africa.

In commercialisation, currently, the Centre's most prominent public–private agreement is with Real IPM Ltd, a Kenyan-based company that has taken on the task of introducing several *icipe* biopesticides into markets across Africa. In accordance, in 2014, Real IPM Ltd completed the registration of ICIPE 62, a biopesticide for the control of aphids on vegetables.

Real IPM Ltd has plans to commercialise *icipe* biopesticides in Asia, Europe and North America. Other partners are also expected on board to increase the reach of *icipe* biopesticides, and for this purpose, the Centre has prepared a set of selection criteria to help identify partners that are best placed to ensure

Through its partnership with CIRAD, *icipe* has expanded its research portfolio to include management of coffee pests and diseases in the agroforestry systems of eastern Africa. Here, Dr Regis Babin, a CIRAD scientist, is pictured with Mr Dickson Mwenda, an *icipe* technician, attending to experiments on this research in the Centre's labs.

the impact of *icipe* technologies. In October 2014, *icipe* signed an MoU with Kenya Biologics Ltd, to establish a facility for the production of *icipe*'s fruit fly bait.

icipe has also commenced patenting processes that will secure its innovations. For instance, in November 2014, Wageningen University (WU), filed a patent titled Insect Repellent Composition and Methods of Use, on behalf of partners collaborating in the SolarMal project. The patent application is currently in the provisional phase and it will proceed to examination in late 2015.

In collaboration with WU, Vanderbilt University and Yale University, *icipe* is currently preparing a provisional patent to cover its 'Aggregation Pheromone of Bean Flower Thrips'. Two patents on insect attractants and repellents, and one on antimicrobial agents, are also currently in progress.

Q. What progress has *icipe* made to enhance its visibility among key stakeholders?

A. In 2014, *icipe* created a Communications Unit, and as a result press coverage has been enhanced, with an approximate 130 reports featuring almost all of the Centre's projects in traditional local and international media, and on social media. One of *icipe'*s key publicity events was the official launch of the African Reference Laboratory for Bee Health by His Excellency William Ruto, Deputy President of the Republic of Kenya, on 3 November 2014, which attracted over 50 local and international media reports.

The Centre also increased its visibility through project launches, and a number of new communications tools, including revamped internal and external newsletters, were introduced. An overhaul of the *icipe* website is currently ongoing, and once complete, it will provide a synergised, interactive, multimedia tool between the Centre and its various audiences.

Q. How would you describe your reception as *icipe* DG by key stakeholders?

A. I have found the reception from various stakeholders welcoming and supportive. As an example, during my first year as DG of *icipe*, I was invited to speak in high profile events across the world on diverse issues around science, technology and innovation, food security and health.

I delivered keynote presentations at: insect forum, organised by Stockholm Environment Institute; the CGIAR Independent Science & Partnership Council (ISPC) 10th and 11th meetings; The Africa Day, co-organised by the Italian Ministry of Foreign Affairs, and TWAS, The World Academy of Sciences; and at the official opening of the Insects to Feed the World conference. I was also invited to speak at the European Commission, Food Security Session; at the International Conference on Research Infrastructures; and at the Swedish Society of Parliamentarians & Scientists (RIFO) seminar.

In addition, I have been invited to join a number of science and technology advancement processes. I have also been appointed the Deputy Chair of the Association of International Research and Development Centers for Agriculture (AIRCA), in which *icipe* is a member. In 2014, I served on several international science award juries, including that of the L'Oreal–UNESCO Regional Fellowships for Women in Science in sub-Saharan Africa.

These activities are an endorsement, and an indication of the respect accorded to *icipe* and its leadership by key communities around the world. They also provide great platforms to articulate the Centre's vision, showcase its achievements and, overall, advance its mission.

Q. How has being the DG of *icipe* merged with your own vision as a scientist and a scientific leader?

A. Having grown up in a remote village in Ethiopia, I know only too well the problems faced by rural communities. I grew up undertaking tasks such as weeding, picking coffee berries, collecting firewood and fetching water. I am aware that many people, especially women, continue to undertake these backbreaking, endless chores on a daily basis. My dream has always been to be able to contribute towards lessening this burden, and my career as a scientist has made me clearly aware of the dramatic changes that focused agricultural research can have on the lives of people. Being at the helm of *icipe* is therefore an important opportunity, as it enables me to continue my contribution towards the development and dissemination of technologies and strategies that have a real impact on the livelihoods of communities in Africa. Some of the Centre's major outcomes that have contributed to income generation, employment opportunities, addressing food security needs, improving access to education and health care, and most importantly, providing women with economic empowerment are demonstrated later in this report (**Research Impact**, page 31). They include the Centre's push–pull technology (which addresses the major constraints of cereal production in Africa), its various integrated pest management projects (which alleviate the hindrances in horticultural farming), and its commercial insects programme (which helps develop community-based silk and bee industries in marginalised areas).

Q. What are some of the Centre's plans for the future?

A. While we are proud of the distance we covered in 2014, we are profoundly aware that, in many cases, our journey has only just begun.

In 2015, one of *icipe*'s main focus will be a review, through a consultative process between the management and the staff, of the scientific reporting structure, to simplify and clarify it around three Themes: Environmental Health; Human and Animal Health; and Plant Health, and alongside them a series of support units. The aim is to increase accountability, and as a result empower leaders at all levels of the research chain. In accordance, we have commenced the recruitment of various science leaders, including the appointment of a head of the human and animal health theme.

In close linkage to this restructuring, *icipe* has commenced a review of its malaria research, the main focus of which is the development of integrated vector management tools beyond the traditional insecticide-based approaches. The Centre's goal is to develop a comprehensive and innovative framework that will integrate its research with efforts to manage other diseases on national and global levels. A further intention is to reorient *icipe*'s malaria research collaborations, with the aim of illuminating issues around project leadership and the quality of the knowledge being produced.

icipe researchers collecting samples which led to the identification of a naturally-occurring chemical that attracts pregnant malaria-transmitting mosquitoes. To boost malaria research, the Centre intends to consolidate all its activities in this area.

Currently, *icipe* has a small social science group that is providing project-level support for monitoring and evaluation (M&E). In 2015, the expansion of our Social Science Unit, which will enhance a Centre-wide, strategic M&E encompassing impact assessment and gender related components, is a priority. Towards this goal, *icipe* is currently recruiting additional staff to strengthen the social science team. These appointments will be supplemented through the appointment of social scientists within restricted projects.

In R&D, *icipe* will, in 2015, endeavour to respond to several requests to expand its push–pull technology to a number of countries in Africa. In addition, the Ethiopian government, through the country's food security initiative and poverty alleviation programme, has made a commitment to have at least 20,000 Ethiopian farmers using push–pull technology during 2015 alone. *icipe* will support this goal through training of trainers programmes (ToT), technical backstopping and display sites. *icipe* will also address the lack of sufficient desmodium seed, a key constraint to large-scale rollout of push–pull technology.

A major refurbishment to bring the Duduville R&D complex to modern laboratory standards will start in July 2015, planned for completion during the second quarter of 2016. The Centre's Muhaka and Nguruman field stations will also be upgraded, to renovate existing facilities and buildings, improve security, and in the case of Muhaka, to construct animal handling facilities to support tsetse fly research.

Finally, a 'greening of *icipe'* initiative to minimise the Centre's carbon footprint through reduced reliance on Kenya Power, the national electricity provider, by generating renewable energy using solar panels, is ongoing and will be completed in the third quarter of 2016. We are also initiating a water conservation programme, through rainwater capture, installing cooling systems and the use of water efficient equipment.

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

Research Excellence

Ms Rhoda Abong'o, an *icipe* push–pull farmer from western Kenya, pictured in her field of healthy maize.

Conducting World-Class, Impact-Oriented Research in Africa

In the past one year, the pursuit of scientific excellence has remained at the core of icipe*'s research activities, demonstrated through three key outcomes: a growing rate of peer-reviewed publications; a variety of advances across the Centre's range of Themes and projects, and increasing global recognition of its scientists.*

Research Publications

Between January and December 2014, *icipe* scientists, scholars and partners, published 136 peer-reviewed articles, a record for the Centre. This is indeed a significant achievement, and while it is difficult to choose a favourite amongst the many, two publications do stand out.

The first example is a publication titled *Plasmodium falciparum* infection increases *Anopheles gambiae* attraction to nectar sources and sugar uptake, which was published in the high impact *Current Biology* journal, and highlighted in *Nature* journal under the title Parasite drives host to nectar. This paper, which resulted from *icipe*'s chemical ecology malaria research, provides further knowledge on how *Plasmodium*, the malaria parasite, manipulates the behaviour of *A. gambiae*, its transmitting mosquito. The importance of this publication is further underscored by its recognition by the Centre's governing council, which awarded it the prize for the best published science paper by an *icipe* scholar.

The second example is based on the successful completion in April 2014, of the mapping of the genome of *Glossina morsitans morsitans* tsetse species. This milestone was achieved through a 10-year project led by the International Glossina Genome Initiative (IGGI), which brought together more than 150 researchers from nearly 100 institutions across the world. *icipe* was instrumental in the description of the sensory genes, which, in this and other tsetse species, are responsible for guiding interactions between the flies and their environment. Tsetse flies transmit the deadly African trypanosomiasis (known as sleeping sickness in humans, and nagana in livestock), causing devastating losses in sub-Saharan Africa. It is anticipated that the knowledge on the genome of *G. morsitans morsitans* will contribute towards developing tools for the control of tsetse flies and the diseases they transmit. Key global recognitions of this research include its publication in the prestigious *Science* journal (prominently featured on the cover page of the 25 April 2014 issue), and in several satellite papers in the *PLoS* family of journals.

As part of the the International Glossina Genome Initiative (IGGI), *icipe* contributed significantly to the mapping of the genome of *Glossina morsitans morsitans* tsetse species, and to the global quest for strategies to combat these deadly insects. The Centre also enhanced its capacity building objectives including doctoral training, for instance that of Ms Rosaline Macharia, who is pictured here making a presentation on this research at the ISCB-Africa ASBCB conference on infectious diseases relevant to Africa.

Research Advances

Plant Health

The Centre continued to expand its phenomenally successful push–pull technology, including enabling more farmers in the drier regions to adopt the climate-smart version, which uses drought-tolerant companion plants.

icipe made significant progress in its research on the Napier Stunt Disease (NSD) that has in recent decades constrained the production of Napier grass, the most important fodder in East Africa and a key component of the Centre's push–pull technology. In March 2014, *icipe* and collaborators released NSD resistant Napier varieties to farmers in western Kenya. They also started the field validation of diagnostic tests for the disease and its vectors, which are currently ongoing.

The Centre's researchers working on thrips commenced studies on Maize Lethal Necrosis Disease (MLND), a serious new disease that appeared in farmers' fields in eastern Africa in 2011. The scientists reported, for the first time, that lethal necrosis also occurs in finger millet. Globally, it is known that the maize chlorotic mottle virus (MCMV), one of the component viruses of the disease, is transmitted by corn thrips *(Frankliniella williamsi)*. *icipe* researchers generated new information, which revealed onion thrips *(Thrips tabaci),* sap beetles and curculionid weevils as alternative vectors of MCMV. Based on this knowledge, the scientists are currently evaluating management strategies for thrips vectors using *icipe* biopesticides.

The Institut de Recherche pour le Développement (IRD) team based at *icipe* advanced its research to understand and predict changes in the geographical distribution and dynamics of cereal stemborers and their natural enemies. In East Africa, yield losses in maize due to stemborer infestation is currently estimated to be 12-50% of the total production, depending on the pest species, region, maize variety, cropping pattern and soil fertility level. Moreover, global warming and climate change are expected to have significant consequences on the abundance of stemborers, with serious impact on cereal crop production, and therefore food security in the region. The IRD–*icipe* studies are intended to generate integrated pest management strategies of stemborers, to mitigate these adverse effects.

The reputation of *icipe*'s African Fruit Fly Programme (AFFP) in supporting the horticultural industry from the fruit fly menace has continued to expand. In 2014, *icipe* received requests for assistance from the governments of Kenya, Benin, Botswana, Cameroon, Côte d'Ivoire, Democratic Republic of Congo, Lesotho, Mali, Mauritius, Mozambique, Namibia, Niger, Tanzania, Senegal, Sudan, Zimbabwe, Swaziland, South Africa and Zambia. *icipe* responded to many of these requests, for instance by organising training of trainers (ToT) workshops, thereby enabling thousands of farmers and other stakeholders across the horticultural value chain, to use various combinations of the Centre's fruit fly IPM technologies. The researchers also trained key government representatives on aspects of fruit fly identification, monitoring and management. Another major accomplishment of AFFP was the development of postharvest disinfestation parameters for *Bactrocera dorsalis* on avocado, citrus and mango, to allow their export to quarantine-sensitive markets. Since 2008, this pest has caused losses amounting to millions of dollars in Africa, due to quarantine restrictions placed on it in export markets. *icipe*'s research provided phytosanitary security information, which is being used by fruit growers and exporters, enabling them to access the lucrative, quarantine-sensitive markets abroad.

icipe researchers have also progressed studies on *Tuta absoluta,* an extremely harmful leaf mining moth with a strong preference for tomato, but which also attacks other crops such as eggplant, sweet pepper, potato and wild

plants. So far, they have completed an assessment of the pest's abundance, distribution and range of host plants. The scientists found the pest to be well established in all tomato growing regions of Tunisia and Sudan, noting that in the latter country, it also attacks several other cultivated and wild plants. The studies also led to first time detections of *T. absoluta* in Kenya and South Sudan. Using CLIMEX modelling, the researchers projected regions at high risk of the pest to be: central, eastern and western Africa; most of Asia; the Mediterranean basin and the western states of America. The scientists also recovered 10 parasitoid species that attack *T. absoluta* in Peru, and they are now evaluating the performance of one of them, *Dolichogenidea gelechiidivoris,* in the biological control of the pest. In addition, *icipe* is working towards developing a new attract-and-kill product.

Based on surveillance studies of *Tuta absoluta* across Africa, *icipe* is now working on strategies to control this pest which causes extensive damage to tomatoes. Here, Faustine Muga, a technician at the Centre is pictured harvesting *T. absoluta* larvae from tomato plants, to enable the researchers conduct the necessary studies.

Human and Animal Health

In 2014, *icipe* and the Kenya Medical Research Institute (KEMRI), conducted a comprehensive assessment of their experiences implementing integrated vector management (IVM), for malaria in Kenya, with the aim of sharing lessons that might promote its wider application in Africa. The IVM strategy is recommended by the World Health Organization (WHO), as the most ideal way of improving and sustaining the control of malaria and its vectors, mosquitoes. The approach is based on the concern that although there has been considerable progress towards eliminating malaria in Africa, the interventions that have led to this success are not sustainable. IVM recommends the use of chemical as well as non-chemical methods, which should then be integrated into a country's healthcare system. However, the adoption of this approach in Africa is still very low. The *icipe*–KEMRI study examined two IVM projects effected by the two organisations between 2006 and 2011 in Malindi, one of Kenya's major tourist destinations, and in Nyabondo, a rural plateau situated about 30 km from Lake Victoria. The findings, which were published in the high impact *Environmental Health Perspectives* journal, showed that IVM for malaria can only be successful if there is strong participation and collaboration between community-based groups, non-governmental organisations, international and national research institutes and various government institutions.

icipe and collaborators made significant progress in Rift Valley fever (RVF) research, continuing to identify knowledge gaps and strategies to address them. By end of 2014, the researchers had developed improved testing and surveillance tools for RVF and its vectors and had begun building the capacity to use them among stakeholders, including public and animal health officers and community members.

Researchers from the University of Canterbury, New Zealand, in affiliation with *icipe,* accomplished several milestones in 2014 in their research on mosquito-specialist predators (species that prey specifically on mosquitoes). Among the achievements was a publication in *Animal Cognition* journal of the first article showing the viability of using 'expectancy-violation' methods to investigate the memory of jumping spiders. The researchers also published an in-depth study in *Royal Society Open Science*, of *Paracyrba wanlessi*, a jumping spider that preys on all active stages of mosquitoes (larvae, pupae and adults).

In its research on disease vectors, *icipe* takes a holistic approach aiming to understand the entire ecosystem. Here, David Tchouassi, a postdoctoral research fellow in *icipe*'s Behavioural and Chemical Ecology Unit, displays nets consisting of adult mosquitoes trapped using carbon dioxide baited CDC light traps in the Mpala Research Centre, Kenya, as part of studies to understand the association between biodiversity and arboviruses.

In 2014, *icipe* in collaboration with the Kenya Medical Research Institute (KEMRI) collaborators started examining the risk factors associated with leishmaniasis. The team investigated a reported outbreak of kala-azar (visceral leishmaniasis) in Marsabit, northern Kenya, between May and August 2014, with 112 cases – 10 of them fatal – being attended to in the county's hospital.

A total of 3000 sandflies, the insect vectors of the leishmania parasite, were collected from indoor and outdoor habitats such as termite mounds, swampy areas, human dwellings, toilets and animal sheds. It was found that a combination of post-kala-azar dermal leishmaniasis (a condition that occurs a few months after the successful treatment of the disease), and termite hills could contribute to the continuous disease transmission in the area. The researchers are now investigating ways to address these two significant risk factors.

In December 2014, the Ethiopian Government, through the office of the Prime Minister, requested *icipe*'s support in controlling an outbreak of tsetse flies in the country. *icipe* scientists joined their Ethiopian colleagues on a mission to the impacted region in early February 2015 to determine the extent of the problem, the species of tsetse flies involved and the most suitable technologies to be deployed.

icipe also re-started its research on ticks, which transmit a wide range of pathogens, to humans and animals, through studies conducted in Baringo and Homa Bay, Kenya. Apart from incidences of outbreaks of arboviruses in these two counties, other tick-borne pathogens (TBPs) remain understudied. In 2014, *icipe* researchers analysed ticks from the two regions and identified eight tick species, and the presence of a number of disease agents in them. This information is important to public health in mitigating TBPs and possible disease outbreaks in these areas.

The Martin Lüscher Laboratory for Emerging Infectious Diseases (EID) developed an assay for differentiating various arboviruses in samples, which will have applications in surveillance programmes. The technology platform also has the potential to be used to differentiate species of *Plasmodium*, mosquito blood meal vertebrate host identification, mosquito species differentiation and bovine MHC differentiation. The arbovirus assay has been submitted for publication to the prestigious journal *PNAS*.

The Centre tested the viability of a Livestock Protective Fence (LPF), using long-lasting insecticide treated nets, to control vectors and vector-borne diseases, and other nuisance insects in intensive zero-grazing dairy farms in Kisii and Bungoma counties of Kenya.

Environmental Health

Research conducted through the Centre's Bee Health project on stingless bees led to the design of new hives that stimulate better colonisation by the bees and facilitate proper honey harvesting. The researchers also introduced natural enemies into the hives and instituted methods to prevent pest attacks on the bees. In collaboration with the African Union InterAfrican Bureau for Animal Resources (AU-IBAR), *icipe* conducted a variety of training sessions to transfer these technologies to ministries of agriculture and livestock staff from 42 countries in Africa.

The Commercial Insects Programme launched research on the rearing of the eri silkworm *Samia cynthia ricini*, with the aim of starting commercial production of its silk in Kenya. This research is based on the fact that among the non-mulberry silks, the production of the eri variety is the only one that is increasing. The *icipe* studies included evaluation of the performance of eri silkworms on different target and non-target food plants. The findings show castor to be superior, and the only food plant that can rear silkworms to maturity. *icipe* has successfully conducted five eri silkworm rearing cycles (5000 worms per cycle). The Centre has also finalised a protocol to be used for six-month field trials in Makueni, eastern Kenya starting in May 2015, in collaboration with a number of partners from Kenya and across Africa.

Significant advances were also made within the Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa (CHIESA) project, a four-year initiative aimed at increasing knowledge on the impacts of climate change on ecosystem services in the Eastern Afromontane Biodiversity Hotspot, funded by the Government of Finland. The accomplishments included the graduation of 10 MSc scholars. Fifteen PhD scholars are currently undertaking their research within CHIESA, and half of them expect to complete their studies by July 2015. To ensure comprehensive knowledge sharing, review and feedback, CHIESA partners organised consultations, seminars and workshops involving different stakeholders around Jimma highlands, Ethiopia, Mount Kilimanjaro, Tanzania and the Taita Hills, Kenya. Reflections from such sessions highlighted the need for urgent actions and interventions in the management of water resources and prevention of land degradation. In addition, CHIESA developed community-based climate change adaptation action plans for each target area of its research. Conservation agriculture demonstration trials were successfully conducted with about 100 small-scale farmers.

CHIESA was scheduled to end in July 2015 with a proposed cost free extension to December 2015. However, the Government of Finland, which is the key donor, has invited *icipe* to submit a proposal to enable the results of this important project to be fully translated into impact.

Dr Tino Johansson (centre), project coordinator of the *icipe*-led Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa (CHIESA) project, is pictured with partners of the initiative during the installation of a rain gauge in Tanzania. These devices will enable farmers to monitor rainfall trends complementing data provided by the project, which, in the long-term will enable them to plan their farming activities better, against the background of climate change.

Research Support Units

Within the Biosystematics Unit, *icipe* and collaborators undertaking inventory surveys of Kenyan insects in the coastal forests of eastern Africa discovered a new, enigmatic wasp genus and species hitherto unknown to science, in Muhaka forest along the Kenyan coast. The unusual wasp genus has been named *Muhaka icipe* – a double tribute, first to the habitat, which is part

Dryinus digo sp., a new wasp species found by *icipe* and collaborators in the Kaya Kinondo forest, has been named in honour of the Digo people (one of the nine Mijikenda tribes) who consider this particular Kaya sacred and therefore act as its guardians.

of the sacred Mijikenda Kaya forests, and second, to the role that the Centre plays in advancing knowledge of Africa's remarkable insects. While conducting an updated checklist of Dryinidae, Embolemidae and Sclerogibbidae wasps of Kenya and Burundi, *icipe* and colleagues discovered 13 other previously unknown wasp species in the two countries. In naming the new species, the researchers have immortalised various sites and individuals from the two countries, and from across the world.

These discoveries contribute much needed knowledge to the global taxonomy hub. Although, in general, there are significant taxonomic gaps on most living organisms, the scenario is even more critical in regard to the smaller ones, such as wasps. Yet, wasps are significantly beneficial to humankind, specifically because of their ability to naturally control agricultural pests.

This is because the majority of wasps (over 100,000 species) are parasitic. Indeed, *icipe* has, in the past, recorded significant success in using wasps to control pests of cabbages and maize in Africa. It is also hoped that the discovery of new species will help support more intense conservation strategies to safeguard important habitats like the coastal forests, which are facing constant threats primarily related to factors such as increased population pressure.

In early 2014, using airborne hyperspectral data, *icipe*'s geographic information systems (GIS) team produced a map showing the abundance and distribution of flowering plants in Mwingi, eastern Kenya, a significant honey-producing region in eastern Kenya. Such maps are extremely useful for sustainable honey production, as they increase understanding of landscapes, and enable analysis of possible hive productivity and bee health. This knowledge can also be used to quantify pollinators, and as a guide and an incentive for their protection.

The Centre's modelling team made progress in projecting potential climate change induced impacts in the distribution of insects in Africa and globally. They observed possible increases in some crop pests, and also showed the synchrony between some species and natural enemies to be at risk. These findings indicate possible rises in pest infestations on crops and, as a result, more yield losses and increased food insecurity. In addition, in eastern and southern African countries, changes in population densities and boundary shifts of major malaria vectors (*Anopheles gambiae s.s.* and *An. arabiensis*) are predicted.

Capacity Building and Institutional Development

As mentioned previously in this report, in 2014, *icipe* appointed Dr. Rob Skilton as the new Head of the Capacity Building and Institutional Development (CB&ID) Programme. Dr Skilton is guiding a re-design of *icipe*'s CB&ID to enhance its effectiveness, in accordance to the findings of an external review conducted in 2012.

One key change made so far in CB&ID is the establishment of benchmark figures on the recipients of *icipe* training in regard to geographical distribution and gender. This data will enable the Centre to refine and develop its capacity building programmes to ensure that it reaches those most in need.

A key focus of *icipe*'s CB&ID is the training of a critical mass of young researchers from Africa in arthropod-related sciences at MSc, PhD and postdoctoral levels, conducted through the African Regional Postgraduate Programme in Insect Science (ARPPIS), the Dissertation Research Internship Programme (DRIP) and the Postdoctoral Fellowship (PDF) programme.

In 2014, 30 ARPPIS PhD fellows, from nine African countries, 36% of them women, were at different stages of their doctoral programmes. Thirty-five DRIP research fellows (43% of them women) from 11 (7 African and 4 non-African) countries were undertaking PhD research. Still under DRIP, 69 MSc fellows (54% of them women) received support in 2014 to conduct research at *icipe*. Seventeen postdoctoral fellows were being hosted at *icipe*, eight of them conducting two years research, and nine undertaking research work for periods of six to eight months.

In specific regard to these three programmes, various efforts, including a review of university partners, have been put in place to ensure that the training the students receive at *icipe* is of the highest quality. The Centre has also enhanced strategies to augment the research skills of the scholars through additional, tailor-made training courses. In accordance, in 2014, *icipe* and partners organised sessions covering: introduction to information literacy and e-resources/e-journals; introduction to modelling; behavioural bioassays in neuroscience and statistical methods for arthropod research.

In total, *icipe* has trained over 700 postgraduate students over the years, who, during their tenure at the Centre, contribute immensely to the advancement of various research themes. In 2014, *icipe* commenced efforts to gather data on its alumni; for instance, details on their career trajectories since completing their studies. The information will facilitate a detailed monitoring and evaluation of *icipe*'s capacity building activities (planned for 2015). Early feedback has revealed that 90% of *icipe* alumni are today employed in research or associated roles across Africa.

Beyond the postgraduate training programmes, *icipe* also aims to increase the capacity of diverse stakeholders in producing and utilising science. Towards this goal, in 2014, the Centre conducted over 50 training workshops involving 1268 participants (32% of them women) from 47 African countries. The topics covered included: strengthening linkage and collaboration for demand and supply of agricultural innovation systems in Kenya and stakeholder engagement (targeting malaria consortium staff). In addition, the Centre's researchers and collaborators held more than 1000 farmers' field days, reaching 44,000 participants, out of whom 54% were women to increase the dissemination and adoption of various technologies and strategies.

icipe's capacity building programme brings together and nurtures emerging talent from across Africa. Pictured, scholars undertaking postgraduate research at the Centre in 2014, and their mentors, during a cultural day.

Table 1: Summary of PhD, MSc and Postdoctoral fellows at *icipe* in 2014

Country	ARPPIS PhD	DRIP PhD	DRIP MSc	Post Doctoral	Total
Burkina Faso	1				**1**
Benin		2	1		**3**
Cameroon	4			3	**7**
China		1			**1**
Colombia		1			**1**
DR Congo	1				**1**
Ethiopia	2	3	3		**8**
France		3			**3**
Ghana	1				**1**
Italy		1			**1**
Kenya	15	19	54	9	**97**
Mali		1			**1**
Mozambique	1				**1**
Netherlands			5		**5**
Nigeria	1	1		2	**4**
Sudan	1		2		**3**
Tanzania		2	4		**6**
Tunisia		1			**1**
Uganda	1			2	**3**
Zimbabwe	2			1	**3**
Total	**30**	**35**	**69**	**17**	**151**
Female	**11 (36%)**	**15 (43%)**	**31 (45%)**	**8 (47%)**	**66 (44%)**
Male	**19 (64%)**	**20 (57%)**	**38 (55%)**	**9 (53%)**	**85 (56%)**

Table 2: Short-term training courses provided to new postgraduate scholars in 2014

Course title	Coordinator (Department/Unit)	Dates	No. of participants
Introduction to Information Literacy and e-Resources/ e-Journals	J. Lago (IRC)	14 Feb	18
Introduction to Biostatistics	D. Salifu (Statistics)	10 - 21 Feb	16
Biosystematics and Taxonomy	B. Copeland (BSU)	24 Feb - 7 Mar	11
GIS and Remote Sensing	T. Landmann (EOU)	10 - 14 Mar	25
Economic Valuation of Ecosystem Services and Goods	T. Johansson (CHIESA)	19 – 21 Mar	21
Molecular Biology & Bioinformatics	D. Masiga (MBBU)	24 - 28 Mar	13
Modelling	H. Tonnang (IPM)	15 - 17 Apr	15
Behavioural & Chemical Ecology	B. Torto (BCED)	21 - 25 Apr	12

Global Recognition

In 2014, several *icipe* staff and projects won a number of prestigious global recognitions, including:

- **Segenet Kelemu** (Director General), received the L'Oréal-UNESCO Award for Women in Science for Africa and the Arab States. She was also appointed a Fellow of the African Academy of Sciences (AAS), the continent's premier honorific society, whose primary aim is to honour internationally renowned African scientists. Further, Dr Kelemu was featured in *Forbes Africa*, May 2014 issue, as one of the top 100 most influential African women. She was also included in a commemorative calendar celebrating the 25th anniversary of the Organization for Women in Science for the Developing World (OWSD – under the auspices of TWAS, The World Academy of Sciences). The calendar recognises some of the senior members of the OWSD from eastern and southern Africa for their contribution to gender, science and technology. Over the 2014 Christmas holiday, Dr Kelemu was the focus of a globally broadcast episode of CNN's *African Voices* programme.

- **Zia Khan** (Leader of the Push–Pull Programme), was inducted as a member of TWAS, The World Academy of Sciences, during its General Assembly Meeting in Muscat, Oman in October 2014.

- **Baldwyn Torto** (Head of Behavioural and Chemical Ecology Unit), was appointed a Fellow of AAS. Prof. Torto was also selected to serve as a member of AAS Commission on Sciences Education, one of four established to build capacity and set the agenda for science in Africa. He has also been invited by AAS to serve on the jury for the award of the Africa Union Prizes.

- **Fiona Nelima Mumoki** (a research assistant in *icipe*'s Molecular Biology and Bioinformatics Unit), received the African Women in Agricultural Research and Development (AWARD) Fellowship, a highly competitive, merit-based, career-development programme, which aims to foster and mentor women agricultural scientists across sub-Saharan Africa. Fiona was also granted an OWSD Postgraduate Training Fellowship, to undertake PhD studies at the University of Pretoria, South Africa, starting in April 2015.

- **Dr Fathiya Khamis** (postdoctoral researcher) and **Dr Jeremy Herren** (Visiting Scientist), were nominated by Prof. John Pickett, the former Chair of the Centre's GC, for the Royal Society Pfizer Early Career Award.

- **Muliru Farmers Conservation Group:** A community group based adjacent to Kakamega forest, which is supported by *icipe* and partners in the mission of improving its members' livelihoods while conserving the forest, won two prestigious awards and a training package from the Government of Kenya, funded by the Swedish Government: the overall 2014 NETFUND Green Innovations Award, and in the water thematic category.

Mr James Ligare (right) from the Muliru Farmers Conservation Group receives the NETFUND Green Innovations Award from the Kenya's First Lady, H. E. Margaret Kenyatta.

New Research Directions

In 2014, *icipe* in collaboration with the R. Geigy Foundation/Swiss National Science Foundation, started the Spirovector project, to advance Africa's capacity in developing insect endosymbiont-based strategies for the control of vector-borne diseases. Dr Jeremy Herren, who is leading the project, is pictured observing samples as part of the research.

Responding to Emerging Challenges

In the past one year, icipe's research portfolio has evolved in a number of ways, driven by the mission of responding to emerging developmental challenges in innovative ways. The article below discusses novel research being conducted around the 'insects for food and feed' topic, and on the development of insect endosymbiont-based strategies for the control of vector-borne diseases in Africa.

Insects for Food and Feed

Globally, issues surrounding population growth, urbanisation, climate change, diminishing land and water resources, over- and undernutrition, and persitent poverty, have created uncertainties and pressures on current food and economic systems.

Against this background, the use of insects as alternative sources of food for human consumption and feed for livestock, has captured the imagination of the global research and donor community, as well as the general public. This is because insects are ubiquitous: they reproduce quickly, have high growth and feed conversion rates and low environmental impact. Insects are also valuable sources of minerals and vitamins essential for human development.

In late 2013, *icipe* began to consider 'insects for food and feed' as a new strategic research opportunity. In 2014, the Centre made significant progress in this area, by conducting background research, preparing proposals and establishing linkages with a broad range of national and international stakeholders (including donors, research institutions, public and private institutions). The Centre compiled an inventory titled "African edible insects for food and feed: inventory, diversity, commonalities and contribution to food security", which was published in the new *Journal of Insects for Food and Feed*. *icipe* also established the Insect for Food, Feed and Other Uses (INSEFF), programme as the platform for consolidating and strengthening its activities in this area. Under the INSEFF umbrella, the Centre has commenced three research projects: GREEiNSECT, INSFEED and ILIPA, which are discussed in greater detail in this article.

GREEiNSECT: Mass-Rearing Insects for Greener Protein Supply

Through the GREEiNSECT initiative, which is led by University of Copenhagen, Sweden, *icipe* is working with a consortium of public and private sector partners from Africa, Asia, Europe and USA, to investigate ways of mass-rearing insects in small, medium and large-scale industries. The overall aim is to integrate insects as a new, sustainable and inclusive component in addressing food, nutritional and feed security, and as part of the transition towards greener agriculture in Kenya.

icipe has identified 'Insects for Food and Feed' as a new strategic research opportunity, with the overall aim of addressing food, nutritional and feed security, and the transition towards greener agriculture in Africa.

icipe has joined the global community in its quest to harness the potential of insects as alternative sources of food and feed. Here, Dr Sunday Ekesi makes a presentation during the first international conference on "Insects to feed the world", organised by FAO and Wageningen UR in May 2014.

In Kenya, insect species such as lake flies, termites, black ants, crickets and grasshoppers, have traditionally been part of people's diets. However, there is minimal understanding of their contribution to food and nutritional security. Moreover, the insects consumed in the country are harvested in an uncontrolled manner from the wild or from semi-domesticated informal set-ups. Ultimately, this can lead to habitat destruction and even the extinction of species. In addition, as is the case globally, there is lack of a proper institutional framework to oversee and document edible insects in the country.

Currently, there is a global quest to incorporate 'greening' measures in agricultural systems, aimed at climate change mitigation and biodiversity conservation. Studies have shown that compared to other livestock, insects are far more efficient in converting organic matter into protein leading to lower greenhouse gas emissions. Therefore, insects have the potential to become a cornerstone in 'greening' feed and food production. In addition, as shown through examples from various parts of the world, insect species such as black soldier flies and house flies can be used in organic waste management. However, in developing countries such as Kenya, proper research is required to back the mainstreaming of insects as part of greener systems. Studies are also needed to gain solid understanding of appropriate insect species that can be mass-reared, including knowledge on breeding, production management, and ways to pre-empt and control diseases and environmental risks.

Moreover, for it to succeed, mass-rearing of insects must appeal as an emerging industry to a range of entrepreneurs and investors across the value chain. Importantly, the sector also has to be supported by regulations and policy frameworks encompassing food safety and trade issues on national, regional and international levels.

The GREEiNSECT initiative will endeavour to address these issues, by merging traditional and modern scientific knowledge to enhance food, nutritional and feed security through the use of insects. Its multidisciplinary nature will facilitate the amalgamation of already existing local and international knowledge on insect mass-rearing innovations. The consortium will also provide a platform for international collaboration, bringing together South–South and North–South partnerships. For instance, partners from South East Asia, where the edible insect sector is more advanced, will contribute valuable scientific expertise, complementing the traditional know-how available in Kenya.

To develop sustainable insect rearing, harvesting and postharvest technologies, the partners will identify ways to domesticate species and scale-up their production. Towards this end, the researchers are conducting trials in rural and peri-urban settings, using crickets as a model for small-scale mass rearing, and black soldier flies for poultry and aquaculture feed. Research is also being conducted on disease risks that might arise in mass-rearing of insects, on insect life cycles, and on international food and trade security standards and assessments of insects as part of greener socio-economic growth.

The researchers are also investigating appropriate business models, to help industry players identify entry points and barriers. This process includes mapping of feed needs, assessment of barriers of international trade and understanding the social acceptability of insects as feed; for instance, by gauging consumer perceptions. These findings will form the basis for recommending economic and political incentives for entrepreneurs keen to undertake mass-rearing of insects.

The partners will endeavour to disseminate the knowledge gained from this research, with the aim of building the capacity of Kenyan institutions towards a greener protein supply based on an inclusive, pro-poor, public–private sector cooperation model.

INSFEED: Integrating Insects in Poultry and Fish Feed in Kenya and Uganda

In developing countries, the poultry and fish industries are the fastest growing agri-businesses, with over 60% of the producers being women. However, the two industries are constrained by poor availability, low quality and high cost of feed. Currently, feed costs represent 60–70% of the cost of poultry and fish production, with protein alone accounting for 70%. In addition, soybeans and cereals, the key ingredients of poultry and fish feed, are also foods for human consumption.

In Asia and the Pacific, insect protein is already being used as an ingredient in homemade poultry feeds. In West and Central Africa researchers have documented the use of termites, house flies and cockroaches in poultry feed. However, in East Africa, little research has been conducted on the use of insects as an alternative protein source for livestock. The INSFEED project, which is jointly supported by the International Development Research Centre (IDRC), Canada, and the Australian Centre for International Agricultural Research (ACIAR), aims to address this gap, by exploring the potential of insects as possible, sustainable, safe and cost-effective protein sources for poultry and fish industries in Kenya and Uganda.

INSFEED plans to establish strong scientific bases to test the technical feasibility and economical profitability of insects as feed. The partners intend to take a holistic approach around three themes: establishing strong scientific bases for the use of insects as feed for poultry and fish; testing the technical feasibility and economical profitability of the proposed technology; and creating favourable social and political conditions for using the technology on a large scale.

The researchers are conducting studies to understand attitudes and practices regarding the use of insects for feed. They have also prepared strategy documents on gender mainstreaming, monitoring and evaluation, and communication. Other documents that have been produced so far include an impact pathway, project implementation plan, and the protocol for socio-economic and gender assessment.

The project partners are compiling a preliminary inventory of key insect species that could be used as

Joshua Wambua displays a colony of black soldier flies being reared in the *icipe* Animal Rearing and Containment Unit. With proper research, this insect species can be used in organic waste management as part of greener agriculture.

Crickets, such as the one pictured here, are among insect species that could be used as alternative protein sources for poultry and fish feed. *icipe* and partners are investigating ways to mass-rear them for this purpose.

feed protein sources. Colonies of black soldier flies, crickets and locusts have been initiated at *icipe*. The researchers have also developed protocols that will support the insect rearing activities and help to assess microbial contamination, and they are now calibrating procedures for insect nutritional profiling.

Currently, in Kenya and Uganda, government regulations on poultry and fish feed consider insects as impurities, and as such their use is not regulated. To enable the two countries develop standards and legislation for the use of insects as feed, the researchers are developing two position papers titled 'Safety and policy situation concerning utilisation of insects for fish and poultry feed in Uganda and Kenya', and 'Utilisation of insects for fish and poultry feed in Africa'. They also plan to initiate strategic discussion with regulatory bodies in both countries.

ILIPA: Improving Livelihood by Increasing Livestock Production in Africa

ILIPA is the newest addition to *icipe*'s portifolio on insects as feed, through a collaboration with Wageningen University. The initiative aims to exploit the commercial potential of insects, mainly the black soldier fly, *Hermetia illucens,* in production of affordable, high-quality protein for poultry, pig and fish industries. To create an effective agribusiness model, the project partners will conduct research that will ensure high nutrition and microbial safety of the insect-based protein products. The research will also focus on creating awareness and identifying market opportunities for the technology. A participatory approach will be used, involving farmer groups, with particular focus on women and youth.

Advancing Development of Insect Endosymbiont-Based Strategies in Africa

Vector-borne diseases are estimated to account for 17% of the entire global burden of infectious diseases, exerting their greatest impact in developing regions. These diseases are transmitted by insects such as mosquitoes, ticks and fleas, which convey infectious agents (also known as pathogens) including parasites, viruses or bacteria, between people, or between animals and people.

Effective prevention strategies for vector-borne diseases have remained elusive, complicated by a variety of factors such as the resistance of insects against insecticide, and the ability of pathogens to become resistant to drugs. For instance, in regard to malaria control, mosquito control and treatment methods that have previously been effective are now largely ineffective, due to the growing prevalence of insecticide-resistant mosquitoes and drug-resistant parasites. As a result, there is great need to develop new strategies for the sustainable control of vector-borne diseases.

Globally, insect endosymbionts are emerging as a promising alternative in vector management strategies. Insect endosymbionts are microbes (generally bacteria), that live inside the cells or body of an insect host, and are continually transmitted from mother to offspring. These microbes have significant impacts on the interaction

between their host insects and other pathogens. This is because to promote their own survival, the microbes often 'assist' their host insects in the defence against pathogens. As such, they can potentially be used to make vectors more resistant to pathogens and prevent the transmission of vector-borne diseases.

There has been minimal progress in the development of endosymbiont-based strategies to address vector-borne diseases of great importance to Africa. In contrast to the explosion of research on endosymbiont-based strategies to control arboviral diseases, there has been much less research on similar strategies for vector-borne diseases that are caused by parasites. This distinction is important because most of the important vector-borne diseases in Africa are parasites (e.g. *Plasmodium*, the malaria parasite; *Leishmania*, which is responsible for leishmaniasis, and *Trypanosoma,* which causes African trypanosomiasis etc). Therefore, the slow pace in endosymbiont-based strategies can be attributed to a lack of endosymbiont species that demonstrate parasite-specific protection.

In 2014, *icipe,* in collaboration with the R. Geigy Foundation/Swiss National Science Foundation, started the Spirovector project, an initiative that is intended to advance the development of insect endosymbiont-based transmission-blocking strategies in Africa. The researchers have screened populations of numerous disease vectors throughout Kenya, and have identified several new endosymbionts of significant interest, key among them, spiroplasmas.

Through field studies conducted in the Mwea Irrigation Scheme, Kenya, three distinct strains of *Spiroplasma* have been isolated from a population of *Anopheles arabiensis* (which belongs to the malaria-carrying *An. gambiae* species complex). The *icipe* researchers found the three *Spiroplasma* strains to be present at frequencies of 1 – 5% of mosquitoes sampled. Of particular significance is the discovery that one of the strains is a member of the *S. poulsonii* group. This is because all *S. poulsonii* strains that have been previously discovered have exhibited a number of traits, including parasite protection, that confer in them great potential for controlling the transmission of vector-borne diseases.

Currently, the researchers are collecting *Spiroplasma*-infected *An. arabiensis* and starting laboratory colonies that will enable further characterisation of the infection. In addition, studies aimed at examining positive or negative correlations between the presence of *Spiroplasma* and *Plasmodium* are ongoing.

The discoveries made by *icipe* and collaborators so far are an important step in the long term vision of advancing the utility of endosymbiotic microbes in the prevention of insect-vectored parasites, thereby mitigating the huge impact of vector-borne diseases in Africa.

The Spirovector project intends to advance Africa's capacity in developing insect endosymbiont-based strategies for the control of vector-borne diseases. Here, Sharon Towett, an MSc student in the project is screening *Spiroplasma* endosymbionts.

Infrastructure Upgrade

A Carl Zeiss Primo Star stage microscope fitted with a Zeiss Axio Camera (105 colour), one of the equipments in the newly-launched African Reference Laboratory for Bee Health, at *icipe*. This installation arrangement permits the viewing of prepared biological samples on microscope slides at four to 100 times objective magnifications, presenting the possibility of live specimen viewing, video and still photo capture, and measurement of specimen size.

Enhancing *icipe*'s Centre of Excellence Status

In 2014, icipe *significantly upgraded its infrastructure, demonstrated particularly through the newly-inaugurated African Reference Laboratory for Bee Health, and the acquisition of a variety of cutting-edge chemistry instrumentation. The article below discusses the motivation and the implications of these upgrades on* icipe*'s own ability to innovate and overall, on Africa's insect sciences research.*

Creating an Infrastructure for Bee Health Research in Africa

Bees are one of the most important insects to mankind. In Africa, as *icipe* has shown over the past several decades, honeybees are extremely critical in improving the lives of millions of people, especially those living in marginalised areas. For such communities, beekeeping often provides one of the few viable livelihood options.

Beyond this, bees also provide a critical, though often unrecognised and undervalued free service, through the pollination of many food and non-food crops. Indeed, more than 70% of the production of the world's major crops relies on bee pollination. Bees also pollinate grasses and forage plants, therefore contributing indirectly to meat and milk production.

The idea of establishing an African Reference Laboratory for Bee Health arose out of a number of factors. First, it was based on *icipe*'s extensive experience conducting research on bees, with the aim of improving livelihoods while conserving biodiversity. Through these activities, *icipe* recognised the rising threats to bees in Africa resulting from factors such as climate change and habitat loss due to deforestation caused by population pressures, among others.

Against this background, the Centre noted significant gaps in knowledge, and the absence of systematic procedures to monitor, analyse and safeguard bees. Moreover, the Centre observed lack of proper approaches to incorporate bees into development strategies in Africa, as well as inadequate understanding of their economic impact, especially in regard to pollination services.

Closely interlinked to *icipe*'s concerns, were growing global anxieties surrounding bee health against the background of the colony collapse disorder (CCD). This is a phenomenon that has since 2006 become a serious problem and a major threat to commercial beekeeping and pollination operations in Europe and USA. The factors that have so far been identified as the most likely contributors to CCD include Varroa mites,

The lateral view of the newly-launched African Reference Laboratory for Bee Health, at the *icipe* headquarters in Nairobi.

His Excellency William Ruto, Deputy President of the Republic of Kenya, pictured addressing guests during the official launch of the African Reference Laboratory for Bee Health. He commended *icipe*, AU-IBAR, and funding partners, for the vision of this facility, which will enhance food security and elevate the livelihoods of smallholder farmers in Kenya and across Africa.

diseases (particularly viruses vectored by Varroa), pesticide exposure, stresses associated with modern beekeeping practices and poor nutrition.

In 2008, through an international collaboration, *icipe* conducted research on African honeybees within the context of CCD. These studies showed that honeybees in Africa are less vulnerable to brood diseases, parasites such as Varroa mites, and pests like the small hive beetle. In addition, the researchers found that Africanised honeybees in the USA, many of which are hybridised crosses with European species, tolerate these maladies better and do not often succumb to them. These findings imply that knowledge on African honeybees could contribute in general towards alleviating global threats on the health of honeybees.

Based on these two sets of factors, regional and international, *icipe* strongly recognised the need for a dedicated infrastructure on bee health research. The Centre envisioned a state-of-the-art facility that would primarily provide a continent-wide platform for monitoring and preventing bee diseases and pests, as part of the process towards securing the bee industry in Africa, while contributing to global sustainability of bees. The Laboratory was also envisioned to provide technical support to four satellite stations in Africa (in Burkina Faso, Cameroon, Ethiopia and Liberia, with an additional training site in Madagascar).

The construction of the African Reference Laboratory for Bee Health started in 2013, as a partnership between *icipe* and the African Union Inter-African Bureau for Animal Resources (AU-IBAR), with financial support from the European Union (EU), amounting to €13.1M. Additional financial support was obtained from the International Fund for Agricultural Development (IFAD), the World Trade Organization (WTO), and from *icipe*'s core donors: Aid for Africa, the Government of France (in-kind support), the Government of Kenya, the Swedish International Development Cooperation Agency (Sida), the Swiss Agency for Development and Cooperation (SDC) and UK Aid, and attributed funding from The German Federal Enterprise for International Cooperation (GIZ) on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ).

The African Reference Laboratory for Bee Health was officially inaugurated in November 2014, by His Excellency William Ruto, Deputy President of the Republic of Kenya, providing *icipe* researchers a new home and focal point for cutting edge research towards improved bee health and pollination services, with the ultimate aim of enhancing the livelihoods of beekeepers and farmers across Africa, through improved honey products and crop productivity.

Researchers are now conducting extensive studies on pests, including Varroa mites, small and large hive beetles and wax moths, and on bee diseases. Studies are also underway to evaluate how African bees are affected by pesticides used in agricultural systems in the region. This knowledge is being used to design strategies for surveillance, risk assessment and diagnostics of bee apiaries, honey and pollen. In turn, this information will guide approaches on beehive management, including the protection and treatment of bees from identified threats.

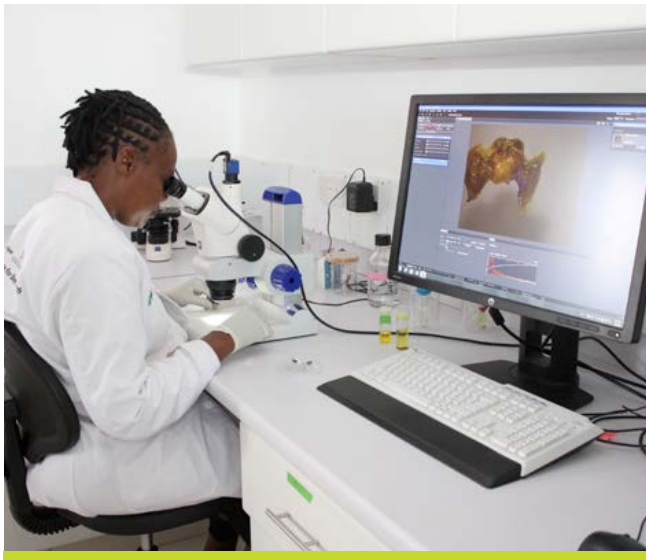
Indeed, research has already commenced towards developing and validating biopesticides that will safely and sustainably combat bee pests and diseases.

A key undertaking of the African Reference Laboratory for Bee Health is the comprehensive assessment of the diversity of Africa's remarkable bee biodiversity, including generation of knowledge on their physiology, ecology and genetics. This knowledge is important, for instance, in discovering more efficient bee pollinators, or those that are more resistant to diseases. In turn, this information will guide bee conservation strategies, as well as activities to breed and domesticate resilient bee species through artificial insemination of the queen bee with selected drone semen.

These studies will be conducted using a range of scientific approaches, and for this purpose, hi-tech equipment (including that for undertaking molecular and analytical chemistry procedures), which is available in the African Reference Laboratory for Bee Health. For instance, the facility is fully equipped with the tools that are necessary for evaluating bee pollination efficiency on cultivated crops and identifying bee pollen and propolis sources. Sophisticated instrumentation is also available for rearing non-domesticated social and solitary bees. Central to this, is the rearing of queen bees, which are important in reproducing colonies with desirable traits, such as pest and disease resistance.

Research will also be conducted on the plant–pollinator interface, to ascertain how landscape changes are affecting bee health and diversity. For this purpose, the African Reference Laboratory for Bee Health has a dedicated section on geospatial analysis, which is equipped with geographic information system (GIS) and global positioning system (GPS) tools.

The studies at the Laboratory are intended to take a complete value chain approach, and therefore, attention will be paid to identifying market opportunities and constraints. A significant aspect of this is the improvement of honeybee and hive products, including beeswax, propolis and royal jelly. The aim is to enable farmers to produce value-added products that can be marketed globally. The researchers are, therefore, developing a framework and procedures for product quality control; for instance, towards organic certified honey and hive products. The Laboratory's advanced technological equipment, including liquid chromatography-tandem mass spectrometry (LC-MS/MS) and high-performance liquid chromatography (HPLC) instruments, will enable the testing of pesticide residues in bee products, which is key for certification purposes. The facility also has a dedicated section for developing skills in proper processing and packaging of honey and hive products.



Pamela Seda, an MSc student is pictured conducting neuroendocrine studies in the African Reference Laboratory for Bee Health Neurobiology Laboratory. The studies are aimed at investigating the impact of diseases and pest infestation on the dopamine titres and neuropeptides in the honeybee brain, which are responsible for sensitisation and olfactory learning, and are very useful for foraging activities and nectar collection for honey.

The African Reference Laboratory for Bee Health will contribute towards developing community-owned

The African Reference Laboratory for Bee Health will enable farmers to to produce value-added products that can be marketed globally, including the Eco Honey brand pictured here, which has been developed through *icipe*'s research.

marketplaces for honey, wax, and other beehive products, with model marketplaces for processing, packaging, and trading of honey and hive products being established in each participating country. These activities will be supported by socio-economic and environmental impact analysis.

In addition, *icipe* and AU-IBAR intend to contribute towards the development of an African framework on bee health national and regional strategies, harmonised procedures and legislation policies and institutions for bee health, and guide their incorporation into national development agendas across the continent.

Through the regional satellite stations, *icipe* and AU-IBAR also intend to conduct extensive capacity building of beekeepers, farmers and national agricultural research systems (NARS) staff, in regard to the strategies that will be developed in the Laboratory. The ultimate goal is to devolve bee health management, to give ownership to Farmers' Federations and community members, with *icipe*/AU-IBAR providing technical supervision.

Becoming a Centre of Excellence in Analytical Chemistry

Chemistry-based research has always been an integral part of *icipe*'s research and development strategy. Through this discipline, which is centralised within the Behavioural and Chemical Ecology Unit (BCEU), the Centre conducts studies towards identification, formulation and evaluation of pheromones, kairomones, allomones and hormones mediating arthropod behaviour.

Over the years, significant accomplishments have been made through *icipe*'s chemistry-based research, including enhanced understanding of chemical communication in disease-causing mosquitoes and tsetse flies, insect pests of crops such as locusts and stemborers, and their natural enemies, and parasitic plants and their interaction with cereals. In turn, this knowledge has led to the development of important environmentally-sound methods to reduce or suppress pests, and to increase populations of beneficial insects. Among these technologies is the Centre's innovative tsetse repellent collar technology.

Chemistry-based research requires high-tech analytical instruments, and therefore, *icipe* makes it a goal to ensure that BCEU is sufficiently equipped to conduct its activities. In 2014, *icipe* received extra funding amounting to Swedish Kronor 10M (approximately USD1.5M) from one of its core donors, the Swedish International Development Cooperation Agency (Sida). This funding enabled the Centre to significantly upgrade its chemistry laboratories with the best-in-class instrumentation for analytical and organic chemistry research.

The funding was used to purchase over 10 analytical pieces of equipment, including two high-end liquid chromatography-mass spectrometry (LC-MS/MS), one of them being a triple quadruple LC-MS/MS for

identification and quantification of targeted molecules (including pesticides, pharmaceuticals and aflatoxins) and the other a high resolution LC-MS/MS for discovery work. Other instruments purchased include gas chromatographs (GC), gas chromatographs/mass spectrometers (GC/MS), ultra high-performance liquid chromatography (HPLC) equipment, and a range of microscopes and gas generators.

In selecting the equipment, *icipe* considered their affordability as well as the running costs, superiority of analytical capability and overall robustness and dynamism in a wide range of applications.

The new instruments are being used in various applications, including insect science studies, food and feed safety analysis, metabolites profiling, nutrient analysis, environmental studies and pharmaceutical applications. Moreover, the Centre is building the capacity of academic and research organisations across Africa, by providing training on these instruments to scientists, postgraduate and graduate students, and research assistants.

Xavier Cheseto, a PhD scholar at *icipe*, is pictured working on a new LC-QTOF-MS instrument in *icipe*'s BCEU laboratory, equipment purchased through a grant from Swedish International Development Cooperation Agency (Sida). Using this equipment, Cheseto has advanced his research on host marking pheromones of African fruit flies, achieving a breakthrough by identifying compounds that could be used to protect fruits against fruit flies.

This upgrade will enable *icipe* to broaden its service base. Towards this goal, the Centre has already applied for accreditation with the Kenya Pest Control and Products Board (PCPB), so that it can conduct laboratory efficacy testing in pesticide residue analysis. This accreditation will be instrumental in the Centre's pursuit of the OECD Good Laboratory Practice (OECD-GLP) accreditation. Overall, *icipe* now stands out as a Centre of Excellence in analytical chemistry in sub-Saharan Africa.

Research Impact

A man pictured with a healthy harvest of mango, produced using *icipe*'s integrated pest management (IPM) strategies for fruit flies. Through the IPM packages, *icipe* is enhancing the income and nutrition of smallholder families by improving yield and quality of horticultural produce.

Improving Livelihoods Across Africa

In all its activities, a key focus of icipe is to develop and disseminate technologies and strategies that have a real impact on the livelihoods of communities in Africa. This section features success accrued through three of the Centre's research initiatives: the push–pull technology, the African fruit fly integrated pest management and the screening for arthropod pathogens programme.

Push–Pull Technology

Cereals, which include maize, sorghum, millet and rice, are the main staple and cash crops for millions of small-scale farmers in most of sub-Saharan Africa (SSA). However, their production is hugely constrained by insect pests, notably stemborers, the parasitic weed known as striga and poor soil fertility.

Over the past 20 years, *icipe* and Rothamsted Research, United Kingdom, and partners in Africa, have developed the push–pull technology, which simultaneously addresses these three challenges. The strategy involves intercropping cereals with a repellent plant, such as desmodium, which repels or deters stemborers from the target food crop. An attractant trap plant, for instance Napier grass, is planted around the border of this intercrop, with the purpose of attracting and trapping the pests. As a result, the food crop is left protected from the pests. In addition, desmodium stimulates the germination of striga and then inhibits its growth. The push–pull technology also has significant benefits for dairy farming, since desmodium and Napier grass are both high quality animal fodder plants. Moreover, because both plants are perennial, push–pull conserves the soil's moisture and improves its health. *icipe* and partners continue to test and improve the push–pull technology, to expand its agroecological reach, and to address any emerging challenges.

In partnership with government institutions, non-governmental and community based organisations, and private sector stakeholders, *icipe* has intensified dissemination of the push–pull technology, to ensure that its immense opportunities are made accessible to as many small-scale farmers in Africa as possible. The Centre uses a variety of pathways, such as field days, farmer teachers and farmer field schools; the mass media, information bulletins, video and mobile phone technology. These tools are continuously assessed; for instance, in relation to their responsiveness to gender-specific needs regarding the adoption of the push–pull technology. The findings from the reviews are then validated and applied to intensify or formulate the most effective and economical push–pull dissemination pathways.

The Centre is also optimising the push–pull technology, specifically, its adaptation to the increasingly dry and

In view of climate change, *icipe* is developing a variant of push–pull for crops such as millet, grown in dry areas that is suitable for hot conditions associated with climate change, using suitable repellent and trap crops such as greenleaf desmodium and *Brachiaria* cv Mulato, as shown in this picture.

hot conditions associated with climate change. Focusing on crops grown in dry areas (mainly sorghum and millet), the researchers are identifying repellent and trap crops that can be used in a climate-smart version of the technology. In collaboration with Rothamsted Research, *icipe* has so far selected greenleaf desmodium and *Brachiaria* cv Mulato, as possible component crops in the climate change-adapted push–pull technology.

By end of 2014, 92,000 small-scale farmers (60% of them female), had adopted either the conventional or the climate-smart push–pull technology variants in different agro-climatic conditions and farm typologies in Ethiopia, Kenya, Uganda, Tanzania and Nigeria. Assuming an average household size of seven, an estimated 640,000 people were benefitting directly from the push–pull technology. A key development is the decision by the Ethiopian government, in 2014, to take leadership in scaling-up the push–pull technology, aiming to reach 20,000 new farmers per year.

An independent impact assessment of push–pull conducted in 2009 to establish its impact on the livelihoods of smallholder farmers, found that the push–pull technology has contributed significantly to reducing the vulnerability of farm families by ensuring higher and better yield stability. Of the assessed farmers, 75% indicated threefold to fourfold increases in maize yield. For instance, some push–pull farmers reported maize harvests of more than five tonnes per hectare, up from previous yields of below one tonne per hectare. In addition, the farmers referred to push–pull as a 'springboard' for diversifying farming systems, especially through the incorporation of dairy operations using Napier and desmodium as fodder.

These benefits have contributed to increased wellbeing at household and village levels. By selling their surplus grains, milk and fodder, push–pull farmers earn extra income, which they use to pay school fees for their children, purchase household items, and improve their housing, overall nutrition and health. The study, therefore, suggested that push–pull is "probably the single most effective and efficient low-cost technology for removing major constraints faced by the majority of smallholder farmers in the region, resulting in an overall and significant improvement of their food security and livelihoods".

Push–pull was also seen to contribute to national food security, rural employment, better education and increased farming knowledge. Furthermore, the impact assessment found push–pull to be an environmentally friendly technology that is likely to increase agrobiodiversity and contribute to provision of ecosystem services.

icipe's goal is to continue scaling-up the adoption of push–pull, while addressing one outstanding challenge: making the inputs of the technology, in particular desmodium seeds, more accessible to farmers. This will involve community seed production and distribution, as well as partnerships with private sector companies to create viable commercial seed production systems.

icipe and partners are also addressing the Napier Stunt Disease (NSD), which first appeared in East Africa in the late 1990s threatening the cultivation of Napier grass, and therefore, the smallholder dairy industry which relies on it for intensive zero-grazing. NSD also hinders the success of the push–pull technology, since Napier grass is one of the key components of the technology. In collaboration with Rothamsted Research (UK), *icipe* has established the long-elusive cause of NSD to be a phytoplasma, and the leafhopper known as *Maiestas banda* Kramer to be one of its vectors in Kenya. The researchers also identified two varieties of Napier grass that are resistant to the phytoplasma, which have undergone successful trials in farmers' fields. In collaboration with farmers' groups, national and research institutes, the NSD resistant Napier varieties have now been distributed to over 3000 growers (close to 60% of them women), in western Kenya.

Fruit Fly Integrated Pest Management

In Africa, horticulture offers one of the most important opportunities for income generation, employment creation, addressing food security needs, improving access to education and health care, and providing women with economic opportunities in rural economies.

However, Africa's horticultural sector is significantly constrained by a variety of factors, including insect pests that reduce yield directly by attacking crops, or indirectly by passing on viral diseases. Some of these insects are considered quarantine pests with restrictions, resulting in the rejection of horticultural produce from Africa in export markets. Most fruit growers are smallholders who often lack access to effective pest and disease control tools, forcing them to rely on synthetic insecticides. Such products are often ineffective, as the pests eventually become resistant to them. Synthetic pesticides also eliminate natural enemies that could biologically control a percentage of the pests. The indiscriminate and frequent use of chemicals is detrimental to the health of the growers, consumers and the environment. The European Union has also introduced the maximum residue level (MRL) legislation for pesticides on imported fruits and vegetables, which further hampers the export of produce from Africa.

Among the key horticultural pests are fruit flies, which cause estimated annual losses amounting to USD2Billion in Africa. Over the years, *icipe,* in collaboration with partners from Africa, Asia, Europe and USA, has developed integrated pest management (IPM) packages for exotic and native fruit flies, including: baiting and male annihilation techniques; biological control with biopesticides and parasitoids; cultural control through field sanitation and minimal use of pesticide in localised bait stations of spot spray.

The *icipe* IPM packages are aimed towards 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. Overall, the IPM strategies should increase the market competitiveness of fruit from SSA and, as a result, elevate the income and livelihoods of people involved in the value chain.

The technologies have been disseminated widely, with tremendous success, across Africa, supported by a programme of training of trainers, establishment of IPM learning sites, demonstration of proven IPM technologies, organisation of field days and massive release of parasitoids. By end of 2014, an estimated 21,000 people in seven African countries were applying *icipe*'s fruit fly IPM strategies. Adoption of the packages is estimated at more than 70% among smallholder mango growers.

In 2014, socio-economic assessment studies were conducted to determine the impact of the *icipe* IPM packages on mango (*Mangifera indica*) production in Embu and Meru counties, Kenya. In Embu County, the study, which involved 257 households, revealed an

Ms Janet Muganyizi, from the Ministry of Agriculture, Food Security and Cooperatives, Tanzania, is among those trained in the application of *icipe*'s fruit fly integrated pest management (IPM) packages. Here, she is presenting farmers with IPM starter kits.

average reduction of 54.5% in the amount of mango produce being rejected by buyers. It also showed a 46.4% decrease on insecticide expenditure and that the net income that farmers were obtaining from mango production had increased by 22.4%.

The evaluation study in Meru assessed the impact of different combinations of the fruit fly IPM packages on a randomly selected sample of 1200 mango producers. The study estimated mango losses due to fruit fly infestations to have gone down by 17%, and observed a reduction of about 45% in the expenditure on pesticides. On the whole, the net income of farmers using the *icipe* IPM packages in mango production had increased by about 48%, which was significantly higher than that of other growers.

The study also illuminated the benefits of using different combinations of the IPM packages, and proposed the ones that could ultimately provide the highest impact, and which could therefore be up-scaled.

Biopesticides

Globally, the replacement of synthetic pesticides with biological alternatives is seen as an ideal strategy towards sustainable agriculture and the conservation of biological biodiversity. In accordance, *icipe* has been screening arthropod pathogens, especially entomopathogenic fungi, for their efficacy against insect pests and disease vectors.

Entomopathogenic fungi are naturally-occurring pathogens that cause infections in insects, either killing or seriously disabling them. Entomopathogens are known to specifically attack pests and vectors, and because they do not produce toxic residues, they are also environmentally safe.

icipe's research has led to the development of several biopesticides based on isolates of *Metarhizium anisopliae*. These products have been found to be compatible with other components of *icipe*'s integrated pest management (IPM) strategies. Through a partnership with Real IPM Ltd, a Kenya-based private sector company, three *icipe* biopesticides have been commercialised as Campaign® (ICIPE 69), Achieve™ (ICIPE 78) and Met 62® (ICIPE 62).

Campaign® has been registered in Ethiopia, Kenya, Ghana, South Africa and Tanzania, where it is being used against mealybugs, thrips and fruit flies, in crops such as cucumber, mango, papaya, roses and tomatoes, among other crops. In particular, Campaign® is receiving growing attention across Africa for its efficacy as a drench treatment to kill soil-dwelling stages of fruit flies. Based on its effectiveness and increasing demand by mango growers, the Centre is exploring methods to enhance the use of Campaign®. For instance, the possibility of using the biopesticide in an autodissemination strategy has been demonstrated. In this case, adult fruit flies would be attracted to the biopesticide using visual, chemical or food lures. The pests would then pick up the fungal spores, becoming infected themselves, and before their own death, they would horizontally transmit the biopesticide spores to others, through mating, physical contact and lek formation (gathering together to attract females) by male flies. In field trials, a combination of Campaign® and DuduLure®, a bait developed by *icipe*, in an autoinoculator resulted in the suppression of 94.3% of fruit flies in mango orchards. In fields treated with the biopesticide, fruit infestation was 7.2%, compared to 54.9% in untreated orchards. These outcomes present one of the strongest possibilities for reducing synthetic chemical pesticide use in fruit fly control in Africa.

Achieve™ is active against red spider mite, for use on papaya, roses, cucumber and tomato. Its registration is in progress in various African countries. The biopesticide is formulated as pure spores in vegetable oil, and as

a total fermented product. In field trials, it has been found to control target pest mites, such as spider mites, *Tetranychus urticae,* and *T. evansi*, without killing predatory mites, such as *Phytoseiulus* and *Amblyseius*. There is also potential of using Achieve™ to control varroa mites, parasites of bees, without harming the bees.

Met 62® is effective against a variety of aphid species including the cabbage aphids, cowpea aphid and melon aphid. Infestations by these aphids on a variety of vegetable crops can significantly hamper productivity and quality of the plants through direct feeding, contamination with their sugary secretions, and transmission of viruses. Met 62® is one of the most potent environmentally benign products currently available for aphid control.

Negotiations are underway between Real IPM Ltd and *icipe* to increase the global reach for the commercialisation of Campaign®, Achieve™, Met 62® (and various other products in the pipeline), in Europe, North America and Asia. In the meantime, *icipe* is still making significant progress in developing new biopesticides, which are expected to be ready for dissemination in the coming months.

icipe research has led to the development of entomopathogens-based biopesticides, which are environmentally safe alternatives to chemical pesticides. Through a partnership with Real IPM Ltd, a number of *icipe* biopesticides, including Campaign® (ICIPE 69) and Achieve™ (ICIPE 78), pictured here, have been commercialised and are now being used by farmers across Africa to control a range of horticultural pests.

List of abbreviations and acronyms

AAS	African Academy of Sciences
ACIAR	Australian Centre for International Agricultural Research
AFFP	African Fruit Fly Programme
AIRCA	Association of International Research and Development Centres for Agriculture
ARPPIS	African Regional Postgraduate Programme in Insect Science
ASBCB	African Society for Bioinformatics and Computational Biology
AU-IBAR	African Union InterAfrican Bureau for Animal Resources
AWARD	African Women in Agriculture Research and Development
BMZ	German Federal Ministry for Economic Cooperation and Development
CCD	Colony collapse disorder
CDC	United States Centers for Disease Control and Prevention
CHIESA	Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa project
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement
DRIP	Dissertation Research Internship Programme
EIF TF	Enhanced Integrated Framework Trust Fund
EU	European Union
GIS	Geographical information systems
GIZ	German Federal Enterprise for International Cooperation
GLP	Good Laboratory Practice
GPS	Global Positioning System
GREEiNSECT	Insects for green economy
IBCARP	Integrated Biological Control Applied Research Program
IFAD	International Fund for Agricultural Development
IGGI	International Glossina Genome Initiative
ILIPA	Improving livelihood by increasing livestock production in Africa
INRB	Institut National de Recherché Biomédicale
INSEFF	Insect for Food, Feed and Other Uses
INSFEED	Insect feed for poultry and fish production in Sub-Saharan Africa
IPM	Integrated pest management

IRD	Institut de Recherche pour le Développement
ISCB	International Society for Computational Biology
ITAACC	Innovation Transfer into Agriculture Adaptation to Climate Change
IVM	Integrated vector management
KEMRI	Kenya Medical Research Institute
LPF	Livestock Protective Fence
M&E	Monitoring and evaluation
MHC	Major histocompatibility complex
MoU	Memorandum of understanding
MRL	Maximum residue level
NARS	National agricultural research system
NETFUND	National Environment Trust Fund
NSD	Napier Stunt Disease
OECD	Organisation for Economic Co-operation and Development
OWSD	Organization for Women in Science for the Developing World
PLOS	Public Library of Science
Q-TOF	Quadrupole Time-of-Flight
R&D	Research and development
RVF	Rift Valley fever
SCIPM	Strengthening Citrus Production Systems through the Introduction of IPM Measures for Pests and Diseases
SDC	Swiss Agency for Development and Cooperation
Sida	Swedish International Development Cooperation Agency
SSA	Sub-Saharan Africa
TBP	Tick-borne pathogen
ToT	Training of trainers
TWAS	The World Academy of Sciences
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNOPS	United Nations Office for Project Services
WHO	World Health Organization
WTO	World Trade Organization

icipe is grateful for the support of its donors from around the world, with funds provided by governments, research organisations and United Nations agencies. *icipe* also benefits from partnerships with universities, research institutes and the private sector. A full list of donors and institutions providing funding support to *icipe*'s research, development and capacity building activities is available online at: **www.icipe.org**

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icipe

Annual Report 2014

African Insect Science for Food and Health

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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ISSN 2309-3838

ISBN 978-9966-063-07-6