2017 *icipe* CORE ANNUAL REPORT

PROGRAMMATIC REPORTING BASED ON RESULTS BASED MANAGEMENT (RBM) WITH THE AID OF THE LOGICAL FRAMEWORK APPROACH (LFA)

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icipe

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EXECUTIVE SUMMARY

icipe 2017 Results Based Management Report

icipe's Results Based Management (RBM) with the aid of the Logical Framework Approach (LFA) is an institutional approach which ensures that management, scientists and staff contribute systematically to achieve the Centre's strategic objectives and mandate. In this 2017 RBM report, we highlight the Centre's achievements and work in progress which are contributing to *icipe's* research and development (R&D) objectives on insect science. Through research with partners and dialogue with stakeholders at all levels, the Centre is working towards a transformation in agriculture, health and nutrition sectors that will simultaneously support food and nutrition security, poverty alleviation and environmental sustainability.

RBM with the aid of the LFA (RBM-LFA) focuses on the entire programme management cycle; and plans, implements, monitors and measures the changes from an intervention, rather than just the inputs provided, or activities conducted. RBM-LFA focuses on the end results (expected outcomes).

The report is structured in four sections: an **introductory** section that provides a brief background on *icipe* and outlines its Centre-wide programmes. It also provides a brief description of the Centre's RBM journey. In the **second** section, we summarise *icipe's* 2017 advances in R&D. In brief, we are pleased to report the following programmatic achievements.

Plant Health Theme:

- Constructed the first DNA barcode reference library for the African Citrus triozid, *Trioza erytreae*, the principal vector for the African form of citrus greening disease.
- Following the detection of the citrus psyllid *Diaphorina citri* in Africa, the behavioural evidence for the attraction of the psyllid to citrus, specifically to lemon, has been documented.
- Launched an innovative facility to commercially produce a fruit fly protein bait known as Fruitfly Mania®, a product developed through public-private sector partnership for the control of fruit flies.
- Demonstrated that climate-smart Push-pull technology effectively controls fall armyworm (*Spodoptera frugiperda*) – a pest that continues to pose major threat to food security in Africa. *icipe* continues to play a major role in the management of fall armyworm and *icipe* participated in panel discussion on the subject at the World Food Prize in Iowa, USA.
- Introduced from Peru into Africa, a co-evolved parasitoid of *Tuta absoluta* (*Dolichogenidea gelechiidivoris*) for field releases against the damaging pest of tomato.
- Developed, for the first time in Africa, an evidence-based Insect-Feed Standard to guide the use of insects as feed ingredient in two countries (Kenya and Uganda) with the active participation of policy makers.

Animal Health Theme:

- Identified for the first time, the main vectors of surra in camel that includes *Hippobosca camelina*, *Stomoxys calcitrans, Pangonia ruppellii and Tabanus* spp. and the team is investigating their chemical interaction with camel.
- Showed that repellents placed at intervals of 10 meters and integrated with NGU traps (named after Nguruman, where it was developed) could effectively reduce the chances of tsetse flies crossing into protected areas by up to 68% thereby providing an opportunity to use novel and smaller reinvasion barriers as a cost-effective approach to protect livestock from vectors of trypanosomosis.
- Found that the waterbuck repellent blend (WRB) developed for *Glossina morsitans morsitans* was also effective against the vector of human African trypanosomiasis, *Glossina fuscipes fuscipes*, lowering biconical trap catches by between 30 - 50%.

Human Health Theme:

- Demonstrated that the use of a repellent 'push' and attractant 'pull' reduced house entry rates of the two major malaria vectors species (*Anopheles gambiae* s.l. and *An. Funestus*) by >50%.
- Found a strong negative correlation between *Microsporida* sp. infection density and *Plasmodium* infection density by experimentally challenging *Microsporida* sp. infected and uninfected *Anopheles* mosquitoes with *Plasmodium*.

- Employed plant DNA barcoding targeting multiple genes to identify host plants of field-collected Afro-tropical mosquito vectors: *Anopheles gambiae* (malaria), *Aedes aegypti* (dengue), and *Aedes mcintoshi* and *Aedes ochraceus* (Rift Valley fever) and this database will be exploited in vector surveillance and control.

Environmental Health Theme:

- Found that the African savannah honeybee which maintains lower mite colony infestations (~ three-fold lower) removed more mites and inflicted more damage categories to mites from their colonies than the European counterparts suggesting resistance mechanisms against the mite.
- Has succeeded in bar coding of seven silkworm stock to determine their genetic makeup and the results showed that the COI marker discriminated between *Eri* and *Bombix mori* species.
- Promoted climate change adaptation activities (e.g. installation of drip irrigation kits, roof rain water harvesting systems, conservation of soil and water resources, demonstration of improved maize technologies, release of parasitoids) in Kenya, Tanzania and Ethiopia.
- Organized bee research strategy workshop in September 2017 with an aim of discussing and developing priorities for bee research at *icipe* relevant to the continent of Africa and beyond.

The Social Science and Impact Assessment Unit (SSIAU) team documented that adoption of integrated pest management (IPM) by farmers to control fruit flies not only improved production efficiency but also contributed to environmental health by reducing pesticide use by 43% through adoption of three or more IPM components. The team highlighted the need to strengthen women access to malaria control and prevention information and health service delivery systems. This is to enhance agricultural productivity based on studies on gender heterogeneous effects of malaria risk on agricultural productivity in Ethiopia. The work on Push-pull technology (PPT) adoption and women empowerment showed a positive and significant effect on women dietary diversity score (WDDS) in western Kenya. In addition, the team found that there was no gender heterogeneity in the adoption of PPT indicating that the technology is gender-neutral.

icipe recently established the Technology Transfer Unit (TTU) with funding from a Swiss family through the Biovision Foundation. This Unit is operational and is pioneering the dissemination of Push-pull technology beyond east Africa to southern Africa. The Bioinnovate Africa Phase II Programme announced a second call for proposals, with a 3-year funding commitment of US$ 5 million.

The Centre has continued to make a significant contribution to building the capacity of individuals and institutions through the development of MSc, PhD and postdoctoral capabilities, and continued to conduct training and capacity building for various stakeholders who facilitate the adaptation and adoption of *icipe*'s technologies. *icipe* has also continued to conduct trainings for researchers, farmers, national program partners, and others in knowledge intensive areas of *icipe* technologies and products.

In the **third** section, we document detailed progress towards expected outputs and outcomes of the specific RBM logical framework for the Centre's four themes, insects for feed and food programme, social science and impact assessment unit as well as capacity building and institutional development programme.

In the **final** section, we provide a list of *icipe* publications. In 2017, the Centre published 137 peer-reviewed journal articles. Several of these articles were published in open access journals and some in very high impact journals. *icipe* scientists also edited/authored a book entitled "*Fruit Fly Research and Development in Africa: Towards a Sustainable Management to Improve Horticulture*", published by Springer International Publishing, Switzerland. The book has 34 chapters contributed by experts from Africa, Europe, Latin America and the USA.

SECTION 1: INTRODUCTION

1.1 *icipe* Brief Background

Established in 1970, the International Centre of Insect Physiology and Ecology (*icipe*) (www.icipe.org) is a pan-African, non-governmental and non-profit Centre of Excellence for research, development and capacity building in insect science and its application. It is headquartered in Nairobi, Kenya with 556 scientific and support staff. The Centre works on a 4-H (Health) paradigm, including plant, animal, human and environmental health, with arthropods as the common denominator to help alleviate poverty, and ensure food and nutritional security for smallholders in Africa. *icipe* focuses on green and sustainable pest control and is presently engaged in 30 African countries, and has thriving partnerships and excellent networks with many universities and research organisations in Europe and North America.

icipe is a founding member of the Association of International Research and Development Centers for Agriculture (AIRCA), a nine-member alliance that was established in 2012, which is focused on improving global food security by supporting smallholder agriculture within healthy, sustainable and climate-smart landscapes (www.airca.org) and is hosted at its Nairobi Campus. *icipe* is a designated Food and Agriculture Organisation of the United Nations **(FAO) Reference Centre** for vectors and vector-borne animal diseases, which include tsetse flies and animal trypanosomosis as well as arthropod-transmitted viral animal pathogens. Since 2010, *icipe* is a United Nations Environment Programme (UNEP) **Stockholm Convention Regional Centre** on Persistent Organic Pollutants (POPs). The Stockholm Convention is a United Nations international environmental treaty that aims to protect people, animals and the environment from chemicals.

In May 2017, *icipe* was officially designated as an **OIE Collaborating Centre for Bee Health in Africa** by OIE – World Organisation for Animal Health (the intergovernmental organisation responsible for improving animal health worldwide). This designation is significant as it formally recognises *icipe's* role as a hub for bee health R&D and expertise in Africa and globally. This recognition of *icipe* as an OIE Collaborating Centre for Bee Health in Africa will elevate its continent-wide basis and mandate and provide further confidence for stakeholders in Africa to collaborate with the Centre. *icipe* was granted a **National Commission for Science, Technology and Innovation (NACOSTI) Certificate of Registration**, jointly endorsed by the Cabinet Secretary, Ministry of Education, Science and Technology, and the Director General, NACOSTI, Kenya in March 2017. The certification signifies *icipe's* compliance with the Science, Technology and Innovation Act (No. 28 of 2013), which, in part, mandates NACOSTI to regulate and assure quality in the science, technology and innovation sector.

The Centre has outstanding research facilities including FAO accredited quarantine facilities as well as a Good Manufacturing Practices (GMP)-compliant enhanced Biosafety level 2/3 laboratory (the Martin Lüscher Emerging Infectious Diseases Laboratory), insectaries, and a state of the art African Reference Laboratory for Bee Health. These facilities enable the Centre to address the increasing need for preparedness and response to emerging animal and human diseases in the region.

1.2 *icipe* Centre-wide programmes

The following are the overall objectives of the 4-H (health) Themes and Capacity Building and Institutional Development (CBID) Programme.

Plant Health Theme: Contribute to stabilising horticultural and staple food production by reducing quantitative and qualitative pre- and post-harvest yield losses due to insect pests, mites, weeds and mycotoxin-producing fungi by developing economically viable and ecologically sound production systems with low pesticide input.

Animal Health Theme: Contribute to the improvement of livestock health and productivity through the development of integrated strategies and tools for livestock disease vectors' control and adoption by development partners, thus leading to greater availability of meat and milk, hides and draught power and thereby assisting livestock owners to get out of the poverty trap.

Human Health Theme: Contribute to the reduction of malaria and other vector-borne diseases by developing tools and strategies that control the vectors and break the cycle of transmission, and which can be integrated with other disease management efforts.

Environmental Health Theme: Conservation and sustainable utilisation of the agricultural production base and important natural ecosystems, by encouraging and utilising arthropod diversity, cataloguing and sharing biodiversity data, and discovering endemic wealth by bioprospecting for useful natural products.

Capacity Building and Institutional Development (CBID) Programme: Develop well-trained and highly motivated human capacity and strengthen institutional and policy making capacity and capability required to respond to the arthropod-related development challenges in Africa.

1.3 Brief on icipe's Results Based Management Framework

The *icipe*'s journey towards Results Based Management (RBM) with the aid of the Logical Framework Approach (LFA)[1] started in early 2010, when *icipe*'s Governing Council (GC) and Management, in consultation with its core donors, agreed to develop an RBM framework to support the Centre's Strategic Priorities, Policies and Guidelines for research and development (R&D) of insect science. Prior to the implementation of the RBM-LFA, *icipe* used the Medium-Term Plan as a reporting framework but like many other international organisations, it introduced RBM in early 2011 as its new strategic planning and management tool. Since 2012, *icipe* instituted the RBM as an operational framework that explicitly links the strategic objectives and priorities of the Centre to the various programmes and projects that it finances that collectively helps towards achieving its goals and objectives.

The RBM-LFA is useful for *icipe* in promoting efficient management techniques. The systematic approach of gathering and assessing progress of results that is measured against key objectives is a cost-effective way to diagnose early weaknesses in implementation plans. Periodic and targeted information enables the GC and *icipe* Management to recognise activities that generate the highest pay-offs in terms of results, or those that require support to deliver key results that are aligned with strategic priorities. Using this approach, the Centre is able to track and measure progress towards objectives, and thus reach targeted decisions to improve performance on a progressive basis. Process monitoring is a critical part of the exercise to monitor whether portfolios are being implemented as intended, standards are being met, and resources are being used efficiently.

Each of *icipe's* core activity area has specific RBM framework. All projects activities go through a cycle of knowledge management and continuous learning. The Thematic Programmes and Capacity Building frameworks cover a cycle of planning, periodic performance assessment and organisational learning – all of which are supportive of knowledge creation and sharing. Learning from the R&D activities influences strategy development and programmatic and project design, and lessons learnt periodically feeds back into programme/project implementation. The learning component is also critical for identifying and managing risks while bearing in mind the expected results and resource levels. This has helped to increasingly expand the knowledge of each operation through learning, knowledge dissemination and feedback for decision making, project design and strategy development.

RBM-LFA is indeed a strategic management approach that ensures *icipe*'s R&D activities are implemented in collaboration with our partners to contribute to a logical chain of results that provide knowledge-based solutions aimed at equipping the communities in Africa to sustain livelihoods within a rapidly changing global environment.

In 2017, the Centre, achieved great milestones in its R&D activities as captured in the following reports for each of the focal area at *icipe.* During the reporting period of January – December 2017, *icipe* published a total of 137 peer reviewed journal articles and several other articles and publications of scientific value.

[1]Ortengren, K. 2016. A guide to Results-Based Management (RBM), efficient project planning with the aid of the Logical Framework Approach (LFA). Swedish International Development Cooperation Agency (Sida), Stockholm, Sweden, 42p.
https://www.sida.se/contentassets/9d257b83f4124113a324c61715150722/21920.pdf

SECTION 2: 2017 Advances in Achieving Research and Development (R&D) Objectives

icipe contributes collectively to steadily increase its influential position as a scientific organisation working actively in more than half of all the countries on the African continent. *icipe*'s blend of R&D activities that span the spectrum of new discoveries in fundamental science to strategic applications that deliver practical outcomes have continued to impact its constituents. *icipe*'s main focus on 4-H paradigm is providing solutions for tackling challenges in health, food and nutritional security.

Research activities of all four health themes continue to match their focus on science with a parallel commitment to making a difference on the ground by employing diverse combinations of technology transfer models, partnerships, training and communication to encourage adoption and improve livelihoods.

A few examples in achieving the major R&D objectives in 2017 are highlighted below.

2.1 Plant Health Theme

2.1.1 Controlling citrus insect pests and diseases

DNA barcode reference library for the African Citrus Triozid, Trioza erytreae: *Trioza erytreae* is the main vector of '*Candidatus Liberibacter africanus'*, the causative agent of Greening disease in Africa. We have generated a novel barcode reference library for *T. erytreae* using DNA barcoding as a rapid tool for accurate identification of the pest to aid phytosanitary measures. Triozid samples from citrus orchards across Kenya, Tanzania and South Africa, and from alternative host plants were analyzed. All samples analysed linked to a *T. erytreae* of accession number KU517195 from GenBank. The phylogenetic tree was paraphyletic with two distinct branches. The first branch had two clusters: a) cluster of all populations analysed with GenBank accession of *T. erytreae*; and b) cluster of all the other GenBank accessions of *Trioza* species analysed except *T. incrustata*, *T. eugeniae* and *T. grallata* that occupied the second branch as outgroups forming sister clade relationships. These results have been substantiated with genetic distance values and principal component analyses.

First report of Diaphorina citri in Kenya: The Asian Citrus Psyllid, *Diaphorina citri*, a damaging pest of citrus globally was detected in East Africa. This insect is notorious for its ability to vector the fastidious phloem-limited bacterium *Candidatus Liberibacter asiaticus* (CLas), the putative causal bacterium of Huanglongbing or Asian citrus greening disease. Molecular tools based on the use of DNA barcode were employed to confirm the identity. In addition to *D. citri*, the occurrence of *T. erytreae* in the same sampling locations of different elevations in three countries (Tanzania, Kenya, Zanzibar) was also determined. *Diaphorina citri* was sympatric with *T. erytreae* at the mid to higher elevations of 1375–1666 meters above sea level (masl) and no *T. erytreae* or its open-gall symptoms were detected below 523 masl. Sequences obtained were queried via BLAST and all linked to *D. citri* of different accession numbers, already available in GenBank. This is the first report of the presence of *D. citri* in Kenya and Zanzibar.

Development of semiochemical based tools for the management of the African Citrus Triozid (ACT) Trioza erytreae: The use of semiochemicals has been identified as a potential management tool against the African Citrus Triozid, a major pest of Citrus in Africa and some parts of Europe and Asia. Behavioural evidence for the attraction of ACT to citrus, specifically lemon, has been established and confirmed in olfactometer and Ethovision bioassays. Sex pheromone studies have revealed that males are attracted to female odour whereas females avoided male odour. Studies are ongoing to elucidate the components in the odour profiles of the different sexes to identify the sex pheromones towards identifying different potent lures for field monitoring of ACT populations.

2.1.2 Management of fruit flies

Description of new fruit fly species: *icipe* team contributed to description of five new *Ceratitis* species from the eastern and southern parts of the Afrotropical region. These are *C. (Pterandrus) quilicii* De Meyer, Mwatawala & Virgilio sp. nov.; *C. (Ceratalaspis) pallidula* De Meyer, Mwatawala & Virgilio sp. nov.; *C. (Ceratalaspis) taitaensis* De Meyer & Copeland sp. nov.; *C. (Ceratalaspis) sawahilensis* De Meyer & Virgilio sp. nov.; and *C. (Ceratalaspis) flavipennata* De Meyer & Virgilio sp. nov. DNA barcodes were developed for all new species. *Ceratitis taitaensis* is a new species from

Taita Hills. Using several integrative taxonomy tools, *icipe* researchers resolved the identity of *Ceratitis quilicii*, formerly considered to be the highland population of *Ceratitis rosa*, an important pest of commercial fruits. Subtle differences in molecular and morphological characters led to the recognition that the closely related forms (highland and lowland *C. rosa*) were actually separate, sibling species. In addition, the hitherto unknown male of *C. (Pardalaspis) serrata* De Meyer, 1996 was described, based on material collected in the Democratic Republic of Congo.

Screening for facultative endosymbionts in African fruit flies: Screening for endosymbionts in *Bactrocera dorsalis*, have yielded *Spiroplasma* and *Wolbachia* as the two major endosymbionts in this pest. The observed trend in our screening and laboratory reared colonies showed a rapid increase and almost stable equilibrium of *Wolbachia* infection in *B. dorsalis* populations. The team has characterized the detected *Wolbachia* sp. as belonging to two major supergroups i.e. A and B, with supergroup A being the most dominant type.

Fruit fly bait production facility in Kenya inaugurated and Fruitfly Mania™ produced: A facility to commercially produce a fruit fly protein bait known as Fruitfly Mania™, a product developed through research by *icipe* for the control of fruit flies, was launched in Kenya on 29 March 2017. The plant was constructed through a public private sector partnership between *icipe* and Kenya Biologics Ltd. The project team optimized an extract from waste brewer's yeast (an industrial by-product from East Africa Breweries Ltd), to develop Fruitfly Mania™, which was tested in farmers' fields and found to be effective, leading to its commercialization. The retail cost of Fruitfly Mania ™ is 70% less than the other commercially available products. The Fruit Fly Protein Bait Facility has a production capacity of 2,000 litres per day, enough to meet the local demand of over 229,000 households whose livelihoods depend on mango production in Kenya. An additional 400,000 mango growers will benefit from Fruitfly Mania™, once the product is registered across East Africa (to include Uganda and Tanzania). *icipe* is currently testing more ecofriendly toxicants that can be pre-mixed with Fruitfly Mania™. Our preliminary findings have identified two bacterial based biopesticides that have the same killing efficacy as the other commercial toxicants.

2.1.3 Push-pull technology

Climate-adapted push-pull effectively controls fall armyworm: Fall armyworm (FAW) *Spodoptera frugiperda*, an economically important pest native to tropical and sub-tropical America has recently invaded Africa, causing substantial damage to maize and other crops. Annual losses to African economy attributable to FAW on maize alone are estimated at US$ 6.2 billion. The team has evaluated functionality of climate-adapted Push-pull using drought-tolerant Greenleaf *Desmodium* (*Desmodium intortum*) and *Brachiaria* as intercrop and border crops, respectively, to manage FAW in Kenya, Uganda and Tanzania. Direct field observations and farmers' perceptions indicated that there were highly significant reductions in infestation by FAW larvae and plant damage in climate-adapted Push–pull compared to maize monocrop plots. Maize grain yields were 2.7 times higher in the climate-adapted Push-pull plots. Farmers rated the technology as significantly superior in reducing FAW infestation and plant damage rates. These results demonstrate that the technology is effective in controlling FAW and represent the first documentation of an urgently needed technological option that can be immediately deployed for the management of this pest in East Africa and beyond.

Drought-tolerant Desmodium species effectively suppress parasitic Striga weed and improve cereal grain yields: The parasitic weed *Striga hermonthica* is an increasingly important constraint to cereal production in sub-Saharan Africa (SSA), often resulting in total yield losses in maize and sorghum. Forage legumes in the genus *Desmodium*, mainly *D. uncinatum* and *D. intortum*, effectively control *Striga* and improve crop productivity in SSA. In further adaptation of the *Desmodium*-based intercropping, we had earlier screened 17 accessions comprising 10 species of *Desmodium* for their tolerance to drought stress. From these, *D. incanum* and *D. ramosissimum* were selected as the most promising species as they tolerated drought stress better and also had desirable phenotypes with greater potential of above ground biomass production. In validation studies with farmers, the two *Desmodium* species effectively suppressed *Striga* infestation in both maize and sorghum, resulting in significant grain yield increases. These results indicate the incremental capability of *Desmodium* species in *Striga* suppression and in enhancing cereal productivity, especially in dry areas.

2.1.4 Management of the tomato leafminer (*Tuta absoluta*)

***Classical biological control of T. absoluta*:** *Dolichogenidea gelechiidivoris* (Marsh) (Hymenoptera: Braconidae: Microgastrinae), a co-evolved parasitoid of *T. absoluta*, was received at *icipe* Bio-containment facility in March 2017. Currently, performance and specificity studies on the African *T. absoluta* population are underway as well as non-target studies on related Gelechidae for subsequent field releases. In Sudan, a parasitoid belonging to the same genus (*Dolichogenidea*) has been found to form new association with *T. absoluta*. This parasitoid is new to science and is currently being described.

***Semio-chemicals for T. absoluta management*:** Responses of *Tuta absoluta* females to a wild (*Lycopersicon esculentum var. cerasiforme*) and cultivated tomato was assessed in a dual–choice olfactometer. The female moths were attracted to the cultivated but repelled by the wild variety. In field trials, cultivated tomato intercropped with the wild tomato, had a lower *T. absoluta* population as well as significantly lower infestation levels. Furthermore, gas chromatography–linked electroantennography (GC–EAD) revealed a large proportion of EAG–active compounds from the two varieties. Of these, 13 compounds (trans-3-hexenol, verbenene, 4-keto-isophorone, camphor, citronellal, isopulegol, limonene oxide, linalool propanoate, germacrene A, β-elemene, germacrene B, germacrene D, and β-bisabolene) were unique to the wild tomato possibly conferring the repellence trait. This study lays foundation for exploiting semiochemical characteristic of the wild tomato variety for innovative management of *T. absoluta*.

2.1.5 Plant parasitic nematode research

Two species of PCN (potato cyst nematode) detected in Kenya: PCN was reported for the first time in Kenya (and in the region) in 2015 with funding from FAO TCP. We have confirmed the identification of two species (*Globodera rostochiensis* and *G. pallida*) in all the 20 counties in Kenya. It is noteworthy that this is the first report of *G. pallida* in Kenya and a publication on the same is in preparation. *icipe* has also participated in training of 26 Government technicians and students. BMZ, Germany has also recently provided funds to *icipe* for a project on PCN, that will be used for characterization of Kenyan populations of PCN, and initiate the search for efficient trap crops and biological control agents.

MUSA – a new programme for sustainable technologies for control of key pests in banana: *icipe* together with partners from Europe (Italy, Spain, Belgium, UK), Central America and the Caribbean (Costa Rica and Cuba) and SSA (Kenya and Ethiopia) have been granted a 4-year project funded by the EU (H2020) to study endophytes and biocontrol agents (EBCAs) against key banana pests. *icipe* will be involved in the screening of EBCAs against the burrowing nematode (*Radopholus*), the lesion nematode (*Pratylenchus*) and the banana weevil (*Cosmopolitis sordidus*). All these pests feed on and damage roots of banana, weakening the plant and causing toppling even with the lightest winds.

2.1.6 Insects for food and feed (INSEFF) Programme

Insects for poultry and fish feed: Research showed that layer chicken fed on black soldier fly based feed laid 62% more eggs and kept egg laying above economic threshold longer than those fed on conventional feed based such as soybean and fish meal. Insect based feed also provided 23% higher weight than conventional feed for Tilapia and catfish while on broiler chicken, both conventional and insect based feed performed equally. Insect as alternative protein source is further estimated to reduce feed production cost by 23-37.5%. These findings have enabled the team to develop for the first time Insect-based Feed Standard, in collaboration with policy makers, to guide the use of insect as feed ingredient in Kenya and Uganda.

Nutritional profiling of edible insects: Grasshoppers, crickets and saturniid caterpillars are among the edible insects consumed in East Africa. We have conducted studies on the proximate composition of *Ruspolia differens*, *Gryllus bimaculatus* and *Gonimbrasia belina* when freeze and oven dried, and in the case of *R. differens* from Uganda when boiled and fried. The dry matter contents varied from 31.6% in *G. bimaculatus* to 94.7% in fried *R. differens*. Oven dried *G. belina* has the least crude fat content of 12.8% while fried *R. differens* has the highest with 62.4%. The crude protein content ranged from 43.4% in winged *R. differens* to 28.1% in fried *R. differens*. The ash content ranged between 2.8 in winged *R. differens* and 4.9 in boiled *R. differens*. The highest amounts of acid detergent fiber (20.6%) and crude fiber (14.7%) were recorded in freeze dried and oven dried *G. belina,* respectively.

2.2 Animal Health Theme

2.2.1 Tsetse fly research

Evaluation of the integrated use of tsetse repellents with traps to minimize tsetsefly reinvasion of farmland around parks: To exploit the *icipe's* novel tsetse repellent technology as a new approach to tsetse control, the effectiveness of repellent-based reinvasion barriers around the Shimba Hills National Reserve was evaluated in collaboration with the Kenya Wildlife Service. Repellents placed at intervals of 10 meters and integrated with NGU traps (named after Nguruman, where it was developed) reduced the chances of tsetse crossing into protected areas by up to 68%. This demonstrates that with improvements, such repellent-based barriers could be used to stop the vectors from re-invading areas where they have been cleared. Further, data from year-round collections using 171 biconical trap revealed that more than 80% of tsetse flies occur within 0.5 km off the park boundary and nearly all within 2.5 km of the park. This provides an opportunity to use novel and smaller reinvasion barriers around the park as a cost-effective approach to protect livestock from vectors of trypanosomosis.

Evaluation of repellents for control of vectors of human sleeping sickness: This study aims at adding repellents to the arsenal of low-cost vector control tools against sleeping sickness. The waterbuck repellent blend (WRB) was developed and tested for the Savannah-dwelling tsetse fly species, *Glossina morsitans morsitans*. In this study, carried out in islands in Lake Victoria, WRB was evaluated against *G. fuscipes fuscipes*, the major vector of Human African Trypanosomiasis (sleeping sickness). It was found that WRB is effective against the species lowering biconical trap catches by 30 - 50%. Reducing the blend complexity to lower its cost by removing either delta-Octalactone or Pentanoic acid did not impact its effectiveness against *G. f. fuscipes*. These results show the potential of WRB against the infective bites of this abundant vectors of human sleeping sickness. The finding that the constituents of the blend can be reduced without significant loss of efficacy demonstrates that the cost-effectiveness of such a tool could be further optimized.

2.2.2 Camel Health

Attractive and effective killing and repellent system for control of key vectors of surra: Camel trypanosomiasis caused by *Trypanosome evansi* is the most important infectious disease that affect camel health and productivity. The team aims to develop an environmentally friendly technology to interfere the chemical communication between biting flies and camel. To achieve this objective, the team has identified the main vectors of surra as the following: *Hippobosca camelina*, *Stomoxys calcitrans, Pangonia ruppellii* and *Tabanus spp* and is currently investigating their chemical interaction with camels. The identified semiochemicals include such as *p-cresol*, n*aphthalene*, *decanal, β-pinene, acetophenone,* and *camphene*. Once the most suitable attractant(s) and effective repellent(s) compounds have been identified, they will be field-tested as a proof of concept at watering point as well as in camel enclosure to protect camels from biting flies, and from the disease they transmit.

2.3 Human Health Theme

2.3.1 Novel tools development for malaria control

Pilot field study to test a Push-pull strategy for malaria vector control: In this Grand Challenges Exploration Grant, funded by the Bill & Melinda Gates Foundation, the team evaluated the impact of a repellent "push" to divert malaria mosquitoes from houses and an attractant "pull" to remove mosquitoes from the environment in 12 standardized experimental houses. These houses were specifically built for the project and occupied by families in a rice-farming village of western Kenya. Push-pull reduced house entry rates by >50% of *An. gambiae* s.l. and *An. funestus*, the two major malaria vectors species in Kenya. This is the first time that Push-pull for malaria vector control has been evaluated under a typical household setting and the results indicate that the intervention could form a promising new tool for the control of malaria mosquitoes, particularly in regions where mosquitoes are outdoor or early evening biting and where resistance to pyrethroid insecticides has been reported.

Tracking the mothers - applying microsatellite genetic makers to estimate the number of female malaria vectors laying eggs in an aquatic habitat: The team studies the population genetics, oviposition behaviour and dispersal of the malaria vector *Anopheles arabiensis*. To study how many gravid females visited a site, the team needed to be able to identify sibling larvae from a

breeding site. For this, 15 microsatellite markers for *Anopheles arabiensis* were optimised and their Mendelian inheritance patterns validated in known pedigree families. Preliminary pairwise relatedness analysis on 425 larval samples across the 18 ponds suggested up to 81 ovipositing females and potential high rates of skip oviposition. This work will inform the development of more targeted, and novel tools for larval control (targeting outdoor malaria vector populations) such as auto-dissemination approaches.

Investigating the malaria transmission blocking capacity of mosquito symbionts (Spirovector Project): The team is investigating *Anopheles* mosquito symbionts as a *Plasmodium* transmission-blocking strategy to decrease disease burden in developing countries. Two novel microbes (*Spiroplasma* and *Microsporida* sp.) were isolated that have potential transmission blocking activity. By experimentally challenging *Microsporida* sp. infected and uninfected *Anopheles* mosquitoes with *Plasmodium*, the team demonstrated that there is a strong negative correlation between *Microsporida* sp. infection density and *Plasmodium* infection density. This clearly suggests that *Microsporida* sp. inhibits the transmission of *Plasmodium* under laboratory conditions. The team found that *Microsporida* sp. prevalence varies during the wet season, from an initially low prevalence of less than 10% to reach higher levels by the end of the wet season (60-80%). These findings serve as a proof of concept that symbiotic microbes (naturally associated with *Anopheles* mosquitoes) can block *Plasmodium* transmission. *Microsporida* sp. is a ubiquitous parasite in natural *Anopheles* populations (and colonies), with highly effective transmission strategies. It therefore, has many of the characteristics that would make it highly effective as part of a strategy to control malaria.

2.3.2 Neglected tropical diseases research and management

***Tungiasis (sand flea disease) risk factor analyses*:** Tungiasis, a parasitic skin disease, inflicts pain and suffering on millions of people in SSA, and yet gets little attention from donors, scientists, governments and health workers. It is an ectoparasitosis affecting the poorest of the poor living in tropical and subtropical conditions. In resource-poor communities, prevention is the most valuable control measure. Risk factor analyses revealed that all the factors identified to double and triple disease risk were directly associated with lowest socio-economic status (poor housing, lack of hygiene, and poor clothing including the absence of shoes). Results indicated that simple measures could be implemented to prevent the disease. The team currently advocates for tungiasis to be included in WHO's official list of NTDs and pursues avenues for project funding on proof of principle.

2.3.3 Arboviral research and management

Assessing the risk of Transmission of Yellow Fever, Dengue and other arboviruses: The risk for transmission of key mosquito-borne viral diseases including Yellow Fever and Dengue in selected parts of Kenya has been an ongoing research area at *icipe*. Sites include the three main cities, Mombasa, Nairobi and Kisumu and along the borders with two counties (West Pokot and Turkana) which have recently experienced outbreaks. Risk was being measured by: estimation of vector abundance (larval indices); determination of vector potential (competence in virus transmission and feeding preference); and estimation of disease seroprevalence among the selected populations. The latter is based on vector abundance for *Aedes aegypti* (DEN-vector) and *Aedes simpaoni* (YF-vector), and risk of transmission of dengue is high in Mombasa and Kisumu but low in Nairobi. The risk analysis is critical to decision making towards disease prevention/control through cost effective targeted vaccination coverage, and targeted vector control intervention. These measures will help put in check alarming re-emergence of dengue, Yellow Fever, Chikungunya and others in East and Central Africa.

***Sandfly-arbovirus association*:** In a climate of emerging/re-emerging arboviral pathogens often associated with unpredictable outbreaks, risk assessment through active monitoring for their circulation in disease vectors becomes crucial. The team has uncovered a previously unknown phlebovirus from sandflies in Kenya. The virus showed broad permissiveness growing in cell lines from a broad range of mammalian hosts (wildlife: monkeys, rodents and bats; livestock: cattle, swine, goats and chicken) and humans. It was also found to be pathogenic in suckling mice causing illness and resulting to death following infection. The team found evidence of human infection with the virus following detection of neutralizing antibodies to the virus in sera samples from patients with non-specific fevers. Overall, the data highlight the zoonotic potential of a previously unknown human pathogenic arbovirus circulating in East Africa.

***Plant-feeding association of Afrotropical Disease vectors*:** Plants contribute to the fitness of mosquito disease vectors, yet the identity of plant species they feed on in nature remains largely

unknown. The team has employed plant DNA barcoding, targeting multiple genes to identify host plants of field-collected Afro-tropical mosquito vectors: *Anopheles gambiae* (malaria), *Aedes aegypti* (dengue), and *Aedes mcintoshi* and *Aedes ochraceus* (Rift Valley fever). Based on detailed chemical analyses combined with electrophysiology, the team identified antennally-active components comprising terpenes, benzenoids, aldehydes and alkenes whose levels and detection varied among the host plants and between the mosquito vectors. Further, significant antennal responses by *An. gambiae*, *Ae. aegypti* and *Ae. mcintoshi* to specific monoterpenes, common in all the plants, suggest involvement of signature cues in plant location. These findings will be exploited in vector surveillance and control.

2.4 Environmental Health Theme

2.4.1 Bee pests and diseases control

***Mechanisms of resistance and tolerance in African and European honeybees,* Apis mellifera*, against Varroa destructor*:** The team compared grooming and hygienic behaviors in the African savannah honeybee, *Apis mellifera scutellata* in Kenya and *A. mellifera* hybrids of European origin found in the United States of America to identify the resistance and/or tolerance mechanisms that confer survival in *A. m. scutellata* against *Varroa destructor* mite. The team identified two additional undescribed damaged mite categories associated with the grooming behavior in both honeybee subspecies. The team also found that the African savannah honeybee which maintains lower mite colony infestations (~ three-fold lower) removed more mites and inflicted more damage categories to mites from their colonies than for their European counterparts. However, the expression level of hygienic behaviour was similar in both honeybee subspecies. This finding suggests that grooming behavior could be a potential tolerance mechanism displayed by the African savannah honeybee towards mite attack. However, both hygienic and grooming behaviours could not explain the lower mite-infestation levels recorded in *A. m. scutellata* colonies suggesting that other resistance mechanisms might play an important role in their survival against the mite.

Plant based biopesticides for bee pests and diseases control: A non-toxic plant-based biopesticides have been under development for control of bee pests and diseases as an eco-friendly alternative to harmful synthetic acaricides that are currently in use for control and management of pests in bee hives. Validation studies for the fumigant biopesticide product, *Apicure®*, have been initiated in Kenya and other African countries under semi-field and field conditions, where it was shown to be effective in killing varroa mites and repelling hive beetles in bee colonies. The invention is protected by a patent and a registration dossier has been compiled and discussions initiated towards its registration with Pest Control Products Board of Kenya, and subsequently to be modified for submission to other African countries. Over 15,000 packaged pieces of the product have been produced and some have been provided to beekeepers/farmers in some countries in Africa for initial testing.

***Alternative livelihoods for food and income security in four Indian Ocean Island Nations (Mauritius, Seychelles, Comoros and Madagascar) and in Zanzibar*.** The focus is on technology transfer in beekeeping, building capacity of partnering institutions and development of honey market places. The parasites and pathogens detected include *Varroa* (Mauritius, Zanzibar and Madagascar), small hive beetles, *Nosema,* and Black queen cell virus (in all 5 islands). Additional pathogens were found in Zanzibar (Deformed wing virus, Israeli acute paralysis virus and Acute bee paralysis virus). The diversity of honey bee viruses is correlated with the presence of *Varroa* and the duration of interaction between mites and the honey bees. An emerging fact is that beekeepers are currently reporting higher colony survival rates compared to when Varroa mites were first reported in cases where chemicals have not been used.

Nesting ecology, genetic diversity and phylogeny of African stingless bees: Survey and inventory of stingless bee species to assess diversity, nesting ecology and impact of landscape on species distribution have been accomplished in selected forest habitats and their surroundings in Kenya, Zanzibar and Madagascar. Management technique for underground species is still being investigated. The Pollination Ecology unit has also received a grant from Bayer-Germany to carry out additional research work on pollination in greenhouse, nesting ecology, genetic diversity and phylogeny of African stingless bees with emphasis on species discrimination based on wing geometry, morphometrics, mitochondrial DNA and microsatellites from samples taken mainly from D. R. Congo, Ethiopia, Cameroon, and Kenya. Other countries (Botswana, Gabon) with endemic

species are also targeted. In addition, a stingless bee book from data collected in previous and new countries will be edited to include the new found information.

***Microbe-based strategies for improved bee health management*:** The main goal of the work is to increase honeybee fitness and thus bee pollination services by investigating gut microbial diversity and the nature of specific beneficial interactions between microbes and honeybees. The plan is to lay the foundations for microbe-based strategies (e.g. development of probiotics) for improved bee health management. The team is currently analyzing bee gut samples from different locations in Kenya and the Indian Ocean Nations to uncover novel gut microbiota members and their abundance. In parallel, the team has succeeded in isolating 400 single bacteria strains to establish an African bee gut microbiota library for physiological studies. The team is focused on detecting endosymbionts that reside in the bee hemolymph that could also be used as potential indicators of bee health.

2.4.2 Youth Entrepreneurship in Silk and Honey (YESH) project

***Demonstrating insect based technologies in support of youth livelihoods*:** As of September 2017, the project had recruited, trained and engaged a total of 3,119 unemployed beneficiary youth (26.5% female) in apiculture and 553 (66% female) in sericulture in the six project districts in Ethiopia. Following a thorough recruitment of needy unemployed youth by local authorities against technical criteria set by the project team, the project has rolled out a series of training workshops in all project sites for all recruited youth on entrepreneurship skills development. A total of 3,119 of the recruited youth and the local extension staff received technical training in apiculture or sericulture at village level. The beneficiary youth have been organised into 205 registered youth beekeeper enterprises and 34 sericulture youth enterprises. These enterprises have also established group savings accounts with local microfinance institutions and made total savings of US$ 83,000 in apiculture sites and US$23,000 in sericulture sites, to meet some initial establishment costs and gain access to credit services.

Expanding job opportunities along the value chain: With the view to generating additional job opportunities and encouraging local market linkages, the project has identified and engaged 17 small- and three medium-scale woodworks enterprises to manufacture all the frame hives needed for 2007. These alone have opened up at least 148 direct additional jobs. The three beekeeper protective clothing suppliers also employed 17 additional assistants to deliver on these contracts. Likewise, for sericulture starter kit supplies, a new youth enterprise with 25 members was established to supply the project with silkworm rearing trays. These local suppliers have been delivering starter kit items since August 2017.

2.4.3 Silkworm farming and management

***Characterization and conservation of genetic diversity in silkworms*:** The team is focusing on population genetics studies (Genome characterization) of *Bombyx mori* and *Samia cynthia ricini* silkworm strains in Kenya and Ethiopia. The main aim is to establish the population diversity - genetic variability, polymorphism, inbreeding index and molecular characterization among other traits, that will help characterize the best population for marker assisted selection, to improve *icipe* stocks. The team has undertaken bar coding of seven silkworm stocks (ICIPE I, ICIPE II, QXB, QXH, SXM, 75xin and Eri species) to determine their genetic makeup.

2.4.4 Adaptation to climate change and ecosystem resilience

***Adaptation for food security and ecosystem resilience in Africa (AFERIA) project*:** The project team is strengthening the capacities to monitor and adapt to climate change impacts in the Eastern Afromontane Biodiversity Hotspot. The main objective is to improve food and nutrition security, and the livelihood of small scale farmers, achieved with the help of local partners in the four target regions with a focus on implementing the community-based adaptation action plans. The project team has conducted adaptation activities in Taita Hills and Murang'a in Kenya, Kilimanjaro region in Tanzania and Jimma Region in Ethiopia. They introduced and promoted bee-keeping as an alternative livelihood, and through intervention and awareness creation campaigns, promoted conservation of soil and water resources. The team also succeeded in demonstrating benefits from improved maize technologies (30 sites), and pre- and post-harvest coffee management practices (30 sites), and released parasitoids as natural control for pests. In addition, they also supported adoption of avocado as an enterprise and as an alternative crop and conducted workshops and field activities for trainings on all the interventions.

2.4.5 New identifications and discoveries in biodiversity and conservation

Survey and inventory of Kenyan insects: The Biosystematics Unit continued its very productive Malaise trap survey of Kenyan insects, adding ~ 7500 specimens, with an emphasis on parasitic Hymenoptera, to the *icipe* collection. Collaboration with taxonomists worldwide resulted in nearly 150 unknown species described and published, a few of these even collected on the *icipe* Nairobi campus during training of ARPPIS students on the basics of insect taxonomy and identification. Many more are being studied and named at present, in several "in press" and submitted manuscripts.

***Discovery of new species* - Neopauroripdius muhakaensis**: This new species is yet another gem unearthed in *icipe*'s Muhaka Forest and has been given the name *Neopauroripidius muhakaensis*. Members of this tribe are all endoparasitoids of roaches. Females are neotenic, mature specimens resembling larvae but fully developed physiologically. As a consequence, the females are wingless and even less frequently collected than are the males.

Identification of new species of* Cotesia *and its use as a biological control agent towards* Sesamia nonagrioides *in Europe: The L'Institut de recherche pour le développement (IRD) team at *icipe* in collaboration with the IRD team based at CNRS at Gif-sur-Yvette is developing a classical biological control programme in France to control *Sesamia nonagrioides*, an important maize pest. *Sesamia nonagrioides* is an African cereal stemborer that invaded Europe and near and Middle East. It has become a major pest of maize and sorghum in Mediterranean countries and in France, where it has progressed up to the Loire valley in the last 10 years. Chemical control is the only method deployed to reduce infestations. In this context, the team has identified a new parasitoid species namely, *Cotesia typhae* Fernandez-Triana sp. n., associated with *S. nonagrioides* populations in Kenya, opening new avenues for utilisation as a biological control agent to control *S. nonagrioides* in the Mediterranean region.

Discovery of new parasitoid species in the African Indigenous Vegetable IPM project*:* The team has identified two important indigenous parasitoids that can be considered for conservative and augmentative biological control of amaranth Lepidopteran defoliators. *Apanteles hemara* was effective against the leaf webbers, *Spoladea recurvalis* and *Udea ferrugalis* while a new species of *Cotesia* that was recently described by the team has been found effective against the leaf worms *Spodoptera littoralis* and *S. exigua*. This parasitoid has also been found to be effective against the fall armyworm (*S. frugiperda*).

2.4.6 Geo-information

Geo-Information for bee health: The Geo-Information working group has developed an operational modelling framework to assess the spread of important bee pest (*Aethina tumida, Galleria mellonella, Oplostomus haroldi* and *Varroa destructor*) in eastern Africa. The group found that remote sensing variables (i.e. vegetation seasonality) improve climate-variable driven modelling analysis of pests in Africa. Moreover, the effect of climate change on the pest distribution patterns was analysed to help countries better plan their pest intervention strategies going forward.

***Geo-Information, species diversity and climate change*:** Spatial distribution shifts of honeybees (*Apis mellifera*) abundances were assessed for Zanzibar Island (Tanzania). The climate projections, specifically temperature driven, showed where and how spatial patterns will change until the year 2055. This new data set will help stakeholders in the Indian Oceans Islands region to improve their understanding of the role of temperature changes on the spatial distribution of honeybees.

***Geo-Information and Rift Valley Fever (RVF) propagation*:** The Geo-Information group has used animal movement ecology of sentinel livestock herds in northern and central Kenya and geo-spatial information relevant to mosquito vector habitat availability to ascertain the risk and spread of RVF in livestock herds in Kenya. This is the first comprehensive study that shows the potential of using several geo-spatial data feeds (Global Positioning System–collaring, remote sensing and climate variables) and sophisticated modelling (in this case logistic regression modelling) for health risk mapping at explicit landscape scales.

Crop productivity mapping: The project team succeeded in revealing the potential of spectral data from high resolution satellite imagery to map stemborer infestation levels at field level in Kenya. This accomplishment is a milestone in assessing pest infestations in Africa since remote sensing has previously not been used over a wider area to map actual areas affected by stemborers. Going

forward, IPM strategies will benefit from spatial data sets that illustrate where crop productivity interventions should be prioritized.

2.5 Social Science and Impact Assessment Unit

***Economic and environmental impacts of integrated pest management (IPM) in Kenya*:** The impact of IPM technologies to control mango infesting fruit flies on mango productivity, cost effectiveness and the environment was examined using household-plot level data collected in four counties of Eastern Kenya. Farm size, extension service, group membership, training on pest management, improved mango varieties and shocks (fruit flies' attacks and diseases) were the key variables in the choice of the number of IPM components. Adoption of IPM was found to be associated with improvement of production efficiency as the production costs per fruit have reduced by 16, 8 and 27 percentage points by adopting one, two and three or more IPM components, respectively. The environmental impact analysis revealed a reduction in use of insecticide quantity by 38, 35 and 43 percentage points with the use of one, two and three or more IPM components, respectively. Results from this study indicate that the IPM strategy is an important policy tool for improving food security while enhancing the environmental sustainability.

***Gender heterogeneous effects of malaria risk on agricultural productivity*:** The team investigated the gender heterogeneity effects of malaria risk on agricultural productivity and malaria reducing effect of integrated vector management (IVM) in Ethiopia. The study was based on 544 randomly selected farm households in 19 villages. Results showed heterogeneous effects according to gender. Malaria effect on productivity is significant when women in a household fall sick, but non-significant for men. Similarly, a one percentage point increase in the intensity of malaria among children below 14 years impacts on annual crop yields. The use of *Bacillus thuringiensis israelensis* (Bti) for mosquito larval control is effective in reducing malaria in households. These results highlight the need to strengthen women's access to malaria control and prevention information and health service delivery system to enhance agricultural productivity.

***Social returns to agricultural technology and women's empowerment in agriculture in western Kenya*:** A detailed household and plot level data collected in 2016 in western Kenya were used to evaluate the impact of adoption of Push-pull technology (PPT), and women's empowerment on women nutrition and agricultural labour supply. The results showed that PPT adoption and women's empowerment have a positive and significant effect on women dietary diversity score. PPT adoption significantly increased harvesting and threshing labour. These results imply that *icipe*'s PPT technology can enhance women's empowerment through improving their nutrition status and reducing workload during a period of critical labour requirement (weeding and ploughing).

***Gender and adoption of Push-pull technology in Kenya*:** The team examined if there is gender differential adoption of PPT on plots managed by women, men or jointly, using plot level and gender disaggregated data. Using a multivariate probit model the team found that there is no gender heterogeneity in the adoption of PPT and this suggests that the technology is gender-neutral. The technology was negatively correlated with grain legume-maize intercropping and rotations; suggesting that adopters of grain-legume intercropping, and rotations are less likely to adopt PPT and vice versa. This is an interesting observation as it demonstrates that this may be a threat to the technology as farmers tend to follow a "food-first approach", particularly if they cannot gain immediate economic benefit from PPT adoption. The team found a complementarity relationship between PPT adoption and adoption of chemical fertilizer, improved maize seeds and manure; suggesting adoption of one technology can encourage adoption of the other technology.

2.6 Technology Transfer Unit

Establishment: *icipe* recognizes technology transfer as a multi-level process of communication that should combine public and private apparatus to identify, develop and deliver innovations and information for the advancement of economic development. In furtherance of this vision, *icipe* established the Technology Transfer Unit (TTU). The Unit has begun operation by pioneering the dissemination of Push-pull technology beyond east Africa to southern Africa. Although, this project is a start-up project for the Unit, TTU plans to work with a mix of technologies from the different Thematic areas of *icipe* in close partnerships with the universities, government ministries, research institutes, NGOs, CBOs and private sector entities to ensure that *icipe* technologies can create opportunities for end users to innovate and benefit from their applications.

Strategic direction of TTU: In order to promote accessibility, affordability and availability of the diversity of technologies and know-how, a brainstorming workshop was held on 25th July 2017, to consult with *icipe* scientists from all divisions on the strategic direction of TTU. An inventory of all *icipe* technologies and their ranking in terms of readiness for dissemination and upscaling across the *icipe* 4-H Themes was outlined at the workshop. The TTU will work to consolidate the progress made thus far by *icipe* and to connect the science with the end users (farmers, researchers, donors, enterprises and governments) through five work streams: database and knowledge management; packaging and innovation; communication, capacity-building, delivery and impact assessment; strategic partnerships; and backstopping and legal framework.

2.7 BioInnovate Africa Phase II

Background: Sida and *icipe* signed a five-year agreement in October 2016 to implement the BioInnovate Africa Programme Phase II (2016 – 2021). Phase II builds on the successes of Phase I (2010 – 2015, which was hosted by ILRI), but with a greater focus on linking scientific outputs from universities and research institutes with businesses and the market. The target countries for BioInnovate Africa are Burundi, Ethiopia, Kenya, Rwanda, Tanzania and Uganda. The Programme's key development objective is to make agricultural/biological processing a competitive and an environmentally sustainable enterprise, so that it becomes an incentive for smallholder farmers and communities in eastern Africa to increase their agricultural productivity, household incomes and ultimately have better living standards. The Programme is unique, and to date, the largest innovation-driven platform in Africa, where scientists, policy makers and industry partners collaborate in translating innovative bioscience research ideas and technologies into products for the market or end users.

First call for proposals and granting: A total of 443 concept notes from the region were received in response to the first call for innovative bioscience proposals made in April 2017. Following an established competitive process, 11 innovation projects (worth US$6 million with 51 partner organisations involved) were selected for funding during the period of 2017-2020. The project teams pitched their bio-based technological solutions and business ideas during the inception meeting and a high level regional bioeconomy symposium was held in November (2-3), 2017. The Programme announced in early November 2017, a second call for proposals, with a 3-year funding commitment of US$ 5 million.

2.8 Capacity Building and Institutional Development (CBID) Programme

icipe considers building the capacity of individual researchers, institutions and communities in Africa as integral to its research and sustainable development activities. *icipe* has continued to make a significant contribution to building the capacity of people and institutions through the development of MSc, PhD and postdoctoral capabilities. Capacity building at these levels also added new research capacity to all Health Themes, which has led to important research outputs and scientific discoveries. Key highlights on *icipe*'s CBID Programme activities in 2017 are listed below:

- ***Fellows.*** *icipe* hosted 81 PhD fellows (45 ARPPIS and 36 DRIP PhD scholars), 74 DRIP MSc fellows, and 11 Postdoctoral fellows.

- ***Country diversity***. Seventeen African nationalities (Benin, Burkina Faso, Cameroon, Cote D'Ivoire, DR Congo, Ethiopia, Ghana, Kenya, Nigeria, Rwanda, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe) and 4 non-African nationalities (Germany, Mexico, Netherlands, Oman) are represented in the postgraduate and postdoctoral programmes.

- ***Pursuing gender equity***. *icipe* is committed to advancing excellence in science through gender equity: 41% of all fellows in the postgraduate and postdoctoral programmes are women. Women's representation is highest in the DRIP MSc programme (45%).

- ***Thesis defence***. Nine ARPPIS PhD scholars, six DRIP PhD scholars and 25 DRIP MSc scholars, defended their thesis and/or graduated.

- ***Publications***. Postgraduate and postdoctoral fellows continue to make a significant contribution to the publication output of *icipe*. 50% were authored or co-authored by postgraduate or postdoctoral fellows.

- ***Conferences and workshops***. MSc and PhD students have also made a major contribution to the presentation of *icipe*'s R&D activities at local, regional and international conferences and workshops.

- ***Alumni tracking***: The *icipe* postgraduate alumni are tracked as part of capacity building monitoring and evaluation (M&E). In 2017, we conducted a web-based tracer study of ARPPIS PhD alumni. The study included all alumni since the inception of the ARPPIS programme in 1983. Only 20% were not 'active', which included those who did not graduate, were deceased, or could not be traced. Of the 80% categorised as 'active' - almost all are working in research, development, or higher education in universities, NARS, international research institutes in Africa, human health institutes, national laboratories and other national systems, government, and private sector in agriculture. Of the 'active' category, 93% are in Africa, while 7% are working outside of Africa - mostly in Universities. A number of alumni are in senior positions, such as Vice Chancellors, Directors of Institutes, Principal and Senior Scientists, Departmental Heads, and Chairs of Departments.

- ***Training and Development***: *icipe* has continued to conduct trainings for researchers, farmers, national programme partners, and others in knowledge intensive areas of *icipe* technologies and products. 54 training courses and workshops were held for researchers, community workers and entrepreneurs, organized by *icipe* projects, CBID and partners, which trained 2,955 participants (42% women) from 17 African countries. In addition, the Push-pull programme held numerous training events with field days and on farm training in six SSA countries for 52,410 farmers, pupils/students, extension workers and other stakeholders (49% women).

SECTION 3: Results Based Management (RBM) Framework: Programmatic Progress Report For 2017

3.1 Plant Health: RBM Report

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
Overall Objective 1: Increase horticultural and staple food production by at least 30% by 2020 by reducing pre- and post-harvest quantitative and qualitative losses due to pests in *icipe*'s target areas.				
Specific objective: Development and implementation of a sustainable IPM and surveillance programme for the invasive tomato leafminer, *Tuta absoluta* (Meyrick), in North and sub-Saharan Africa by 2020				
Natural enemies of *T. absoluta* identified and tested through explorations in Peru, and if feasible, introduced into Africa	• Co-evolved parasitoid(s) identified tested and if feasible introduced to Africa by mid 2015. • Colonies of at least two species of the most promising natural enemies established by end of 2014. • One parasitoid species introduced into at least one of the target countries by end of 2019	• Number of co-evolved parasitoid introduced to Africa by mid 2015. • Number of vibrant colonies established	• One co-evolved parasitoid, *Dolichogenedia gelichidivoris* introduced in Africa • Vibrant colony of the parasitoid established • Non-target impacts and other biological studies on-going in the Biocontainment unit at *icipe* • Field releases of the parasitoid are expected by 2019 upon clearance by KEPHIS	
Specific Objective: Develop and implement integrated pre- and postharvest pest management approaches for thrips and tospoviruses infesting vegetables and grain legume crops in East Africa in collaboration with international and national partners by 2020				
1. Biopesticide for thrips IPM developed and commercialised. 2. Bean Flower thrips pheromone blend optimized	Thrips management strategies for grain legumes encompassing at least two IPM components formulated by 2020.	• At least one tospovirus-resistant cultivar of onion and tomato identified by 2017.	• One highly resistant (VI038552) and two resistant onion entries (VI038512 and AVON 1067) that are resistant to onion-thrips identified (Njau et al., 2017, International Journal of Tropical	

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
3. Thrips IPM strategies based on intercropping, use of biopesticides and semiochemicals developed 4. Field efficacy and use of Bean Flower thrips pheromone standardized 5. Field demonstration of thrips IPM strategies based on intercropping, use of biopesticides, semiochemicals undertaken. 6. IPM technology adapted and validated with grain legume farmers. 7. *Ex-ante* and *ex-post* assessment of the introduced management strategies	French bean, tomato, onion and grain legume farming enhanced by 2015	• Reduction in use of synthetic pesticides by at least 20% by 2020. • No. of peer reviewed publications. • Awareness among at least 200 agricultural extension officers/plant quarantine inspectors enhanced on thrips and tospovirus monitoring/management by 2015. • Awareness among at least 1000 French bean, tomato, onion and grain legume farmers enhanced for adoption of the thrips and tospovirus management strategies by 2015. • French bean, onion, tomato and grain legume yields increased by at least 15%. • Rejection of French beans reduced by at least 10% in local, urban and export markets by 2015 • No. of training reports. • Popular articles, mass media reports. • No. of peer reviewed publications	Insect ScienceVol. 37, No. 2, pp. 98–113, 2017) • Short range dispersal of Western flower thrips characterised to enable understand the field ecology (Nyasani et al., 2017; International Journal of Tropical Insect ScienceVol. 37, No. 2, pp. 79–88, 2017) • One Post doc study on-going for optimization of bean flower thrips pheromone in the lab • Assuming a maximum conservative adoption rate of 1% and a 10%, discount rate for the base deterministic scenario, the NPV of the research was estimated at US$2.2 million, with an IRR of 23% and a BCR of 2.46. • Post-harvest warm-water technologies for ensuring quarantine safety against thrips infesting French bean optimized • One Post doc study on-going for optimization of field use of bean flower thrips pheromone	

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
Specific objective: Development of sustainable management strategies for insect vectors of maize lethal necrosis disease (MLND) in East Africa by 2018				
1. To identify and understand ecology of potential vectors responsible for transmission and spread of viruses causing MLN in East Africa. 2. To develop novel, effective and sustainable seed treatment strategies for the management of MLN. 3. To develop innovative and effective crop diversification strategies that influence both vector ecology and virus epidemiology	Integrated pest management strategies for key vectors of viruses causing MLN developed, through seed treatment, use of biopesticides and crop diversification techniques by December 2015	• At least one key vector of *Maize chlorotic mottle virus* (MCMV) /*Sugarcane mosaic virus* (SCMV) identified by September 2014. • Number of distribution maps of key vectors established by December 2014. • Seasonality and alternate hosts of key vector in MLN hotspot areas studied by June 2015. • Competence of key vectors to transmit viruses causing MLN published by November 2015. • At least two intercrops that reduce the incidence of key vectors and thereby MLN identified by December 2014. • Impact of crop rotations on vector population and thereby the MLN identified by December 2015	• One masters study on interaction of MLN viruses and thrips vector completed • One publication on semiochemical mediated interaction between MLN viruses and thrips vector (Mwando et al., 2018, Journal of chemical ecology) • One masters study on endophyte induced systemic resistance to MLN viruses completed • One publication on endophyte induced systemic resistance to MLN viruses under review (Kiarie et al., 2018, Frontiers in Plant Science)	
Specific Objective: Develop and implement integrated pest management strategies for production of important indigenous vegetables in Kenya and Tanzania by 2018				

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
1. Biology and ecology of major arthropod and nematode pests of amaranth, leafy cowpea and nightshades determined. 2. Effective management tools for target pests on amaranth, leafy cowpea and nightshade developed and implemented. 3. Available germplasms of amaranth varieties screened to identify source of resistance against key pests.	• African Indigenous Vegetables (AIV) IPM strategies that encompass at least three IPM components formulated by 2016	• The key insect pests of at least one indigenous vegetable produced in Kenya and Tanzania identified by 2015. • The key nematode pests of at least one indigenous vegetable produced in Kenya and Tanzania identified by 2015. • The distribution, abundance and dynamics of at least one major pest of amaranth and nightshade determined in Kenya and Tanzania by 2015. • The pheromone biosynthesis activating neuropeptide (PBAN) and its correlation to variability in sex pheromone analysed in at least one AIV insect pest by 2017. • Variation in pheromone binding protein (PBP) and odorant binding protein (OBP) characterised in at least one AIV insect pest by 2017. • The role of indigenous natural enemies against at least one AIV insect	• Higher expression of PBAN gene was found in head and thorax of 3 and 5 days old male pupae • PBAN gene expression was noticeably higher in the female and male thorax of unmated adult during day 3 and 5, respectively • Illumina sequencing generated a total of 120 435 transcript contigs ranging from 201 to 22 729 bases with a mean length of 688 bases • A total of 9 populations of *S. recurvalis* collected from Kenya and Tanzania for molecular characterization were similar in both countries but different from Asian populations • The new *Cotesia* species was named *Cotesia icipe*.It was found effective against *Spodoptera littoralis* and *S. exigua*. • Plots that were previously planted with *Solanum scabrum* or *Solanum villosum* showed a 90% decline in number of *Globodera* spp. females per potato root system • *Amaranthus dubius* reduced *Meloidogyne* spp. by 90% indicating nematode control in nightshade fields through intercropping or rotation with *A. dubius.* • Field screening in Tanzania revealed 1 highly resistant variety and 3 moderately resistant varieties against *S. recurvalis*	

Outputs Expected as per RBM framework plan	Expected Outcomes as per RBM framework plan	Performance Indicator of Outcome as per RBM framework plan	2017 Progress Observed in Obtaining Outcomes	2017 Lessons Learned
		pest determined by 2017. • Classical biological control agents explored for at least one AIV insect pest by 2016. • Diversity, distribution and molecular characterisation of at least one species of nematode pest assessed on nightshade in Kenya by 2015. • Attract-and-kill strategy developed and tested against at least one AIV major insect pest by 2017. • The role of seed dressing assessed against at least one insect pest of AIV by 2018. • The effect of nematophagous fungi, agro-industrial waste and intercropping on the management of at least one nematode species assessed on nightshade by 2017. • Amaranth germplasm and commercial lines assessed against at least one major	• thorax of unmated adult during day 3 and 5, respectively • Illumina sequencing generated a total of 120 435 transcript contigs ranging from 201 to 22 729 bases with a mean length of 688 bases • A total of 9 populations of *S. recurvalis* collected from Kenya and Tanzania for molecular characterization were similar in both countries but different from Asian populations • The new *Cotesia* species was named *Cotesia icipe*.It was found effective against *Spodoptera littoralis* and *S. exigua*. • Plots that were previously planted with *Solanum scabrum* or *Solanum villosum* showed a 90% decline in number of *Globodera* spp. females per potato root system • *Amaranthus dubius* reduced *Meloidogyne* spp. by 90% indicating nematode control in nightshade fields through intercropping or rotation with *A. dubius.* • Field screening in Tanzania revealed 1 highly resistant variety and 3 moderately resistant varieties against *S. recurvalis* • All moderately resistant varieties favored also parasitoid performance	

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
		amaranth insect pest by 2017		
Socio-economic constraints and opportunities for value addition of amaranth, leafy cowpea and nightshades production and protection assessed. Capacity building and technology transfer initiated with national agricultural research partners and growers.	• Awareness on AIV IPM strategies created among agricultural extension officers, plant quarantine inspectors and farmers by 2016.	• Baseline information on current growers' knowledge, attitude and practices (KAP) with regard to IPM and other AIVs production measures collected by 2014. • The effect of growers training on growers KAP evaluated by 2015. • Constraints and opportunities for AIVs' production and marketing evaluated by 2016. • Impact of AIV IPM technologies assessed by 2016. • Awareness created among at least 100 agricultural extension officers and plant quarantine inspectors by 2015. • Awareness created among AIV farmers by 2016. • No. of training reports. • Popular articles, mass media reports.	• 6 PhD students conducted their research in the project in 2017 • 4 papers published in peer reviewed journals Fernandez-Triana et al. (2017) *Journal of Hymenoptera Research* 58, 1–15; Fiaboe et al. (2017) *Journal of Hymenoptera Research* 61: 49 – 64; Othim et al. (2017) *Environmental Entomology* 46 (6), 1284 – 1291; Mureithi et al. (2017) *African Journal of Horticultural Science* 11, 1–17. > 20 presentations at workshops and conferences	

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
		• No. of publications and theses		
Specific Objective: (Improved good agricultural practices and sustained food security) **African nightshade for capturing nematodes – using 'dead end trap crop' technology for tackling a new pest in East African potato production.**				
1. PCN (potato cyst nematodes) characterized - Characterization of PCN species and pathotypes	• PCN (*Globodera* spp.) identified to species level • PCN populations from different regions established • Pure populations of *Globodera* species established. • At least one pathotype identified	• Number of PCN species identified • Number of PCN populations established • Number of resistant potato varieties selected	• Two PCN species identified: *Globodera rostochiensis* and *G. pallida* • One peer review publication • Four populations of PCN from different areas successfully established in culture on potato.	• Knowledge on the different potato production systems amongst small holder farmers necessary and very important to enable correct recommendations for PCN management.
2. Dead-end trap crop identified - Potential trap crops among indigenous solanaceous vegetables in Africa identified and tested.	• At least 5 trap crops identified for trapping PCN –At least 2 trap crop species evaluated under field conditions.	• Number of trap crops selected for further evaluation • Number of farmers involved in field testing using the selected trap crops	• Two trap crops selected for field testing and field trial underway (2017 – 2018).	
3. Roots and exudates analysed - Susceptible/resistance factors in selected trap crop roots and their exudates elucidated	• Mechanisms and composition of root exudates analysed for at least 5 trap crops	• Number of trap crops and their root exudates analysed and evaluated on PCN hatching and behaviour	• 10 accessions of *Solanum scabrum* and *S. villosum* obtained and selected for analysis. Work underway	
4. Biopesticides selected – Potent biopesticides for PCN controlled screened and identified.	• Selected biocontrol fungi comprising at least 2 different species evaluated	• Number of biocontrol fungi selected as effective suppressors of PCN	• Four *Trichoderma* isolates (including a commercial product) and three *Purpureocillium lilacinum* isolates (including a commercial product) are being tested for	

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
	against PCN under natural conditions • Naturally occurring parasitic fungi in field populations of PCN identified	• Novel species of fungi identified from Kenyan populations of PCN	efficacy against PCN in repeated pot trials. Preliminary results show promise	
5. Farmers trained - Capacity building and technology transfer initiated with national agricultural research partners and potato growers.	• Partnerships with NARS established • Joint stakeholder meetings conducted • Students trained and graduated • Farmers in main potato growing areas have obtained basic knowledge on PCN	• Number of students trained/graduated • Number of meetings held • Number of farmers reached	• At least 8 students/interns involved in the activities. • MSc 'Characterization of PCN in Kenya' (*icipe*/JKUAT) • BSc interns on morphological characterization of potato cyst nematodes populations (Kenyatta University /*icipe*). • MSc. Interns, responsible and working on biopesticides and PCN • BSc intern responsible and working on culturing of PCN (*icipe*) and root exudates work • At least 5 meetings and events held.	
Specific Objective: Develop an agroecological farming system for horticultural crops profitable and adapted to smallholder famers with low environmental impact based on a netting technology adapted to tropical climate conditions combined with biological control technics, semiochemicals use and plant association by 2020.				
1. Implementation of a nethouse in 30 farms in 6 sites	• Calculation of the return on investment (ROI) in relationship to the crops grown and the demographic of the potential adopters (e.g., largescale and smallholder farmers), including the cost-effectiveness of	• Number of complete interviews on 30	• 30 interviews on the first season • 23 interviews on the second lesson (the 7 last will be done in 2018) • 1 publication on progress • 1 technical sheet netting technology for horticultural crops on progress	• The netting technology was profitable for all farmers for the 3 crops in rotation: French beans, tomato and cabbage

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
	combining proven biological control agents (bio-pesticides) with net technology;			
2. Development of a business plans through collaborations with partners in sales/marketing evaluation	• Identification of the barriers to sustained adoption of the technology by the target audience, including (a) broad awareness of the technology's potential impact as well as availability, and (b) grower access to innovative low-interest loans or savings schemes that provide the investment capital needed to purchase the technology; and identification of solutions of where possible	• Number of interviewed farmers and stakeholder actors • Number of partners involved in the evaluation	• 1 report from AtoZ Textile Mills on progress	• We need to integrate the Business Plan for the Net House scale up with some agreements or arrangements of ensuring sales of the additional production with farmers. If tripartite agreements are possible (farmers, buyer and financial institution), these should be encouraged
3. Improve financial access for smallholder farmers to netting technology	• A practical and sustainable financial loan scheme that provides funds at an acceptably low interest rate and appropriate repayment terms	• Number of designed business plans	• 1 report from MicroFinanza	• We consider that about 50% of farmers would need a loan to adopt a Net House • Partnerships with financial institutions are to be preferred to an

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
				internal lending option offered directly by AtoZ for a series of reasons
4. Creation of long-term commitment and investment by the prime partnering manufacturer to provide the EFNs/AgroNets and in addressing future designs improvements (wear and tear, bulk roll dimensions, row-cover and support frames, etc.)	• Manufacturing, distribution and sales of AgroNets, and the design of support structures	• Number of nethouse kit sold	• Not communicated by AtoZ	• After the project two farmers built nethouses but not from AgroZ material
5. 4 training sessions on agroecological horticultural farming system based on netting technology in 7 sites	• 926 farmers trained on agroecological horticultural farming system based on netting technology 54 stakeholder actors trained on agroecological horticultural farming system based on netting technology	Number of trained farmers and stakeholder actors	• 926 farmers trained on agroecological horticultural farming system based on netting technology • 54 stakeholder actors trained on agroecological horticultural farming system based on netting technology • 1 report	• The use of certified seeds, grow bag, the use of net houses and safe use of pesticides, Integrated Pest Management was a new ideology to most of the farmers. • Counterfeit products is also a challenge to some farmers. It turned out that excellent

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
				collaboration of all stakeholders is important for a successful farmer field day
6. Study of the distance and contact host plant search and selection strategy in order to identify push and pull stimuli	• *Tuta absoluta, whitefly, Nesidiocoris tenuis, Encarsia formosa* rearing • Identification of volatile emitted by healthy, leafminer or whitefly infested tomato of 4 varieties • Identification of repellent and attractant volatile blend for leafminer and whitefly • Identification of compound emitted by healthy, leafminer or whitefly infested tomato trichome of 4 varieties • Identification of repellent and attractant trichome compound blend for leafminer and whitefly • Identification of companion plant	• Number of colonies • Number of semiochemicals blend • Number of identified companion plant	• 2 whiteflies colonies, 1 tuta rearing, 1 nesidiocoris rearing, 1 encarsia Formosa rearing • Semiochemical will be finished in 2018 as the companion plant • 3 master students • 3 publications on progress	• The infestation and the tomato variety impact the pest attractiveness and oviposition

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
7. Promotion of the biological control	• Identification of natural enemies of leafminer and whitefly in kenya • Study of the effectiveness of the use of 1 predator and 1 parasitoid • Identification of attractant semiochemicals for natural enemies from the plant (tomato) • Identification of attractant semiochemicals for natural enemies from the prey/host • Identification of companion plant to attract natural enemies	• List of identified natural enemies • List of effective natural enemies couple • Number of attractant blend	• 2 interesting natural enemies • 1 Nesidiocoris tenuis rearing, 1 Encarsia formosa rearing • 1 master student • 1 PhD student 1 publication on progress	• Nesidiocoris tenuis and Encarsia Formosa are two interesting natural enemies for tomato protection in Kenya
8. Optimizing netting to enhance its effectiveness in terms of microclimate conditions and crop protection	• models of microclimate under the net, pest and beneficial insect population dynamic • Study of the effectiveness of a semiochemical treated net Study of the impact of push pull companion plant arrangement for pest	• Number of model • List of interesting semiochemicals for the net treatment • Design of the best push pull companion plant arrangement for pest management in the field	• One trial (2 replication) in Mwea • One trial (1 replication, 2nd in 2018) in Arusha • One model on microclimate under the nethouse • 2 publications on progress	• More the mesh is big more the temperature variation under the nethouse is low

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
	management in the field			
9. Environmental economic and social assessment of the crop protection strategy	• Cost-benefit analysis of the system • LCA of the farming system • Socio-technical analysis of the tomato production in Kenya to facilitate the scaling up of this new agroecological tomato farming system	• CBA of at least 10 farms • LCA of at least the 4 modalities in the experimental station • STA of at least 100 farms	• This part will be done in 2019	
Specific Objective:	**Dissemination and Promotion of Mango Fruit Fly Integrated Pest Management (IPM) technologies by 2018**			
Proven fruit fly IPM technologies disseminated and promoted among smallholder mango growers	• Establish partnerships with NARS, NGOs, private sectors, farmers and farmer groups relevant for the implementation of the fruit fly management activities. • Assess the fruit fly composition, abundance and damage at selected project action sites • Evaluate, adapt and validate attractants and biopesticide usage at project action sites.	• At least 5 partnerships established with national institutions and research partners relevant for implementation of fruit fly activities. • The composition and abundance of damaging fruit fly species to mango established in at least 5 project action sites. • At least 2 food attractants and 1 biopesticides identified and adopted for use under local condition at action sites. • IPM package for fruit fly suppression	• Partnership agreements and engagement modalities were signed/ formalised with: Hawassa University (Ethiopia), Agrovet (Kenya), KALRO (Kenya), EIAR (Ethiopia), Ministry of Agriculture and Natural Resources (MoANR) Ethiopia), TechnoServe (Kenya), Real IPM Ltd, Kenya Biologics Ltd, Farmtrack Ltd, HottiServe East Africa Ltd, and Kibwezi Agro Ltd. • The most important fruit fly pests on mango are *Bactrocera dorsalis* and *Ceratitis cosyra*. The former species abundance, comprised 92.7%, 90.6% and 91.2% of the flies recovered from mango from Kitui, Machakos and Makueni, respectively. *Ceratitis cosyra* comprised 7.3%, 9.4% and 8.8% of the flies recovered from mango	• Strong partnerships involving NARS and CESPs enhances development and promotion of technologies, innovations and management practices.

Outputs Expected as per RBM framework plan	Expected Outcomes as per RBM framework plan	Performance Indicator of Outcome as per RBM framework plan	2017 Progress Observed in Obtaining Outcomes	2017 Lessons Learned
	• Conduct community-based dissemination and promotion of IPM technologies.	disseminated and promoted to at least 10,000 growers at action sites. Growers adopt at least 2-3 components of the IPM technologies. Growers reduce fruit fly infestation by 70%; fruit damage reduced by 15%.	at Kitui, Machakos and Makueni. Fruit infestation by fruit flies was 40.7% at Kitui, 17.5% at Machakos and 17.8% at Makueni. • 1344 Starter packs (Traps/MAT+Methyl eugenol, bio-pesticide) provided to farmers in Kenya. Trials on the efficacy of a newly developed *icipe* food-based attractant from waste brewer's yeast (commercially branded as Fruitfly Mania®), in combination with other IPM options showed that Fruitfly Mania® had potential for reducing fruit fly infestation in orchards. Proportional fruit damage was reduced to 13.35% (Fruitfly Mania®+ IPM) against 65.6% under conventional farm in Kenya. icipe continued to provide technical and logistical back stopping to KBL to provide and scale out Fruit fly Mania for fruit fly management. Results from field-based evaluation of the IPM tools showed that IPM sites experienced reduced fruit infestation, with significant progression from 2016 to 2017. Kitui and Machakos recorded significant reductions in percentage infestation from the 2016 levels: 42 to 16%, and 16 to 2%, respectively. Makueni also recorded a slight decline (16 to 16%) in the same period.	

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
Efficient fruit fly parasitoids introduced, mass produced and released in the field and their impact on invasive fruit fly species assessed.	• Process and obtain import permit for introduction of exotic natural enemies into Ethiopia. • Conduct baseline assessment to establish alternative wild and cultivated host fruit species for fruit flies and native natural enemies at the project action sites. • Study trophic interactions between native and exotic natural enemies, pest and selected host fruits. • Large-scale augmentative releases of *F. arisanus* and *D. longicaudata*. • Follow-up on establishment, colonization/dispersal of released parasitoid species and assessment of their impact on invasive fruit fly populations on cultivated and wild host-plants.	• Import permit for at least one parasitoid species granted by Ethiopian government. • At least 3 baseline assessment studies conducted in the project action sites to establish the host range of at least 2 fruit flies species; Establish the native natural enemies for two fruit flies in at least 2 project action sites. • At least 2 trophic interaction studies for at least one natural enemy, one pest and one host fruit conducted. • At least one parasitoid colony established in each of the project benchmark sites with at least 250,000 wasps in place for mass releases. • At least two augmentative releases of one parasitoid species in the project action sites conducted. • At least one study on establishment and dispersal of one parasitoid species conducted in each project action site; At	• Import and release permit for *F. arisanus* and *D. longicaudata* granted by Ethiopian. • Establishment and efficacy studies were initiated. Studies on trophic interactions will be conducted starting in 2018. • Parasitoid colony at icipe was boosted to a tune of 88,800 (annual target = 62,500). • Out of these, a further 67,500 mass releases were successfully made in 2017 (*F. arisanus* (29,500 wasps), *D. longicaudata* (38,000 wasps).	• Sensitization of growers and community regarding the role of parasitoids in fruit fly suppression is essential for parasitoid conservation.

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
		least one impact study of one parasitoid species conducted on one cultivated and one wild fruit type in at least two project action sites		
1. New cheap female biased fruit fly attractants and parameters for postharvest treatment developed, and scientific mechanisms underpinning biopesticide efficacy resolved.	• Develop blends and formulations of new female-biased attractants from compounds of host fruit volatiles. • Identification of host marking pheromones. • Field testing and optimization of host fruit odours and host marking pheromones for fruit fly monitoring, mass trapping and suppression. • Development of food baits from yeast-based products and field testing for monitoring and suppression. • Assess defensive interactions between facultative endosymbionts and fruit fly biopesticide. • Establish and disseminate parameters for post harvest treatment	• At least two formulations of female-biased attractants from host fruit volatiles developed. • At least two host marking pheromones identified. • At least one attractant field tested and optimized for fruit fly monitoring and suppression in at least two project action sites. • At least one host marking pheromone field tested and optimized for monitoring and suppression in at least two project action sites. • At least one yeast-based food baits developed, and field tested at the project action sites. • Endosymbionts screened and characterized in at least one fruit fly species; Defensive interactions between facultative endosymbionts and the	• Studies on the 14 candidate attractants identified, fruit fly biopesticide and host marking pheromone from host fruits for potential use in fruit fly management were initiated. in 2018. Further characterization has identified Wolbachia as belonging to two major supergroups: A and B. Experiments to evaluate the roles of this endosymbiont in *B. dorsalis* are underway including the response of infected flies to key biological control agents, the entomopathogenic fungi Metarhizuim anisopliae as well as egg and larval parasitoids of this fruit fly. We also managed to show tissue infection patterns with Super group A Wolbachia in B. dorsalis ovaries, which collaborates our observations that the endosymbiont is vertically transmitted from mother to offspring. The first trials of the possibility of exploiting this endosymbiont for control of the fruit fly have been set up where data collection is underway for cytoplasmic incompatibility	

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
	based on hot water treatment of mango against fruit flies.	most potent fruit fly biopesticide established. • Post-harvest treatments based on hot water treatment established for at least three mango export cultivars.	between infected and uninfected populations. • Discussion between icipe and Kibwezi Agro Limited KAL on collaboration and materials and data exchange agreements for the utilization of the results for the post-harvest treatment of Kent and Apple mango cultivars, the target export mangoes, were stepped up	
2. Socio-economic impact of the introduced fruit fly IPM and classical biological control technologies assessed	• Develop baseline of knowledge, attitudes and practices (KAP) related to mango production and IPM technologies using complementary methods including focus group discussions and household surveys with data disaggregated by sex and age. • Undertake an *ex-ante* impact assessment to assess economic impact of IPM implementation. • Conduct a follow-up *ex-post* impact assessment of IPM up scaling on smallholder farms with data	• Baseline on KAP related to mango production and IPM technologies developed in at least two project action sites. • At least one *ex-ante* study undertaken in at least two project action sites; Income of growers increased by at least 20% in at least two project action sites; Mango rejection reduced by at least 25% in at least two project action sites; Reduction of insecticide use by at least 30% in at least two project action sites. • At least on *ex-post* impact assessment study undertaken in at least two project action sites; Income of growers increased by at least	• Baseline on KAP related to mango production and IPM technologies done for Ethiopia and Kenya project action sites One *ex-ante* study was undertaken in Arbmich, Ethiopia. • Preliminary analysis of Ex-post data collected from three (3) older IPM site in Dec 2016 [Embu (200 households), Meru (150 households) and Machakos (150 households)] show that while IPM-adopting farmers have higher mango yields and mango net income, they also use lower quantities of insecticide and cause less damage to the environment and to human health.	

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
	disaggregated by sex and age	20% in at least two project action sites; Mango rejection reduced by at least 25% in at least two project action sites; Reduction of insecticide use by at least 30% in at least two project action sites.		
3. Capacity of NARS and other partners in the transfer of fruit fly IPM and classical biological control technologies strengthened	• Train NARS (training of trainers) on pre-harvest management packages. • Conduct Farmers' Field School (FFS)/IPM technology learning hands-on training • Carry out public awareness to facilitate large-scale adoption. • Advanced level training	• At least 40 Agricultural personnel and extension/quarantine officers identified and recruited for project implementation; At least three ToT workshops for training of NARS conducted in the project action sites; At least 40 agricultural personnel and extension/quarantine officers trained on pre-harvest management packages in each project action site. • At least one model farmer identified in each project action sites; At least one IPM learning site identified and used for dissemination of the fruit fly IPM package in each project action site; At least 6 farmers' field	• A total of 40 Lead/ model farmers and 96 Extension offers were trained. • New 31 IPM learning site were established, 29 field days conducted and together with other dissemination efforts, about 4957 additional mango growers in Kenya and Ethiopia were reached during the reporting period. • With active involvement of the private sector in this intervention, it is expected that growers will procure additional materials after they have observed the benefits of the IPM technologies. • A Stakeholder awareness meeting was held in February 2017 in Machakos, Eastern Kenya. The meeting brought together key partners and stakeholders involved in fruit fly IPM. Among the participants were: icipe, EU, farmers, the Anglican Development Services – Eastern (ADSE), Biovision Foundation for Ecological	

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
		days conducted in the project action sites. • At least 60,000 fruit flies training materials (manuals, flyers, posters) distributed to NARS and growers in the project action sites; At least one awareness campaigns conducted through different media (e.g. on local radio stations, TV, farmers' magazines etc); At least one farmers' listening group formed in each project action sites; At least 200 CD recorded/ magazines on awareness campaigns distributed to farmers' listening groups. • At least two PhD students trained in the project lifespan on fruit flies and management.	Development, Switzerland, Ministry of Agriculture, Livestock Development and Fisheries, Kenya, County officials, private sector partners and mango value chain stakeholders. • The project has engaged four students (2 Ph.Ds. and 2 MSc.) to be trained on various aspects of fruit fly biology and management. These are: Mr. Joseph Gichuhi (Kenyan, Ph.D); Mr. Melesse Tora (Ethiopian, Ph.D); Mr. Stanely Onyimbo (Kenyan, MSc.) and Ms. Susan Kerubo Onsongo (Kenyan, MSc.).	
Specific objective: Fruit fly IPM technology up-scaling and dissemination among smallholder fruit growers in East Africa by 2018				
1)To conduct baseline assessment of fruit flies composition and damage caused by different fruit fly species on mangoes in the new project action sites in Kenya and Ethiopia.	• Carry out regular and systematic fruit sampling of mango in the target locations to ascertain the damage, abundance, and fruit fly composition in the two countries.	• The direct damage caused by fruit infesting Tephritids on mango and other key fruits and vegetables in Kenya (Meru, Tharaka Nithi and Kitui) and Ethiopia (Arba Minch) quantified by December 2016.	• Fruit fly species and their damage levels on different host plant species in the project benchmark sites in Kenya and Ethiopia has been established. • Within the vicinity of the study areas in Kenya (Kitui, Meru and Tharaka Nithi), 3 major host plant species (mango, watermelon and	• Due to demand from Tanzania and through the approval of the donor, the project expanded its activities to Tanzania.

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
	• Catalogue and establish the host range of major fruit infesting fruit flies in the locations. • Establish the seasonality of the major mango infesting fruit flies in the target locations	• Host plant range of fruit infesting fruit flies established by December 2017. • The population dynamics of fruit infesting fruit flies established in the target locations by December 2017	butternuts) were found to be attacked by 4 key fruit fly species: *B. dorsalis*, *C. cosyra*, *Z. cucurbitae* and *D. ciliatus*. In Ethiopia, 7 host plant species were frequently attacked by 6 fruit fly species; *B. dorsalis*, *C. fasciventris*, *C. capitata, Dacus cucurbitae*, *C. quinaria* and *Tririhithrum coffea.* • Seasonal dynamics of the most notorious fruit species, *B. dorsalis* in Kenya and Ethiopia are ongoing till the end of the major season in March 2018.	• *icipe*, through the BMZ Mango IPM project already introduced the parasitoids into Tanzania and we had a permit for the same. Hence it was easy to send parasitoids to Tanzania for mass releases in the framework of this current project.
2)To conduct on-farm demonstration, adaptation and validation of existing and novel fruit fly IPM technologies (based on baiting and male annihilation techniques, use of biopesticides and orchard sanitation) in the target locations	• Identify suitable and easily accessible site in consultation with NARS, growers and farming communities. • Establish IPM learning sites jointly with NARS partners. • Mobilize model farmers and other growers in collaboration with NARS partners. • Set up demonstration activities that encompass various IPM management options and assess the impact jointly with NARS and growers.	• One suitable and easily accessible site identified in consultation with NARS and the farming communities in each of the project benchmark sites of Meru, Kitui, Tharaka Nithi and Arba Minch by July 2016. • At least one fruit fly IPM technology learning sites established in each of the project benchmark site in Kenya and Ethiopia by July 2016. • Identification and recruitment of at least 5 model farmers in each project benchmark site willing to be engaged in	• This objective was achieved by end of 2016. A total of 16 suitable and accessible orchards in Kenya and Ethiopia have been established as learning sites jointly selected in consultation with the NARs, growers and farming communities. • In Kenya, Ethiopia and Tanzania, a total of 8, 9 and 1 model farmers, respectively, willing to be engaged in the application of fruit fly biological control and IPM technologies in the target countries have been recruited in collaboration with NARS partners. In addition to the model farmers in each country, 1358 growers (59.4% males and 40.6%) in Kenya, 452 growers in Ethiopia (84% males and 16% females) and 76 growers in Tanzania (57.9% males & 42.1% females) have been identified and	

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
		the application of fruit fly biological control and IPM technologies for implementation in Kenya and Ethiopia by July 2016. • Carry out at least one demonstration session that encompass various fruit fly IPM management options to growers jointly with NARS in at least two benchmark sites, one in each country by December 2016.	are willing to engage in fruit flies IPM activities in the selected sites. • In Kenya, 12 fruit fly IPM demonstration sessions have been conducted in all the project benchmark sites (Kitui, Meru and Tharaka Nithi) for NARS, CESPS and growers. A total of 45 NARS and CESPS (80% males and 20% females) as well as 1538 growers (59.4% males and 40.6% females) were involved in the training. In Ethiopia, 3 demonstration sessions were carried out with 45 NARS (57.8% males and 42.2% females) and 452 growers trained. In Tanzania, 1 demonstration exercise was organized with 23 NARS and CESPS (68.9% males and 39.1% females) and 76 growers.	
3) To carry out large-scale releases of fruit fly parasitoids (*Fopius arisanus* and *Diachasmimorpha longicaudata*) and monitor for establishment and colonization in the new project actions sites in Kenya and Ethiopia	• Catalogue and assess the level of parasitism by native natural enemies attacking major fruit fly species in various locations in Ethiopia. • Apply for and obtain import permits for introduction of *F. arisanus* and *D. longicaudata* into Ethiopia. • Carry out ToT workshop on parasitoid rearing at	• The native natural enemies of fruit flies attacking major fruit species and their level of parasitism in the project bench mark site in Ethiopia quantified by December 2017. • Apply and obtain import permit for the introduction of at least one parasitoid species into Ethiopia by July 2017. • At least 5 NARS personnel trained on	• So far, no native parasitoid of tephritid fruit flies have been recorded in Ethiopia. However, 4 Ethiopian staff have been trained in *icipe* on rearing protocol related to two exotic fruit fly parasitoids (*Fopius arisanus* and *Diachasmimorpha longicaudata*). This is to help them import and establish vibrant colonies of the two parasitoid species for future mass releases in the country. The trainees were also furnished with knowledge on how to continue the search for native natural enemies in	

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	icipe for Ethiopian NARS on natural enemy production, releases and assessment of impact. • The two parasitoid species (*F. arisanus* and *D. longicaudata*) mass produced in large-scale and released at learning sites and selected grower's fields in Ethiopia. • Initiate and maintain laboratory colonies of *F. arisanus* and *D. longicaudata* in Ethiopia. • Follow up on establishment, colonization and impact in target locations.	natural enemy production, releases and assessment of parasitoids' impact by August 2016 • Large cultures of the two parasitoid species (~10,000/week) in place by end of December 2017 for mass releases in the project benchmark site in Ethiopia. • A starter colony of at least one parasitoid species established in the Ministry of Agriculture laboratory in Ethiopia by December 2017. • Establishment and colonisation of the two parasitoids documented for at least 2 sites in terms of percent parasitism by July 2018	Ethiopia and establishment of stock colonies of the same. • The permit to import exotic fruit fly parasitoids (*F. arisanus* and *D. longicaudata*) to Ethiopia has been obtained. Thus, laboratory for rearing the fruit fly host (*B. dorsalis*) as host species and the two parasitoids has been completed with equipment already put in place to receive the parasitoid culture from *icipe*, Nairobi. • Four technical staff have been trained at *icipe* on all aspects related to fruit fly and parasitoid rearing as well as how to monitor the establishment and colonization of the parasitoids in the field after mass releases have been conducted. • Both parasitoid colonies (*F. arisanus* and *D. longicaudata*) in *icipe* have been significantly boosted to produce ~90,000 and ~120,000 parasitoids/month in preparation for shipment to Ethiopia. • The laboratories for rearing the fruit fly host and the parasitoids are operational. Both parasitoid colonies have been boosted and shipment arrangements to Ethiopia are currently underway. • Establishment and colonization of both parasitoid species have been	

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			witnessed in all the project benchmark sites in Kenya from incubated mango fruits collected from the orchards. Results show that the impact is low for now with percent parasitism levels ranging between 1.8 – 6.15%. However, it is expected to increase with time as the populations builds up in the different release locations.	
4)To develop capacity to support up-scaling of fruit fly IPM technologies while strengthening the mango value chain through good agricultural practices (GAP).	• Training of trainers (ToT) workshop on fruit fly biological control and IPM technologies conducted for extension officers (NARS) and community extension service providers (CESPs) in the project benchmark sites. • Awareness campaigns and sensitization on technology availability for fruit fly management technologies in project benchmark sites in Kenya and Ethiopia conducted for farmers, farmer groups and the community at large at the newly established IPM learning sites.	• At least 10 NARS and 5 CESPs personnel recruited and trained on fruit fly IPM technologies and use of parasitoids by August 2016 in each country (Kenya and Ethiopia). • At least 2 awareness campaigns on availability of fruit fly management technologies and application and conservation of parasitoids conducted at IPM learning sites in both countries by end of August 2016. • At least 1000 fruit fly extension and training materials (manuals, flyers, posters, Farmer Field School curriculum) distributed to growers and extension officers at	• Cumulatively, 142 people have been sufficiently trained on fruit fly IPM technologies as well as good agricultural practices in all the project benchmark sites in both countries plus Tanzania, which was a newly selected site for expansion of project activities. • Sixteen (16) awareness campaigns on the availability of fruit fly management techniques and parasitoids conservation have been conducted in all the project benchmark sites in Kenya and Ethiopia as well as in Tanzania (new benchmark site for expansion of project activities). • A total of 189 fruit fly IPM manuals and 19,000 flyers were distributed to growers and NARS in Kenya, Ethiopia and Tanzania. Growers were also provided with starter packs consisting of traps (4350), ME blocks (5152 pieces), Augmentorium (27) and biopesticides (35 containers).	• NARS and CESPs involvement in rolling out the IPM technologies is very important as they have a great influence to the growers and communities at large.

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	• Fruit fly extension and training materials (manuals, flyers and posters) produced and distributed to growers and extension officers in the project benchmark sites. • Contract and engage NARS partners, growers and other development partners in resource mobilisation for testing and sharing of the fruit fly IPM technologies.	each of the selected benchmark sites in both countries by December 2016. • Collaborate with NARS and indentify farmer groups in community that will help in fund raising and assist the growers in accessing fruit fly IPM products as well as market accessibility.	• Meru and Tharaka Nithi farmer groups have approached their local government authorities to help purchase and distribute fruit fly IPM materials to them to combat the devastating fruit fly pest on mango. In Tanzania, the AMAGRO farmer group actively engage in fund mobilization through proposal writing targeting funding agencies like United States Agency for International Development (USAID), International Trade Centre (ITC) and Russel IPM (request funds to combat fruit fly). They also approach local partners to request funds like YARA Tanzania Limited and Banks like Tanzania Investment Bank Limited (TIB) and Eco-bank Tanzania Limited.	
Specific Objective: Develop IPM tools and strategies for major coffee pests in East Africa based on a better knowledge of their bioecology.				
Development of laboratory rearing methods for major coffee pests in East Africa	• Colonies of *Hypothenemus hampei*, *Monochamus leuconotus* and *Antestiopsis thunbergii* continually maintained in the laboratory	• Living insects available for experimentation • Rearing methods published.	• 3 colonies of insect pest of coffee maintained at coffee pest laboratory during 2017 Hundreds of *Antestiopsis thunbergii* and *Hypothenemus hampei* individuals produced for experimentation. Dozens of *Monochamus leuconotus* individuals produced for experimentation • 1 publication for a new rearing method for *Antestiopsis thunbergii* published in International Journal of Tropical Insect Science, in 2016	• Routine colony maintenance induces costs for labour and materials that have to be supported by projects

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			• 1 publication for a new rearing method for *Monochamus leuconotus* published in Journal of Economic Entomology, in 2017 • 1 publication describing a new rearing method for *Hypothenemus hampei* in preparation	
Thermal requirements characterization for major coffee pests in East Africa	• Thermal thresholds determined for *Hypothenemus hampei*, *Monochamus leuconotus* and *Antestiopsis thunbergii* through life table study at constant temperatures and phenological modelling.	• Thermal requirements published. • Set of phenological models available for further demographic simulations	• 1 ARPPIS PhD ongoing in 2017 • Thermal requirements produced for *Antestiopsis thunbergii* and *Hypothenemus hampei* in 2017. • Thermal requirement assessment ongoing for *Monochamus leuconotus* • 1 publication providing *Antestiopsis thunbergii* thermal requirements published in Journal of Thermal Biology in 2017 Publication of *Hypothenemus hampei* thermal requirements ongoing (under reviews by co-authors)	• *Monochamus leuconotus* has a very long-life cycle (2 years at 18°C) that implies long and costly monitoring
Distribution mapping for major coffee pests in East Africa, in the current climate situation and in different scenarios of climate warming	• Demographic parameters simulated from phenological models for *Hypothenemus hampei*, *Monochamus leuconotus* and *Antestiopsis thunbergii.* • A set of risk maps for the 3 pests on coffee in the current climatic situation and in	• Sets of risk maps published in scientific journals. • Sets of risk maps available as a component of an IPM program for major coffee pests, targeting stakeholders of coffee industry	• 1 ARPPIS PhD ongoing in 2017 • 6 risk maps produced for *Antestiopsis thunbergii* in current and 2055 climatic conditions for the CHIESA transect on Kilimanjaro, Tanzania. • 1 publication with risk maps for *Antestiopsis thunbergii* on Kilimanjaro accepted in Plos One (with major revision). • Risk maps for *Antestiopsis thunbergii* and *Hypothenemus*	• ILCYM software used for risk mapping showed some limitations. An improved version of the software should be provided

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	different scenarios of climate warming.		*hampei* in Murang'a County (Central Kenya) under development.	
Characterization of major coffee pest population dynamics in coffee farms and of agroecological factors impacting the dynamics.	• Networks of smallholding coffee farms implemented for observation in different locations. • Data sets for monthly monitoring of *Hypothenemus hampei*, *Monochamus leuconotus* and *Antestiopsis thunbergii* populations and damage in different locations of East Africa. • Main agroecological factors characterized for coffee farms, including microclimate, shade, coffee fruiting cycle, farmer practices. • Models describing the impact of main agroecological factors on major coffee pest dynamics • IPM recommendations developed based on these models.	• Data sets available for modelling work. • Models describing the impact of agroecological factors on major coffee pest dynamics published in scientific journals. • Sets of IPM recommendations for shade management and other best practices available for major coffee pests, targeting stakeholders of coffee industry.	• 2 ARPPIS PhD ongoing in 2017. • 1 data set available for *Hypothenemus hampei* population dynamics along an elevation gradient in Murang'a County (18 months monitoring using Brocap trap and damage assessment) • 1 data set available for *Antestiopsis thunbergii* and *A. facetoides* population dynamics along an elevation gradient in Murang'a County (18 months population monitoring) • 1 data set for climatic data (temperature and humidity) for 18 months along the elevation gradient (hourly T°C and HR records with 15 data loggers) • 1 data set for coffee fruiting cycle (18 months monitoring) • Preliminary study conducted for shade assessment using hemispherical images. • 1 baseline survey conducted for coffee systems characterization (50 plots across Murang'a County) including farmer practices, shade assessment and pest and disease assessment) • 1 publication for the impact of climate and coffee fruiting cycle on seasonal variations of *Antestiopsis*	

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			thunbergii and *A. facetoides* under preparation.	
Identification and utilization of semiochemicals in the management of *Antestiopsis thunbergii*	• Promising bioactive volatiles isolated from coffee berries or conspecifics	• A set of bioactive compounds available for field assessment. • 1 publication for promising kairomones for the control of *A. thunbergii.* • 1 publication for promising pheromones for the control of *A. thunbergii*.	• 1 ARPPIS PhD ongoing in 2017 • 1 attractive blend developed from coffee green berry volatiles available for field assessment. • 1 publication to present the attractive blend published in Chemoecology. • 1 repellent blend developed from coffee red berry volatiles available for field assessment 1 publication to present the repellent blend accepted in Chemoecology (major revision). • 3 stink bug pheromone blends available for field assessment	• Studying stink bugs' chemical ecology is challenging due to alarm pheromones in stink bugs, which make insect manipulation and volatile isolation uneasy.
Specific Objective: Promote adoption of push-pull technology for effective management of striga and stemborers infesting cereals through collaboration with international and national partners by 2018.				
1. Push–pull technology implemented by over 120,000 farm households, and indirectly benefit over 1.5 million people in East Africa	• Food sufficiency and household incomes of 120,000 push–pull farmers increased by at least 50% by 2018 through higher and sustained crop, fodder and milk yields.	• Acreage of farmland under Push–pull. • Household income levels attributable to push–pull. • Number of households having food sufficiency. • Number of farmers having improved dairy animals. • Number of push–pull farmers utilising fodder from push–pull in their dairy production.	• Target surpassed. A total of 22,010 (10,759 male, 11,251 female) more farmers adopted the Push-pull technology in 2017, bringing the cumulative number of direct beneficiaries to 157,890 in eastern and central Africa. This translates to over 950,000 indirect beneficiaries having improved food sufficiency, nutrition and incomes. • Over 157,000 farm households experienced more than double increase in cereal crop yields, fodder, milk, soil fertility, and incomes.	• Push-pull researchers discovered that the technology effectively controls Fall armyworm (FAW) infestation of cereal crops. This discovery is a new drive towards wider adoption of Push-pull in sub-Saharan Africa (SSA).

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		• Number of dissemination channels optimised and employed. • Cereal and fodder yields and milk production levels among target farmers. • Number of partnerships formed. • Number of stakeholders trained.	• *Three more dissemination channels (video, drama and cartoon books) were optimized and used in addition to field days, direct training by farmer teachers and extension staff, exchange visits and agricultural shows to train 30,498 (14,888 male and 15,511 female) farmers. Other stakeholders trained included 1991 extension workers, 84 national policy makers, and 105 researchers.* • Eight new partnerships were formed in Malawi, Zambia and Rwanda for scaling up Push-pull in those countries.	• In promoting the uptake of the technology the use of farmer-based communication channels is sustainable in the long term as it is based on local networks and social capital, and can be used as an innovation platform Integration of cereal and livestock production improves the demand of Push-pull as a multi-functional technology. Farmers in Africa traditionally practice mixed agriculture • Building strong partnerships with the farming communities, national extension networks, NGOs, and the private sector players remains key in scaling up Push-

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
				pull technology. Their involvement also enhances impacts of the technology on beneficiary livelihoods.
2. An integrated management approach for Napier stunt disease.	• Improved incomes and livelihoods of at least 5000 Napier farmers in western Kenya by at least 50% through adoption of an integrated Napier stunt disease management strategy, characterised by increased fodder and milk production by 2016	• Quantity of Napier grass and milk produced. • Number of alternative fodder grasses in use. • Number of farmers using the integrated disease management approach Number of partnerships formed. • Number of stakeholders trained on integrated disease management. • Number of peer-reviewed publications	• Following the re-screening and confirmation of resistant cultivars (Ouma2 and South Africa), they have been multiplied by over four thousand and eighty (4,080) farmers who established bulking sites by the close of the long rains 2017. More than 15,000 additional farmers used the NSD-resistant cultivars, increasing both Napier grass and milk production. • Cumulatively 273 farmer groups were trained on fodder production established through partnerships with 18 stakeholders, including Send-a-Cow, Ministries of Livestock, Agricultural training centres and KALRO.	• Though an increasing number of farmers are implementing an integrated Napier stunt disease management approach, the problem is still prevalent throughout eastern Africa. Solving of the problem has been complicated by the new challenge of Fall armyworm invasion in most areas which has increased demand for planting materials from the station and bulking sites, not only to solve the issue of Napier stunt disease but also to control the Fall

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				armyworms through Push-pull.
3. Stemborer management approach developed by exploiting early herbivory traits and plant signalling.	• Staple food sufficiency achieved by at least 20,000 farmers in western Kenya by 2018 though grain yield increases by 30%. • Novel scientific knowledge on early herbivory and plant signalling generated and applied in crop protection by scientists, extension agents and policy makers by 2017	• Number of 'smart' maize varieties with early herbivory traits identified. • Number of farmers adopting the use of 'smart' maize varieties. • Increase in grain yields. • Number of food sufficient households as a result of use of 'smart' maize varieties. • Number of peer-reviewed publications on early herbivory and plant signalling • Number of stakeholders trained on stemborer control by exploiting inherent plant defence traits.	• Six (6) 'smart maize' cultivars were conducted to investigate early herbivory traits and parasitism levels under real field conditions. • Scientists at *icipe* and Rothamsted Research worked in collaboration to screen for egg induced HIPV emissions in a much wider range of maize germplasm to determine the occurrence of egg-induced early herbivory in improved maize varieties and to enable ongoing genome wide association studies. • Responses of Cotesia sesamiae, a key parasitoid natural enemy of stemborers, to odors from maize plants with and without stemborer, *Chilo partellus* eggs were observed. • Three peer-reviewed papers were published on early herbivory and plant signalling (Agronomy 2017, 7(3), 58; doi:10.3390; Ecology and Evolution 7(8):2835-2845. doi: 10.1002/ece3.2893;New Phytologist 212: 856–870 doi: 10.1111/nph.14274)	• The study demonstrated that parasitism of stemborers is significantly higher on those lines with egg inducible defence traits compared to control lines without the traits. The maize lines with highest parasitism also attracted the parasitic wasps in the olfactometer bioassays in the lab. • Results show that herbivore egg-induced volatile emission is rare in commercial hybrids but common in farmer selected landraces. • Findings demonstrate considerable potential to improve crop defences against

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				insect attack by introgressing traits from landraces. This could benefit resource poor small-scale farmers in Africa who do not use pesticides to protect their crops
4. An integrated management approach developed and implemented for *Striga* control in maize in western Kenya and Nigeria.	• Food sufficiency and livelihoods of at least 30,000 smallholder farmers improved by at least 50% by 20167 through efficient control of *Striga* resulting in increases in maize yields by at least 50%.	• Number of farmers practising integrated *Striga* control methods. • Acreage under integrated *Striga* control methods. • Grain yield increases attributable to integrated *Striga* control. • Number of stakeholders trained on integrated *Striga* control. • Number of publications. • Number of partnerships formed. • Number of partners' joint field days conducted	• At least 22,000 new farmers adopted Push-pull integrated striga control methods, increasing both acreage under integrated striga control methods. Under the climate-smart Push-pull Striga infestation was reduced 18-fold, and concomitantly grain yields increased 2.5 times. • 1991 extension workers, 84 national policy makers, and 105 researchers were trained on integrated *Striga* control using Push-pull. • Eight new partnerships were formed. • Fifty-two joint partner field days were conducted, reaching 10,384 new farmers. • Specific to Striga control, three peer reviewed papers were published (Crop Protection 98, 94-101; Journal of Chemical Ecology 42, (7) 689 – 697; Weed Technology 30, 21-28)	• Climate change effects, such as drought stress, affects the functioning of earlier identified Desmodium spp., mainly D. *uncinatum* and D. *intortum*, which had been shown to effectively control striga and improve crop productivity, necessitating the identification and characterization of new plants possessing the required ecological chemistry to protect crops against the biotic stress of striga under such

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				environmental conditions. • Out of 17 accessions comprising 10 species of Desmodium screened for their drought stress tolerance and ability to suppress striga, Desmodium *incanum* and D. *ramosissimum* were the most promising as they retained their leaves and maintained leaf function for longer periods during their exposure to drought stress conditions.
Specific objective: Baseline information of plants - Lepidoptera stemborers – parasitoids interactions				
1. Baseline information on host plant selection mechanisms by Lepidoptera stem borers (Noctuidae).	• Description of herbivore- plant volatiles induction on oviposition within a community of maize Lepidoptera stem borers. • Study on the importance maize residues to ensure the carry-over of	• Conspecific or heterospecific larvae-infested maize plants produce specific chemical signatures that female moths use as host cues. • Description of the importance of maize residues as compared to wild habitat to	• 1 PhD student is conducting his research in the project in 2017. • Bioassays (Y-tube experiments) and volatiles analyses by GC-MS achieved. • Field surveys in maize field in Makutano and Murang'a are still ongoing. • First release of *Cotesia flavipes* in Makutano and *Cotesia sesamiae* in Murang'a for the follow up on the	• Females of *Busseola fusca*, *Sesamia calamistis* and *Chilo partellus* oriented significantly towards VOCs emitted by both conspecific and heterospecific

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	maize stemborers and their associated parasitoids during the non-cropping season as compared to surrounding wild habitat.	ensure the carry-over of maize stemborers and their associated parasitoids. This is valid in regions where the wild habitat is reduced.	importance of maize residues as compared to wild habitat to ensure the carry-over of maize stemborers and their associated parasitoids.	infested plants as compared to uninfested plants (both laboratory and field observations validated this result). • Appearance of *Spodoptera frugiperda* in Makutano first and later also in Murang'a. This allowed us to start a study on the interactions of this new invasive species with the already indigenous Lepidoptera stem borers.
2. Genome sequencing of *Busseola fusca*	• To understand the biology of *Busseola fusca*, we sequenced, assembled, and annotated the genome and transcriptome of this important maize pest.	• Genome and transcriptome of *B. fusca* sequenced, assembled, and annotated. We identified unique gene families potentially related to metabolism of xenobiotic chemicals, pheromone biosynthesis, and immune response towards parasitism	• For genome sequencing and assembly : Preparation of two libraries for sequencing of *Busseola fusca* legs using a Nextera XT DNA Library Prep Kit, and use of next-generation sequencing using Illumina MiSeq technology. • For transcriptome sequencing and assembly: use of TruSeq RNA Library Prep Kit to prepare libraries of 10 different samples of *B. fusca* and use next-generation	• Important bioinformatic work in order to evaluate the assembly quality, to identify the repeat annotation, to identify functional annotation, to categorize gene ontology term, to analyse orthology,

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			sequencing using Illumina MiSeq technology.	to realise BLAST analyses and to identify horizontal gene transfer. All this process delayed our planed publication
3. Baseline information on host selection mechanisms by *Cotesia* spp. parasitoids (Braconidae) of Lepidoptera stemborers	• Identification of contract kairomone(s) involved in the host recognition and acceptance by *Cotesia* spp. parasitoids of Lepidoptera stemborers. • Variability of the identified host kairomone(s) in host-parasitoid association. • Determination of the candidate genes involved in host acceptance by *Cotesia sesamiae*	• Female parasitoids of *Cotesia flavipes* recognize their host and oviposit in reaction to an α-amylase, which is present in the oral secretions of the larvae of their host, *Chilo partellus*. • Implication of α-amylase in the host acceptance and oviposition involved in different specific host-parasitoid associations	• 1 PhD student is achieving her research in the project in 2017. Her PhD defense is planned in 2018. • 1 paper under revision in Journal of Chemical Ecology. • 1 paper in preparation for submission in Frontiers of Ecology and Evolution.	• For the determination of the candidate genes involved in host acceptance by *Cotesia sesamiae* a good production of both host and parasitoid is crucial
Specific objective:	**Exploration for biological control of the invasive Guineagrass in USA**			
1. Evaluation of the specialist stem borer of Guineagrass in Kenya, *Buakea kaeuae*, on the invasive Guineagrass of USA	• 1 PhD student is conducting his research in the project in 2017. • Bioassays (Y-tube experiments) and volatiles analyses by GC-MS achieved.	• Females of *Busseola fusca*, *Sesamia calamistis* and *Chilo partellus* oriented significantly towards VOCs emitted by both conspecific and heterospecific infested plants as compared to	• First release of *Cotesia flavipes* in Makutano and *Cotesia sesamiae* in Murang'a for the follow up on the importance of maize residues as compared to wild habitat to ensure the carry-over of maize stemborers and their associated parasitoids	• Females of *Busseola fusca*, *Sesamia calamistis* and *Chilo partellus* oriented significantly towards VOCs emitted by both

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
	• Field surveys in maize field in Makutano and Murang'a are still ongoing. • First release of *Cotesia flavipes* in Makutano and *Cotesia sesamiae* in Murang'a for the follow up on the importance of maize residues as compared to wild habitat to ensure the carry-over of maize stemborers and their associated parasitoids	uninfested plants (both laboratory and field observations validated this result). • Appearance of *Spodoptera frugiperda* in Makutano first and later also in Murang'a. This allowed us to start a study on the interactions of this new invasive species with the already indigenous Lepidoptera stem borers.		conspecific and heterospecific infested plants as compared to uninfested plants (both laboratory and field observations validated this result). • Appearance of *Spodoptera frugiperda* in Makutano first and later also in Murang'a. This allowed us to start a study on the interactions of this new invasive species with the already indigenous Lepidoptera stem borers.
2. Conduction of an Africa-wide collection of Guineagrass and analysis of DNA to determine molecular match between African Guineagrass and the invasive	• Collections of Guinea grass of 16 countries in Sub-Saharan countries (South Africa, Botswana, Zimbabwe, Mozambique, Zambia, Cameroon, Democratic Republic of Congo,	• Collections of Guinea grass from 5 African countries (South Africa, Botswana, Cameroon, Ghana and Tanzania) and all planned regions of Kenya.	• AFLPs show South Africa is the match with Texas.	• Importance of scientists networking to be able to collect samples of Guineagrass all over sub-Saharan Africa

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
American Guineagrass	Tanzania, Uganda, Ghana, Togo, Ivory Coast, Benin, Nigeria, Ethiopia and different regions of Kenya).			
• **Specific objective: Strengthening citrus production systems through the introduction of IPM measures for pests and diseases in Kenya and Tanzania by 2018**				
1. Critical gaps in knowledge surrounding the distribution, population dynamics, damage and molecular ecology of targeted pest species and their associated natural enemies filled.	• The distribution, abundance and dynamics of ACP (African citrus psyllid) and FCM (false codling moth) and their natural enemies established by 2017. • Develop predictive phenology models for ACP and FCM under varying climate change scenarios by 2016. • Study on molecular ecology of different populations of ACP and FCM conducted by mid 2017.	• The distribution, abundance and dynamics of ACP and FCM known by end of 2017. • The identity, species composition, and abundance of at least 70% of associated natural enemies known by end of 2017. • Role of biotic (predation, parasitism and disease) and abiotic factors (climate) affecting dynamics of ACP and FCM determined by 2016. • Predictive phenology models for ACP and FCM under varying climate change scenarios made available by end of 2016. • Molecular ecology of varying populations of ACP and FCM	• The distribution and abundance of ACT across the citrus growing regions in Kenya varied with elevation both spatially and temporally. • Survey for host plants of *T. erytreae* yielded eight new host plants of the pest, namely *Stephania abysinica*, *Murraya koenigii*, *Clausena anisata*, *Vepris* sp., *Teclea nobilis, Calodendrum capense, Zanthoxylum usambarense*, and *Casimoria edulis.* Result of laboratory assessment of ACT performance on the 8 host plants showed that the pest preferred *Clausena anisata* and *Murraya koenigii* for oviposition and development while *C. capense* was the least preferred host. • Following the detection of the alien invasive Asian psyllid in Kenya, the survey activities were expanded to other countries in East Africa, namely Uganda and Ethiopia. So far, the pest has not been detected in Uganda.	

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		established by mid 2017 Vibrant colonies of ACP and FCM established by end of 2015	• Results of assessment of distribution/abundance of the second key pest of citrus, FCM showed that the pest is widely distributed across altitudinal gradient in all citrus major growing zones in both Kenya and Tanzania. In general, the FCM damage was positively correlated with altitudes in the two countries, with the highest infestation of 42.2% and 33.9% at high altitudes of Kenya and Tanzania, respectively. • FCM population dynamics studies is ongoing in the two countries at the attitude mentioned. The highest number of moth was recorded in Kenya (150 moth/trap in August) at high altitude while the lowest (15 moth/trap in December) was recorded in Tanzania at low altitude. • DNA of FCM samples collected at three altitudes in Kenya and Tanzania has been extracted, amplified using universal primers and sent for sequencing. • Study of development of ACT immatures stages has been completed for the temperatures 10, 15, 18, 20, 22 and 30°C. • Screening for the bacteria on the ACT laboratory-reared and field populations indicated that in addition to *Candidatus Liberacter*	

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			africanus 5 major endosymbionts are associated with ACT	
2. The incidence, severity and distribution of Huanglongbing (HLB)/citrus greening determined; and pathogen–vector interaction assessed	• Countrywide survey conducted and the incidence, severity and spatio-temporal patterns of distribution of HLB assessed using molecular tools by end of 2017. • The role of HLB infection on ACP vector competence, fitness parameters and dispersal capability assessed by quantitative real-time PCR assays by end of 2017. • Stochastic models developed to assess the patterns of spread of HLB disease by end of 2015. • HLB disease distribution and potential implications on citrus industry on a regional scale assessed using	• Incidence, severity and spatio- temporal patterns of HLB established and geo-referenced maps of their distribution in the two countries made available by end of 2017. • Role of HLB infection on ACP vector competence, fitness parameters (e.g. fecundity) and dispersal capability established using qRT-PCR by end of 2017. • Stochastic model to assess the patterns of disease spread developed by end of 2015. • Hyperspectral pattern of disease spread and regional distribution established using remote sensing tools by end of 2017	• Citrus greening disease (CGD) incidence varied significantly across altitudinal gradient of the surveyed regions. The highest disease incidence was recorded at the high (>1201masl) and mid altitude (501-1200masl) at an average of 100% and 75%, respectively. CGD and ACT was also reported in some warm regions of Ahero, Kenya and Tanga, Tanzania indicating the likelihood of this pathogen adapting to warmer environments. • 42 sites were surveyed in western Uganda for Liberibacters. 21 and 12 were respectively positive for *Candidatus Liberibacter africanus* subspecies *clausenae* (*Claf-cl*), and Claf. • CLaf positive ACT had significantly higher fecundity compared to CLaf negative ACT. However, immature survival was significantly lower for CLaf positive insects. • Dispersal rate was generally low in both groups, although there was a higher propensity for dispersal in CLaf positive ACT. • Habitat suitability maps were generated using bioclimatic variables and both bioclimatic variables and remote sensing variables, the latter proved to be	

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	Earth Observation tools by end of 2017.		more realistic in depicting ACT distribution. Also, risk maps for invasion/establishment of CGD have been generated using GARP and MaxEnt. The models projected that many African countries to be suitable for CGD establishment. Our finding can be used as an early warning tool by the regulatory authorities in these countries	
3. Ecologically sustainable management methods for ACP and associated HLB disease, and FCM developed, tested and implemented.	• Behavioural evidence for kairomonal and female-produced sex attractants and repellents in ACP studied and tools for monitoring and suppression developed by end of 2017. • Potent fungal and viral-based biopesticides and natural products identified, tested and implemented for management of ACP and FCM by end of 2017. • An efficient attract-and-kill product that can be used in combination with biopesticides for management of both	• At least two kairomonal and female-produced sex attractants and/or repellents of ACP identified by end of 2016. • Synthetic analogues of the identified semio-chemicals tested in wind tunnel and in field cages by end of 2017. • At least two isolates of EPF identified and their efficacy tested against ACP and FCM, and one virus product introduced and field tested against FCM by end of 2017. • An IPM measure that combines the use of one soft chemical and biopesticide tested for ACP by end of 2016. • At least one attract-and-kill product introduced into one country, field	• Behavioral evidence for attraction of ACT using olfactory cues of *Citrus sinensis* and, alternative hosts, *C. anisata* and *M. koenigii* have also been confirmed. The volatile profile of these plants as well as other known host plants are being analyzed • Additional 22 fungal isolates have been screened on FCM; 17 of *Metarhizium anisopliae* and 5 of *Beauveria bassiana* for pathogenicity against the adult moth. Among the tested isolates, *M. anisopliae,* ICIPE with one isolate having the lowest LT50. • Potted seedlings of Rough lemon, Carrizo citrange and Cleopatra mandarin were budded with scions from mature-disease-free plants of Valencia, Washington Naval, Pixie and Mineola. So far, the screened plants have shown no sign of disease infection. • Model growers have been selected and based on the results	

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	pests identified by end of 2017. • Citrus plant materials/root stock for HLB resistance screened by mid 2017 using a participatory on-farm approach. • ACP proof nurseries established in strategic locations for production of clean nursery stock and HLB free materials produced by mid 2017. • Best-bet IPM technology for controlling ACP and FCM among citrus growers at selected project action sites implemented by 2017	tested in combination with biopesticide against FCM by end of 2017. • At least 20 citrus genotypes screened for tolerance/resistance to HLB by mid 2017. • At least two insect-proof nurseries established and 500 HLB-free clean stock, produced by mid 2017. • Best-bet technologies based on rotational application of biopesticide and soft chemical and clean planting materials for ACP and HLB management, and biopesticides and attract-and-kill for FCM implemented by 2017	of the on-going suppression trial of FCM, the farm of the selected growers will be used as demonstration plots for the best-bet IPM for suppression of this pest.	
4. Socio-economic assessment of the importance of the ACP and associated HLB disease, and FCM, and the impact of IPM on target biotic constraints established	• Baseline data on farmers' knowledge, attitude and practices of ACP, HLB and FCM management collected by end of 2015. • Economic impact of ACP, HLB and FCM on citrus production established by end of 2016.	• Baseline data on farmers' knowledge and management practices for ACP, HLB and FCM conducted and information on knowledge, attitude and practices collected in at least one action site by end of 2015. • Economic impact of ACP, HLB and FCM on	• Baseline data on ACT, HLB and FCM has been collected and data is being analysed. • KAP analyses established low knowledge among citrus growers on symptoms of ACT, HLB and FCM, while majority used synthetic chemicals to manage these pests. Awareness and utilization of IPM to control these pests was found to be limited. However, over half of the growers	

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	• Potential impact of IPM interventions evaluated by end of 2016. • *Ex-post* assessment of implemented IPM management options for target pests and disease conducted by end of 2017	citrus production assessed in at least one action site by end of 2016. • Potential impact of citrus IPM intervention assessed for at least one action site by end of 2016. • At least one *ex-post* assessment of implemented IPM management interventions conducted by end of 2017.	(60%), were willing to pay for an IPM package (Ksh. 5560) to control FCM, and about a similar number were willing to pay an IPM package (Ksh,5180) for suppression of ACT. • Impact assessment showed a positive return on investments in IPM, with NPV of 60% and BCR 16:1. Consumers seem to gain more from lower prices due to high supply, while producers gain from reduced cost of production, since they use less chemicals, and higher yields per unit area. • Base line survey data has been obtained to build a panel dataset using follow-up survey to be undertaken following the IPM intervention.	
5. Knowledge integration, capacity building, and technology transfer with national public and private sector partners and growers established	• Regular meetings/workshops focusing on trans-disciplinary knowledge integration and learning among partner institutions and stakeholders organised by end of 2016. • ToT workshops on citrus IPM conducted by end of 2017. • Citrus IPM technology learning	• At least one workshop for knowledge integration and learning among partner institutions and stakeholders conducted in each country by end of 2016. • At least one ToT workshop conducted in each of the target countries by mid-2016; at least one technology learning site and one farmer field day conducted in each of	• A consultative meeting on management of citrus pests was held with senior management of Zanzibar Ministry of Agriculture, Natural Resources, Livestock and Fisheries. Plans are also underway to organize an international stakeholder meeting to discuss a comprehensive action plan for containment and prevention of spread of *D. citri* across the continent and the disease it vectors. • Several ToT workshops have been organized in Kenya, Tanzania main land and Zanzibar. A total of	

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	sites established, field days conducted, extension materials produced and disseminated by end of 2017. • Postgraduate training conducted by end of 2017	the target countries by end of 2017. • At least 3 PhD and 3 MSc students trained on bioecology and management of the target pests by 2017.	98 (32% ♀) extension and quarantine officers have been trained on citrus pests' identification and management. • Citrus IPM technology learning sites have been established at the farms of the identified model citrus growers, where farmer field-days were conducted and a total of 196 (43% ♀) citrus growers were trained. • Extension materials have been produced and distributed to the growers. • 6 PhD students continue to make good progress on research work and write-up of manuscripts, one of them has almost completed her research work. Two M.Sc students have submitted their theses	
• **Specific Objective: To improve food and nutrition security, conserve environment, and to increase income and improve health of resource-poor farmers (including women farmers), by reducing crop losses and pesticide use through development and dissemination of effective pest management practices, especially IPM, in East Africa, along maize, rice and chickpea value chains by 2019**				
Production and productivity along maize, rice and chickpea value chains, by reducing crop losses through dissemination of effective IPM options increased	• At least 30% reduction i crop losses (from the baseline) in target communities by 2019 • At least 30% increase in yield (from the baseline) in target communities by 2019 • At least 30% reduction i frequency pesticide	• Number of beneficiaries engaged in IPM technology evaluation and adoption • Percentage reduction in pesticide use in beneficiary communities • Number of extension agents, farmers and graduate students trained	• Demonstrated push pull technology for stem borer control in three countries with a mean maize yield increase of 12.7%. • Farmers practicing IPM technologies are using no pesticide • Over 500 extension workers trained • Over 2000 farmers were trained • 9 students (4 MSc and 5 PhD) are conducting their studies	

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
	applications by 2019 • Atleast 20% increase in household incomes from adoption of IPM practices by 2019 • At least 50% farmers apply IPM practices • At least 70% farmers beneficiaries understand pest damage and behavior • At least 25% reduction in the frequency of pesticide application • Six PhD/MSc students trained • Over 800 farmers and extension agents trained by 2019 (200 a year for 2016, 2017, 2018 & 2019)	Percent yield loss abated in beneficiary communities	• At least 2000 farmers directly reached with the Push-pull technologies in Ethiopia. • At least 280 farmers directly reached with the push pull technologies in Kenya • Over 500 directly reached with rice IPM including tolerant varieties	
Key partners identified, IPM technologies developed and implementation strategies defined for sound sustainable intensification along the maize, rice and chickpea value chains	• Identify key stakeholders and develop implementation strategy by mid 2016 • Problem identification and prioritization by mid 2016	Number of stakeholders participated Number of pest problems identified and prioritized per crop per country	• Key partners include, Ethiopia Institute of Agricultural Research (EIAR), Ministry of Agriculture and Natural Resources; Ambo University, Haramaya University, Addis Ababa University and Jimma University. • Kenya Agricultural and Livestock Research Organization (KALRO),	

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
	• Design and conduct on-farm and on-station IPM participatory trials for rice, maize and chickpea pests, diseases and weeds by early 2017 • Evaluation and assessment of IPM packages and implementation strategies by mid 2017 • Scaling up proven IPM technologies under sustainable intensification systems by end of 2019	Number of respondents interviewed (baseline survey) Number of on-farm trials conducted Number of farmers participated Number of demo trials Number of IPM packages evaluated Percent crop loss abated	Department of agriculture, Kenya Agricultural Value Chain Enterprises. • Tanzania: Agricultural Research Institute, National Biological Control Programme, Sokoine University of Agriculture. • Problems identified include, pod borer, cutworms, blight and wilt in chickpea; stemborers, termite in maize; and stemborers and blast in rice	
Pragmatic pest diagnostic capacity developed	• Identifying local diagnostics and national pest, diseases and weeds priority by mid 2016 • Developing and testing diagnostic kits by end of 2016 • Capacity building and in-depth training on high impact pest and disease diagnosis by end of 2018	• Number of scientists/institutions engaged • Number of pests, diseases and weeds identified and prioritized • Types of diagnostics identified • Number of kits developed and tested • Number of institutions tested the kits	• 3 scientists and 3 institutions engaged • One animation for stem borers for extension works and farmers produced	

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
	Communication and data-network systems with partners by end of 2019	• Number of people trained (short-term and long- term trainings) • Number of pests, diseases and weds diagnosed Number of people accessing data		
Integrated pest management (IPM) communication and education improved	• Develop tailor made communication strategy for IPM to address different stakeholders by mid 2016 • Create awareness and disseminate information on IPM to enhance responsiveness of the stakeholders from 2016 - 2019 • Develop promotional materials targeted to different stakeholders to enhance up-take of the IPM technologies in 2016 and in 2018 • Establish network of key stakeholders in IPM through a web-	• Communication strategy developed • Number of audiences addressed • Number of people aware of IPM practices • Number of people applying IPM practices • Number of targeted stakeholders reached through these awareness campaigns • Number of promotional materials developed • Number of promotional materials disseminated	• Communication framework developed • Reached out to 22,956 farmers • Over 2000 demonstration trials • 5 field days conducted • 1 newspaper reported • 1 TV report • 3 brochures produced in three local languages	

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
	based interface that allows stakeholders to continually access emerging policy messages from the project by mid 2017 • Conduct training need assessments and educate farmers and extensions agents by end of 2018	• Number of people accessing the web-interface • Number of documents downloaded • Types of training needs assessed • Number of farmers and extension workers trained		
Information and capacity building to reform and strengthen policies that influence integrated pest management provided	• Identification of incentives and disincentives, policy gaps and institutional arrangements for adoption of IPM by early 2017 • Conduct a cost benefit analysis for IPM options for maize, rice and chickpea by early 2017 Conduct evidence based policy dialogue to improve adoption of IPM from mid-2017 - 2019	• Number of institutions participated • Policy gaps identified • Internal rate of return • Net present value • Number of policy briefs Number of policy workshops	• Three institutions participated in identification of incentives and disincentives, policy gaps and institutional arrangements • Cost benefit has been conducted for two institutions	
Specific Objective: MUSA - Microbial Uptakes for Sustainable management of major banana pests and diseases evaluated by 2020				
1.. Microbial collections (fungi) and other beneficial EBCAs (Endophytes and Biological Control	• At least 8 EBCAs discovered and identified. • Collected EBCAs cultured and	• Number of EBCAs discovered and identified. • Number EBCAs successfully in culture	• PhD student recruited • Collections of EBCAs initiated • Cultures of PPN and BW started	

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
Agents) for IPM in banana	deposited in *icipe* collection			
2. EBCAs host range assessment	• A number of selected EBCAs active against at least 2 pests in banana (Plant parasitic nematodes (PPN) and Banana Weevil (BW))	• Number of EBCAs successful in control of at least 2 pests in banana	• New project	
3. EBCAs biology in plants, pests and pathogen interactions	• Data on biology and effectiveness of selected EBCAs obtained	• Knowledge on biology and effectiveness of selected EBCAs	• New project	
4. Procedure for EBCAs mass production, storage and application	• Methods for large scale cultivation of microbial EBCAs bio formulation and storage	• Identification of the most appropriate EBCAs culturing methods • Protocol drafts available for partners	• New project	
5. Field integration of EBCA based IPM	• Field data for integration of EBCA (fungi) based IPM against PPN and BW	• Field trial data	• New project	
Objective 2: Minimise the vulnerabilities of horticulture and staple crops to climate change-induced pest problems by at least 10% by 2020.				
Specific objective: To disseminate knowledge of climate change impacts on ecosystem services and food security in Eastern Afromontane Biodiversity Hotspots by 2017				
Complementing, encapsulating and concretizing the research results of the climate change project Phase I (CHIESA) and	• Integration, synthesizing, and reporting of results from different WPs and within WPs from CHIESA by	• Effects of climate change on biodiversity and habitats disseminated • Species distribution maps for pest insects for maize,	• 27 scientific articles, 2 book chapters, 4 CC adaptation brief guides, 4 policy briefs, 10 newspaper articles, and 2	• Development and distribution of materials for capacity building and dissemination

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to make them adoptable and adaptable to specific user groups as well as to wider audiences.	mid 2016. • Integration of scientific capacity at institutional level built to achieve overall objective of climate change adaptation by end of 2016 Synthesized results targeting a supra-regional Eastern Africa Mountain Biodiversity Hotspot, which also increase knowledge on National level impacts with feed into ministerial policies by end 2017	crucifers, avocado and coffee imparted	technology transfer manuals published	purposes greatly exceeded the target. Guide books/manuals for extension workers and other stakeholder groups on coffee management, drip irrigation and integrated pest management were distributed during the Farmer Field Schools and stakeholder training events, seminars and conferences. These have been made available also on-line so the materials can be used in the years to come after the project has ended
Strengthening the capacities of relevant professional partner organizations to be able to further communicate research results and related technology to the end users	• Maintenance and utilization of the GeoNetwork platform and weather monitoring infrastructure by mid 2016 • Strengthen capacity of providers of extension	• GIS platform established for sharing geospatial datasets among at least 25 East African stakeholder organisations regularly utilized. • No. of participants at trainings that showcase	• 65% increase in number of participating public organizations • 7 horizontal capacity building events organized (27% of participants were women) • 50% increase in number of CC adaptation technologies available and used by partner and stakeholder organizations	

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	service by end of 2016 • Improved access to appropriate and affordable technologies by mid 2017 • Implementation of community adaptation plans, including linking with the existing government planning processes by end of 2017	the utility of geospatial products. • No. of new local and regional products derived. • Geospatial datasets in use. • Number of Community training events		
Effective and sustainable distribution and communication of CHIESA research results to specific user groups as well as to wider audiences.	• Appropriate information, training, and communication materials available by mid-2016 • Increased knowledge and information about climate, technology and markets by end of 2016 • Adequate use of information dissemination pathways by mid 2017 • Appropriate political support for communication and dissemination by end of 2017	• Number of out research on household vulnerability and adaptation strategies to climate change done. • Project website to share information among partners and other stakeholders regularly used. • Number of community sensitisation on climate change effects and need for research events conducted.	• 9 radio programs and 4 TV news broadcasted, 2 social media sites operational • 100% increase in visits to the project FaceBook site and 28% increase in followers. • The project website was updated with news on the project activities and digital versions of materials. • 4 new policy briefs, 4 brief guides on technologies, 5 training materials (3 videos) distributed to the stakeholders, such as extension workers	• Radio and TV program in regional channels and languages greatly enhanced dissemination activities • The number of social media (Facebook) followers has increased from 760 in January 2016 to 973 in December 2017. The number of people who saw the content displayed on the AFERIA facebook page increased from 7,248 in June

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				2017 to 14,484 in December 2017.
Specific Objective: Adaptation for Ecosystem Resilience in Africa (AFERIA)-Maize component				
Enhancement of the distribution and abundance of the parasitoids of maize Lepidoptera stem borers	• Releases of *Cotesia flavipes* and *C. sesamiae* (Inland population) in Kenya (Taita Hills, Murang'a and Makutano) and in Tanzania (Moshi). • Farmers sensitization on the use of the parasitoids to control the maize Lepidoptera stemborers and training of the trainers (TOTs i.e. agricultural officers).	• Number of parasitoids released in each target region. • Number of farmers sensitized in each target region. • Number of Kenyan and Tanzanian agricultural officers trained.	• More than 500 adult parasitoids were released in each target region. • More than 300 farmers were sensitized in each target region. • Training of 7 Kenyan and 2 Tanzanian agricultural officers.	• The number of parasitoids to release has to be increased in the target regions. • Important to assess thereafter the establishment of the parasitoids released. • Important to avoid the use of pesticide by the farmers in the regions where the parasitoids have been released even if *Spodoptera frugiperda* is invading these target regions
Specific objective 2.3: Determine the contribution of organic agriculture to sustainable development in the tropics by 2018				
1. Effect of organic and conventional farming systems on pest and disease incidence, severity and damage determined and documented by 2017. 2. Effect of organic and conventional	Long-term organic and conventional farming systems compared and their effects on soil fertility, soil biodiversity, pests and diseases, yield and health determined and widely disseminated by 2018	• At least one major pest and one major disease of maize assessed under the two different farming systems by 2016. • At least one major pest and one major disease of vegetables assessed under the two different systems by 2016.	• Cabbage, spinash and kale were evaluated during vegetable season that ended in February 2017; baby corn was assessed during the long rainy season from March to September 2017 and French beans was studied during short rain season from October 2017 • Major pests recorded on cabbage and kale included	

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farming systems on soil biodiversity assessed, and documented, by 2016. 3. Effect of organic and conventional farming systems on soil fertility and safety evaluated, and documented, by 2018. 4. Yields and incomes generated through organic and conventional farming systems compared. Participatory on-farm research (POR) conducted for wider result dissemination and adoption.		• The effect of both systems on at least one major plant nutrient (N, P or K) determined by 2018. • Effect of farming system on at least one soil physical characteristic assessed by 2017. • Pesticide and nutrient leaching compared for organic and conventional systems by 2018. • Comparative yields and incomes for at least 2 commodities documented by 2018 • Results tested on-farm in at least 3 different locations by 2015.	diamond back moth and aphids with no difference between organic and conventional systems at both sites • Marketable kale and spinach yields were 3 and 3.6 times respectively higher in organic than conventional systems. • Cabbage marketable yields were similar for both systems at Chuka but at Thika, marketable yield was 2.3 times higher in conventional than organic system • Major pests identified in maize were stemborers, fall army worm and termites while thrips and ball worms were observed in beans, with no significant difference between systems • In beans, bean yield during the 1st season 2017 revealed that highest yields were obtained from Masai manure+mulch • PhD studies on N dynamics revealed that N immobilization occurred in the same period for all systems during maize cropping season except for Conv-High at Thika site. • PhD study on microbiology revealed that while total prokaryote diversity was higher in conventional compared to organic system, active prokaryote were	

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			inversely higher in organic than conventional system. • PhD study on termites revealed that termite abundance, diversity and foraging activity were highest in organic systems compared to conventional systems. • MSc study assessing nematodes revealed that beneficial nematodes were higher in organic systems compared to the other systems. • MSc study on phosphorus sorption showed that composts prepared together with rock phosphate had 5 times more P than those without rock phosphate • MSc studies on assessment of pesticide residues in soil revealed that high concentration of imidacropid were found in conventional systems while only traces were found in organic systems • 1 peer reviewed paper was published • Atandi et al. (2017) *Agriculture, Ecosystems & Environment* 247, 265–272	
Objective 3: Assess the effect of hermetic storage on mold and aflatoxin contamination of stored maize and the qualitative changes in grain legumes during hermetic storage by 2018				
Specific objective 3.1: Assess the effect of hermetic storage on mold and aflatoxin contamination of stored maize.				
Effect of hermetic storage on mold and aflatoxin contamination	At least five (5) village communities in Makueni (Kenya) are aware of	• At least one (1) study on mold and aflatoxin contamination of stored	• MSc study showed that hermetic storage bags (PICS) controlled	

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
of stored maize assessed.	the effect of hermetic storage on mold and aflatoxin contamination of stored maize by early 2015	maize conducted by end of 2014. • One scientific publication by end of 2015	postharvest losses and aflatoxin contamination on maize. • 1 peer reviewed paper published (Nganga et al. 2016. J. Stored Prod. Res. 69: 119-128. • 1 poster presented at The First All Africa Postharvest Congress and Exhibition, 28-31 March 2017, Safari Park Hotel, Nairobi, Kenya. • Another MSc study showed that losses due to moulds were significantly higher in private owned stores due to, among other factors, purchase of low quality maize. • 1 peer reviewed paper published. Mwangi et al. (2017) J. Stored Prod. Res. 73: 7-20	
Specific objective 3.2: Evaluate qualitative changes in grain legumes during hermetic storage.				
Qualitative changes in grain legumes during hermetic storage evaluated	Qualitative changes in at least two (2) grain legumes during hermetic storage known by early 2015.	At least one (1) research report and one draft journal article produced by end of 2015.	• PICS bags were very effective in preserving mugbean & pigeopea against *Callosobrucus maculatus* damage (weight loss <1%) compared to polypropylene bags (>13% weight loss). • 2 peer reviewed papers published: Affognon et al. DOI 10.17660/ActaHortic.2016.1120.37; Mutungi et al 2014 J. Stored Prod. Res. 58:39-47	
Objective 4: Undertake acoustic fingerprinting of postharvest insect pests' sound spectra for long-term monitoring of storage pests of grains in bulk storage warehouses in Kenya by 2018				
Specific objective 4.1: To carry out acoustic profiling of sounds produced by 5 postharvest pests of adult and immature stages of *Prostephanus truncatus, Sitophilus zeamais, Sitophilus oryzae, Acanthoscelides obtectus, Tribolium castaneum*				
Acoustic profiles of *Prostephanus*	Acoustic profiles developed for at least	At least one (1) research report and one draft	• Study on effects of hermetic storage on insect activity revealed	• Appropriate software and

Outputs Expected as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress Observed in Obtaining Outcomes***	***2017 Lessons Learned***
truncatus, Sitophilus zeamais, Sitophilus oryzae, Acanthoscelides obtectus, Tribolium castaneum developed	five (5) storage pests by end 2015.	journal article produced by end of 2015.	that detection of time required to halt *Sitophilus zeamais* activity is possible by use of acoustic device. • Study on bioacoustics of *Acanthoscelides obtectus* showed that adults produced low-amplitude impulses at higher rate than the larvae. • 2 peer reviewed papers were published. • Noroge et al.(2017) J. Econ. Entomol. 110(6): 2707-2715 • Njoroge et al. (2017) Florida Entomologist 100(1): 109-115 • 1 PhD Thesis on acoustic detection of insect pests of stored grains in Kenya.	short-term training on acoustic sound signal analysis is required
Specific objective 4.2: To undertake the selection of specific unique frequency identifiers for *Prostephanus truncatus, Sitophilus zeamais, Sitophilus oryzae, Acanthoscelides obtectus, Tribolium castaneum* using sound characteristics that were developed in Specific objective 4.1.				
Unique frequency identifiers for *Prostephanus truncatus, Sitophilus zeamais, Sitophilus oryzae, Acanthoscelides obtectus, Tribolium castaneum* selected	At least five (5) unique frequency identifiers selected for at least five (5) storage pests by end 2015	At least one (1) research report and one draft journal article produced by end of 2015.	• Frequency spectra of broadband sound impulses revealed five categories: Broadband, HighF, MidF1, MidF2 & LowF indicative of the differences in their peak energies and broadness of frequency range. There were differences in impulse counts per burst btetween broadband and MidF2. • 1 peer reviewed paper published (Njoroge et al. 2016 J. Stored Prod. Res. 69: 31-40).	

Outputs Expected as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress Observed in Obtaining Outcomes*	*2017 Lessons Learned*
Specific objective 4.3: To assess the preference for acoustic early warning system in bulk storage warehouses in Kenya				
The value warehouses would attach to acoustic sensors (devices) if developed, i.e. their willingness to pay for the devices gauged.	One report on the valuation (willingness to pay) for acoustic devices by the last quarter of 2015.	At least one (1) research report and one draft journal article produced by last quarter of 2015	• MSc study on willingness to pay for LarvaeSpy acoustic technology revealed that majority of farmers and warehouse/grain traders would not pay for the device due to prohibitive price and unavailability locally. • Draft manuscript prepared for submission to peer reviewed journal for publication.	

1.2 Insects for Food and Feed: RBM Report

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
Objective 5: Promote the utilisation of insects for food, feed, organic waste recycling and pharmaceutical purposes to enhance food security and income generation capacity in sub-Saharan Africa by 2020.				
Specific objective 5.1: Develop and promote Insects for Green Economy (GREEiNSECT) by 2018				
1. An appraisal study to document culturally and environmentally acceptable insect species in Kenya conducted.	• Knowledge regarding edible insects in Kenya enhanced.	• Culturally and environmentally acceptable edible insect species in Kenya documented by end of 2014.	• Studies on the diversity of gryllids has revealed 18 species in six major cricket consumption areas in the coast and Lake Victoria region of Kenya. • *Scapsipedus marginatus* was the most dominant species accounting for 30.3 – 50.5% of the total catches across the studies areas. • Mass rearing systems for two cricket species *S. marginatus* and *Gryllus bimaculatus* have been established and boosted to produce 70,000 – 90,000 crickets per week.	
2. The microbiological content of the key edible insects in Kenya (fresh, processed or stored form) identified and analysed.	• Food safety and risk factors associated with edible insects documented.	• The microbiological content of the key insects as food in Kenya identified by end of 2017. •	• Microbial characterization of bacterial and fungal loads in different cricket species (*S. marginatus* and *G. bimaculatus*) is being carried out. • Entomopathogens (including *Beauveria* spp., *Entomophthora* spp. *Metarhizium* spp.) cricket paralysis virus (CrPV), microsporidia, nematodes, and mites have been documented in laboratory colonies of crickets in *icipe.* • The fungus *Aspergillus flavus* has been detected in cricket colonies, which constitute a possible threat to cricket rearing and colony growth.	

Expected Output as per RBM framework plan	***Expected Outcome as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress observed in Obtaining Outcomes***	***2017 Lessons Learned***
			• Commonly observed bacteria included *Escherichia coli*, *Salmonella typhi,* and *Staphylococcus aureus*.	
3. Potential entomopathogens that pose a threat in the farming of insects profiled and documented.	Knowledge of entomopathogens that threaten production of edible insects enhanced.	• Potential entomopathogens that pose a threat in the farming of insects documented by end of 2017.	• Differential susceptibility of the entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* as potential threat to *S. marginatus* and *G. bimaculatus* production has been established. Out of the 15-species screened Kapiti S3 was the most pathogenic *M. anisopliae* with mortality rates of 60 – 80%, while Caterp B recorded the highest mortality (70 – 90%) among the *B. bassiana* isolates. • The susceptibility of cricket species (*S. marginatus* and *G. bimaculatus*) to four species of entomopathognic nematodes (Mw8A, Naivasha, Palm and Yatta) at different temperature regimes has been established. The percent mortality of both cricket species ranged between 22 – 78% across the different temperature regimes for the different nematodes.	
4. Molecular characterisation of microbial composition (DNA barcoding and/or RAPD) conducted.	Information regarding the microbial composition of the edible insects improved.	• Molecular characterisation of microbes attacking edible insects and that pose a threat for food safety conducted by end of 2018. •	• Molecular identification of different microbes attacking crickets is ongoing	
5. Recommendations for enhancing food safety and quality control of edible insects in Kenya, and	Information to enhance policy regulations and legislations governing the use of	• Workshops to provide recommendations to inform policy for development of standards for use of insects as food and feed conducted by end of 2016.	• Post-harvest processing revealed that boiling at 96°C for more than 5 min or toasting at 150°C for 2 minutes was sufficient to eliminate all possible bacteria and fungi contaminants found in the processed insect.	

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
for international trade provided.	insects as food and feed available.		• Impact of processing methods on microbial load of edible crickets in Africa: inferences to food safety has been completed • Evaluation of fresh, processed and stored crickets showed no evidence of aflatoxins and pesticide residues as contaminants.	
Specific objective 5.2: Develop and promote insect feed for poultry and fish production in Kenya and Uganda (INSFEED) by 2018				
1. Socio-economic surveys carried out on the use of insects for feed in poultry and fish farming. 2. Market demand analysis for insects as feed ingredient for poultry and fish conducted. 3. Economic performance of insect-based feed assessed.	Farmers and feed producers invest more in insect-based feed production and use, and increase adoption by 2018.	• At least 3 focus discussions per target country by end of 2015. • At least 500 small-scale farmers surveyed per target country by end of 2015. • At least 100 livestock feed processors surveyed per country by end of 2015. • Comparative costs of at least 3 insect based feeds assessed by end of 2018 • Market demand and cost benefit analysis conducted for at least one insect based feed by 2017. • Cost efficiency studies of poultry and fish reared on insect based feed evaluated by 2018. • Key market segments described by December 2015.	• Cost effectiveness of insect based feed in broiler chicken documented. • A 16% higher Cost Benefit Ratio and 25% better Return on Investment was recorded when broilers were reared on black soldier fly (BSF) based feed compared to the conventional diet which was 19.0% more expensive. • BSF were sold on the Kenyan market in 2017 between US$0.85-1.00 per kg • Preliminary BSF production costs are estimated at US$0.20 per kg	
4. Rearing techniques for key insects suitable for use as feed developed and adapted. 5. Wild harvesting techniques for swarming insects developed and adapted.	Efficiency improved in insect, poultry and fish rearing for low cost production and high profit margin by 2018.	• Rearing techniques developed for at least 3 insect species by June 2015. • Safe and cost effective substrate for rearing of at least 3 insect species documented by end of 2016. • Chemical and microbial toxicity of at least 3 insect species under different rearing techniques profiled by end of 2017.	• Bacteria identified from unprocessed wild crickets include *Erwinia spp, Enterobacteriaceae, Klebsiella oxytoca* • Fungal isolates from wild crickets include *Aspergillus spp* and *Penicillium roseopurpureum.* • On reared crickets, bacteria isolated include *Enterobacteriaceae, Enterobacter*, *Bacillus nealsonii.*	

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
6. Chemical and microbial contamination determined and protocol developed for safe rearing and handling. 7. Nutritive profile of key insects assessed. 8. Insect based feed formulated and tested.		• Entomopathogens affecting at least 3 insect species colonies documented by 2017. • Wild harvesting techniques developed or adapted for at least 3 species by September 2018. • Effect of trap and post-harvest handling on contamination documented by 2017. • Insect based feed formulas developed by 2017. • Nutritive profile of at least 3 insect based feed assessed by 2016. • Palatability and utilization rate of at least two insect based feeds tested on fish and poultry by end of 2017. • Effect of at least two insect based feeds on fish and poultry growth assessed by end of 2017. • Storage techniques developed for at least 3 insect based feeds by September 2017.	• Fungi isolated from reared crickets include *Aspergillus niger, Trichoderma asperellum,* and *Aspergillus flavus.* • Deep frying, freeze drying and snap freezing cleaned all bacterial and fungal contamination. • 100% BSF based layer feed resulted in 62% higher egg production, 37.5% production cost reduction and longer egg laying time than conventional feed. • 33% BSF based tilapia feed resulted in higher growth rate than conventional feed. • No difference in growth rate was found between conventionally and insect based fed broiler chicken. • Dried BSF and cricket can achieve a shelf life of 7 months in the form of powder. • Substitution of fishmeal and soybean by BSF in feed increased potassium, magnesium and phosphorus levels but reduced iron and sodium levels. • Pellet quality parameters remains the same between conventional and BSF based fish feeds.	
9. Results used to inform policy to support use of insect-based feed in poultry and fish farming.	Enhance awareness among stakeholders and inform policy by 2017.	• At least two stakeholder workshops held by 2017. • At least 10 media coverage stories on the INSFEED project by December 2017. • At least two policy briefs documented by December 2017. • At least two desk studies and expert interviews conducted per country by 2016.	• A total of 3 stakeholder workshops were held in 2017. • More than 500 farmers trained on insect farming. • Standards for insect use in animal feed were approved in Kenya and Uganda in 2017. • One story of change on gender outcome was published. • Two papers were published in peer reviewed journals in 2017:	

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
		• At least one situation paper on the use of insects for feed produced by June 2018. • Documentation of processed feed leading to national and international standards (Codex) developed by December 2017.	Mutungi et al. (2017) *Critical Reviews in Food Science and Nutrition*, doi: 10.1080/10408398.10402017.11365330 Ssepuuya et al. (2017) *Journal of Insects as Food and Feed* 3, 289-302. • Six papers submitted to peer reviewed journals in 2017.	
Specific objective 5.3: Development and implementation of insect-based products to enhance food and nutritional security in sub-Saharan Africa (EntoNUTRI) by 2019				
1. Insect farming and harvesting techniques for edible saturniids, grasshoppers and crickets developed and production systems optimised using locally available substrates.	Edible insect-based technologies to enhance productivity and consumption of insects as food to improve livelihoods and wellbeing of rural and urban communities developed and disseminated by March 2019.	• At least two improved rearing and two improved harvesting techniques for edible insects developed and disseminated by March 2019. • Field ecology of at least two target edible insects assessed by December 2017. • Wild harvesting techniques for at least 1 target edible insects developed by December 2018.	• Stable colonies of long- and short-horned grasshoppers established. • Identity and diversity of edible grasshoppers and saturniids, their seasonality understood. • Molecular characterization of the saturniid caterpillars and their natural enemies completed. • Improved mass rearing protocols for *Schistocerca gregaria* and *Gryllus bimaculatus* communicated.	
2. The nutritional attributes of target insect species (fresh, stored and processed) established and appropriate post-harvest technologies for preservation tested and implemented.		• Nutritional attributes of at least 3 edible insects assessed by Dec 2017. • Improved postharvest handling techniques for at least 2 edible insects developed by Dec 2018.	• Nutritive profile of edible Saturniids and edible grasshoppers was established. • Nutritive profiles of edible insects subjected to various processing technique was documented. • Protocols for the vitamin analysis of edible insects optimized and commercially available.	

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
3. Food safety (chemical and microbiological) and regulatory requirements to inform policy on the use of insects as food established.		• At least 2 target edible insects screened for chemical risk factors by December 2018. • Microbial risks associated with 3 target edible insects assessed by March 2019.	• The saturniid caterpillars stored under clean conditions were mostly free of harmful pathogens and aflatoxin producing fungus. • Detailed assessment on the food safety and entomopathogenic fungi have been undertaken. More closer scrutiny of pathogens which are entomopathogenic and that are relevant to human health will be a key focus in 2018.	
4. Socio-economic assessment – Communities' perception of insects as food and the willingness to accept insects as part of their diets as well as the livelihood effects of edible insects in households assessed and documented.		• At least 2 target country level surveys on community knowledge attitude and practices with edible insects completed by July 2017. • At least 1 survey on consumer willingness to accept edible insects completed by Dec 2018. • Economic situation of edible insects value chain actors assessed in 1 of the target countries by Sep 2018.	• Surveys on knowledge, attitudes and practices of communities, and outcomes indicated that preference for edible insects is declining among the younger generation.	
5. Innovations on insect farming and utilization as food transferred to beneficiaries and R&D capacity and entrepreneurship in the field disseminated.		• Trainings of Trainers (ToTs) on insects to enhance food and nutritional security undertaken for at least 40 stakeholders (20 each for Kenya and Uganda) by Dec 2018. Outreach materials - manuals, posters and leaflets - on insect rearing/harvesting/processing/packaging technologies developed and distributed to at least 1,000 beneficiaries in each country by March 2019.	• One MSc study has been completed with one MSc study on-going. 3 PhD and one Post doc studies are on-going. • Project students participated in the international conferences to present their work.	

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
		• A project website established by Mar2016. • Advanced level training of at least 4 PhD and 5 MSc students, especially women, from Africa and Germany accomplished by March 2019.		
Specific objective 5.4: Improving livelihood by increasing livestock production in Africa: An agribusiness model to commercially produce high quality insect-based protein ingredients for chicken, fish and pig industries (ILIPA) by 2019.				
1. Pilot production and demonstration facilities established at *icipe* 2. Potential scavenging feed resources that can be used as substrate for insect rearing investigated.	Knowledge regarding practicality of scientific methods based on the availability of these feed resources in Kenya enhanced by 2017.	• Pilot production facility and feed sources for rearing BSF that is culturally and environmentally acceptable in Kenya documented by end of 2017.	• Mass rearing of black soldier fly (BSF) has been boosted with production capacity of ~ 70 - 85 kg of 4th & 5th instar larvae/week. • Effects of waste stream combinations from brewing industries on performance of Black Soldier Fly has been completed. Manuscript under internal review. • Threshold temperatures and thermal requirements for production of BSF: Implications for mass production has been completed. • The effects of two types of larval diet, liquid and solid (waste carrot based), on various quality control parameters of the black soldier fly has been investigated. • The developmental time, survival and nutritional profile of black soldier flies reared on different readily available substrates (kitchen waste, market waste, cow dung, goat dung, pig manure, human waste, rabbit dung, chicken manure, spent grains, etc.) have been established with crude protein levels ranging from 35.4 – 52.3%. • Phoretic mites were identified as a new threat to BSF production in sub-Saharan Africa.	

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
3. Socio-economic surveys carried out on the use of insects for feed in poultry, fish and pig farming. 4. Market demand analysis for insects as feed ingredient for poultry, fish and conducted.	Farmers and feed producers invest more in insect-based feed production and use, and increase adoption by 2019.	• At least 500 small-scale farmers surveyed by end of 2017. • Comparative costs of at least 1 insect-based feeds assessed by end 2017 • Market demand and cost benefit analysis conducted for at least one insect-based feed by 2018.	• Socio-economic survey has been conducted with a total of 1625 farmers interviewed. • Majority of the respondents (>70%) are willing to rear insects for sale to commercial feed manufacturers/ processors • Additional > 80% are willing to buy insect-based formulated feeds for poultry, fish and pig production. • >90% of the respondents are willing to consume poultry meat products derived from insect-based feeds. • Over 60% of the respondents are willing to pay a premium price for poultry meat products derived from insect-based feeds compared to meat products of poultry fed on conventional feeds. • More than 10 different feed formulations with BSF larvae have been established for field trials on chicken, pigs and fish. • Factors influencing willingness to pay (WTP) for insect-based feeds among smallholder fish, pig and poultry farmers in Kenya has been completed. • Consumer preferences and willingness to pay for chicken meat products derived from insect-based feeds have been documented.	
5. Awareness on the potential of insect-based feeds for poultry, pig and fish farming raised.	Farmers consider insects as an alternative source of feed for poultry, pig and fish farm enterprises by 2018.	• At least 10 awareness stakeholders meetings organized by 2018. • 5 radio spots realized by 2018. • At least 30% of farmers attending awareness meetings consider insect as an alternative source of feed for poultry, pig and fish farm enterprises by 2018.	• A total of 8 sensitization campaigns on insect-based technologies have been conducted across the four project benchmark sites. • Total number of people trained were 63 extension staff, 8 feed manufacturers and 24 model farmers from different farmer groups (poultry, pig and fish).	

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
			• Organized a total of 24 farmers exchange visits to *icipe* to ensure buy-in and adoption of the technology. • Twenty-four (24) farmer group leaders have been provided with starter kits to initiate pilot centres for BSF mass production and processing in their respective localities. • Farmers and extension officers trained were provided with a total of 2142 flyers bearing information on black soldier fly production. • A total of 95 copies of field or manual guides on black soldier fly was distributed to the Trainings of Trainers (ToT). • Furthermore, 621 young entrepreneurs (40.5% females and 59.5% males) have been trained at *icipe* and provided with flyers and manual guides. • In collaboration with the ToTs (farmers and extension workers), a total of 277 farmer groups (~ 4900 farmers) have been identified and recruited to be engaged in insect-based enterprise. • During farmer field days and workshops, several broadcasting media houses (NTV, KTN, Citizen TV and iNOORO TV etc.) have enormously helped in covering most of the workshop activities in both English and Kiswahili. • Also, project activities across the project benchmark sites have also been featured in Daily Nations and The Standard Newspapers.	
6. Capacity of youth and women farmers (small-scale and commercial) in	Youth and women farmers (small-scale and small commercial) engage	• At least 10 youth and 10 women groups trained in mass-production, harvesting and primary processing of BSF protein by 2018.	• A total of 24 model farmers from 24 different groups (14 youth and 10 women groups) trained in BSF mass production across the project benchmark sites. The 24 farmers were	

Expected Output as per RBM framework plan	***Expected Outcome as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress observed in Obtaining Outcomes***	***2017 Lessons Learned***
mass-production, harvesting and primary processing of BSF (Black Soldier Fly) protein built.	in mass-production, harvesting and primary processing of BSF by 2019.	• At least 30% of the group members produce, harvest and process BSF by 2019.	also brought to *icipe* insect rearing facility for additional training on mass-production, harvesting and primary processing of BSF protein. Thereafter, they were provided with starter kits to start pilot production in their respective communities. • All the 24 farmer groups (100%) engaged in the application of insect-based technology are still at their early stage of production. However, they simply harvest to supplement the diet of the free-range chickens.	
7. Formulations for nutritious insect-based feeds for poultry, pigs and fish established and tested.	Nutritious insect-based feed formulation for poultry, pigs and fish ready for release for mass production by 2018.	• At least one formulation for insect-based feeds for poultry, pigs and fish established and tested by 2017. • At least two commercial small-scale feed companies willing to take the nutritious insect-based feed formulation for mass production by 2019.	• More than 10 different feed formulations with BSF larval-based ingredients have been established for field trials on chicken, pigs and fish. • Two small-scale feed processor based in Nakuru (Josiche General Traders Ltd.) and *Kenya* Marine and Fisheries Research Institute (*KMFRI*) already use the protocol and standards for feed formulation for experimental trials on poultry and pigs in KALRO-Naivasha and fish in KMFR -Sagana, respectively.	
8. Insect based feed tested for microbial pathogens and toxins.	Insect based feed formulation free from microbial pathogens and toxins ready for release for mass production by 2018.	• At least one feed formulation is tested free from microbial pathogens and toxins, and can be proposed for mass production by 2018. • At least two commercial small-scale feed companies willing to take the safe insect-based feed formulation for mass production by 2019.	• Feed formulations with BSF have been tested and shown to be free of aflatoxin and pesticide residues. Commonly observed pathogens on the black soldier fly larvae include *Escherichia coli*, *Salmonella typhi, Staphylococcus aureus* and faecal coliforms. However, postharvest handling measures have been established to sufficiently eliminate all possible bacteria and fungi contaminants rendering them safe for use in feeds. • Beside the two-small-scale feed processors based in Nakuru and *Sagana*, 8 more feed	

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
			manufacturing companies are willing to take the safe insect-based feed formulation for mass production. • The differential susceptibility of black soldier fly larvae to 14 entomopathogenic fungi (*Beauveria bassiana* and *Metarhizium anisopliae*) was documented. • The pathogenic and lethal effects of entomopathogenic nematodes (EPNs) on the black soldier fly larvae under laboratory conditions as well as across different temperatures has been established. • The biodiversity of the gut microbiota of black soldier from six continents has been established.	
9. Protocols and tools for production of safe insect-based feeds for poultry, pigs and fish in the prospect of certification developed.	Protocol and tool for production of safe insect-based feeds used by small-scale feed processors by 2018.	• At least one protocol and tool for production of safe insect-based feeds available by 2018. • At least two small-scale feed processors use the protocol and tools for feed formulation by 2019.	• Protocol for mass rearing of BSF have been established. • Identification and global ecological niche suitability BSF has been completed.	
10. Youth and women farmer groups linked to profitable markets e.g. feed companies for the insect-based protein products.	New sector for employment, value chain for insect protein created in Kenya by 2019.	• At least 10 youth groups and 10 women groups linked to profitable markets for insect-based feeds by 2018. • At least 20% of the farmer group members are selling insects to small-scale feed processors by 2019.		

3.3 Animal Health: RBM Report

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
Objective 1: To develop attractive and effective killing and repellent system for control of vectors of camel trypanosomosis (surra) and to reduce vector and disease levels by 50% by 2020.				
At least one potential control technology developed for vectors of surra.	At least one olfactory bait and one repellent blend tested and available for control of vectors of surra.	• At least 50% decrease in flies attracted to camels. • At least 50% decrease in disease incidence. • Favourable assessments by participating livestock keepers and veterinary staff. • Publications produced.	• Biting flies associated with camels, and which have disease transmission potential identified to species level and documented • Potential Olfactory attractants identified and tested under field condition • Potential repellents from camel as well as from plant, *T.minuta* and *T.diversifolia* crude extract oil formulation developed and tested • *Trypanosoma vivax* and *T.evansi* isolates identified, and associated with hemorrhagic episodes • Mass trapping of the biting fly *Stomoxys calcitrans* and other biting flies done using olfactory baits; 1000s of flies were trapped at the Shurr field site in northern Kenya. • Carvone and β-citronellene identified as attractants for gravid *S. calcitrans* one of the main vector of surra -their efficacy at field condition will be tested in May-June 2018	• Vertical transmission from mother to calf as one way of trypanosomes transmission mechanisms identified, in addition to mechanical vectors transmission. • A strategy needs to be developed to minimize trans-placental transmission of trypanosomes, which may contribute to calf mortality. • Seasonal and ecological variation observed in abundance of biting flies will influence the strategy for control. • Not all vectors are attracted to the developed olfactory and visual bait= necessitated modification of color,

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
			• Development of two manuscripts for publication advanced, Articles ready for submission: • Getahun et a., Non-tsetse biting flies are a significant but overlooked vectors of African animal trypanosomes in tsetse free areas • Getahun et al., *Trypanosome evansi* transmission from mother to calf in camel as one potential mechanism to sustain *T.evansi* in camel herds	pole height, semio-chemicals and options to dispense them. • Plant-based repellents and those identified from camels need to be formulated for long lasting effect as slow release formulation, which is on going
Objective 2: To upscale and adapt tsetse repellent technology in partnership with the private sector and to reduce trypanosomosis risk by 50% by 2020				
1.Repellents for control of vectors of human sleeping sickness evaluated.	• Synthetic and waterbuck repellent blend evaluated for *Glossina fuscipes fuscipes* in Kenya.	• At least two tsetse repellent blends evaluated for control of vectors of human sleeping sickness, *Glossina fuscipes fuscipes* • At least 50% decrease in fly catches in presence of repellents. • No. of trials undertaken. Publications produced.	• A >30% reduction in flies caught in traps containing repellents (both waterbuck and synthetic), compared to un-treated controls.	
2. Integrated use of repellents with traps and screens, and olfactory baits evaluated in push–pull strategies to stop flies reinvading areas where they have been controlled.	• Effective barrier system developed to stop flies from reinvading tsetse-controlled areas.	• Complementary technologies identified with potential for integration with repellent technology to stop reinvasion.	• Integrating repellents and traps/screens as a barrier is under field testing.	• A barrier system can be optimized; efficacy observed when repellents were placed at 10-meter intervals. • Community participation is critical

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
		• Barrier prevents at least 80% flies from entering a controlled area.		
3. Technology for large-scale production of dispensers and repellent compounds passed over to private sector.	• At least one agreement signed with entrepreneurs for further improvement of the dispensers for commercialization of tsetse repellent technology • At least one local entrepreneur identified for manufacturing/ distribution of repellent collars.	• No. of agreements signed. • No. of meetings held. • At least one design prototype tested for upscaling.	• Novel canvas-based dispenser developed, and field testing is on-going. Initial durability testing showed that the canvas collar was durable beyond six months. • Improvements have been made to enhance durability, based on observations from the field.	• Current dispensers are made by the private sector at a cost is adjudged to be higher than would be viable for smallholder farmers ~($50). • New dispensers using durable synthetic materials, locally available are undergoing field testing.
3.1. Business plan for commercialisation, packaging, product registration, marketing and dissemination for rollout of the technology developed. 3.2. Advocacy of the repellent technology enhanced.	• Business plan developed for commercialisation, dissemination, registration and roll out. • Advocacy of repellent technology enhanced in collaboration with stakeholders.	• Business plan developed. • At least one P-P-P partner using the business plan. At least 3 advocacy events undertaken.	• Business plan initiated, pending award of a registration certificate.	• Registration takes longer than estimated, because of multiple agencies involved.
4. Integrated validation trials in Shimba Hills upscaled in partnership with the local county staff of the Ministry of Agriculture and Fisheries in Kwale and KWS, and impact on disease levels and drug use and animal productivity assessed.	• Tsetse repellent technology adapted, up-scaled and integrated with other tsetse and disease control tactics for sustainable trypanosomosis control in Kenya.	• Disease reduced by > 50%. • Incidence of tsetse populations reduced >50%. • Drug use reduced >50%. At least 3000 households use repellent technology.	• *icipe* project reports. • Peer-reviewed publications showing reduction in disease and multiple benefits (livestock productivity, income, drought power)	

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
5. Socio-economic impact of the repellent technology assessed.	• Awareness created and socio-economic impact of the tsetse repellent products documented.	• At least 3 stakeholder trainings held. • At least 3 awareness creation workshops held for local government departments and other stakeholders. • Socio-economic impact study conducted. • *Ex-ante* and *ex-post* financial, socio- and economic impact assessments.	• Socio-economic impact study reports. • *icipe* project reports.	
Objective 3 - A novel ticks management strategy that is based on the use of bioacaricide, semiochemicals and/or botanical, developed and implemented by 2020.				
1. A joint committee (*icipe* and Real IPM) responsible for project implementation and monitoring of activities established. 2. Novel ticks product (bioacaricide) market survey expanded to Tanzania and completed. 3. A business plan to bring novel ticks control product into market developed.	• A novel ticks management strategy based on the use of bioacaricide, semiochemicals and/or botanical developed and implemented by 2020.	• At least 20 fungal isolates screened for virulence to at least two important tick species. • At least 3 isolates identified and their compatibility with semiochemicals, botanicals and synthetic acaricides completed. • A resistance management package for one synthetic acaricide developed. • One large-scale field efficacy trial completed	• Twenty-one (21) fungal isolates (11 *Metarhizium anisopliae* and 10 *Beauveria bassiana*) were screened against different developmental stages of *Rhipicephalus appendiculatus* (larvae, nymphs and adults). • *M. anisopliae* isolate ICIPE 7 was found the most potent fungal-based biopesticide against all the ticks species • Novel formulation of *M. anisopliae* isolate ICIPE 7 was found efficient to control on-host ticks by reducing > 90% of the tick population on cattle	

Expected Output as per RBM framework plan	Expected Outcome as per RBM framework plan	Performance Indicator of Outcome as per RBM framework plan	2017 Progress observed in Obtaining Outcomes	2017 Lessons Learned
		by 2015 for the combination of the most promising individual components.	• Tickoff® – isolate ICIPE 7 was also able to control not only the various tick species but also the major synthetic acaricides-resistant tick, *Rhipicephalus decoloratus* • Mass production of the most promising fungal isolate optimized • Compatibility of ICIPE 7 with semiochemicals, botanicals and synthetic acaricides tested • Novel formulation of *M. anisopliae* isolate ICIPE 7 was found efficient to control on-host ticks by reducing > 90% of the tick population on cattle and can protect animals up to 14 days post-treatment vs. 7 days for commonly used synthetic acaricides • Tickoff® – isolate ICIPE 7 was also able to control not only the various tick species but also the major synthetic acaricides-resistant tick, *Rhipicephalus decoloratus* • Mass production of the most promising fungal isolate optimized	

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
			• Compatibility of ICIPE 7 with semiochemicals, botanicals and synthetic acaricides tested • Mammalian toxicity tests undertaken for the potent *M. anisopliae* isolate ICIPE 7 • ICIPE 7 commercially known as Tickoff®, has been approved by the Kenyan regulatory board and permit/ authorization to conduct the field efficacy trials has been provided • Field efficacy trials for registration purposes have been initiated by our private sector partner - Real IPM, Kenya – in parallel with the field efficacy trials being undertaken by Livestock department. • Wide awareness on the tick biopesticide product has been created both among policy makers in Kenya and Somaliland through policy briefs and through publication of popular articles in “The Organic Farmer” newsletter published by Biovision Foundation and circulated to over 200,000 growers and farm	

Expected Output as per RBM framework plan	*Expected Outcome as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
			sector stakeholders in east Africa.	

3.4 Human Health: RBM Report

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
Objective 1: Contribute towards malaria elimination through the development of effective vector control strategies and public health initiatives by 2020.				
At least two chemical-based technologies for surveillance and/or disruption of malaria transmission developed.	• Odour-baited traps used for malaria control in at least one community by 2015. • Two large semi-field systems established at ITOC for investigating Push-pull systems under near natural conditions by end 2016 • Oduor-baited traps used by scientists for mosquito surveillance in research programmes. • Use of odour-baited traps for mosquito surveillance by at least five locally active government and/or non-governmental agencies by 2020.	• At least two Push-pull strategies evaluated for the control of host-seeking malaria vectors under semi-field conditions by end 2017. • At least one Push-pull system investigated under field conditions by end of 2018. • Available trapping systems developed further to improve catching efficiency based on preliminary semi-field and field trails by end 2018. • Presence/use of attractant baited traps by researchers and national malaria control programmes. • Availability of a potent spatial mosquito repellent or repellent principal.	• Small pilot field study implemented in Ahero Rice irrigation to test push and pull strategies for malaria vector control completed data collection in July 2017 in the field. Mosquito samples were analyzed using molecular tools in the laboratory from July to December 2017. Data analysis is ongoing and indicates that an odour-based Push-pull strategy can reduce mosquito house entry by 50% in the field. A progress report was submitted to the BMGF. • The East African Collaboration on Mosquito Push-pull (EACoMoPP) project has been ongoing since mid-2016. To date 3 spatial repellents and one attractive blend have been tested in two large semi-field systems built at ITOC in 2017. Quarterly progress reports are submitted to IVCC. • Three modes of dispensing spatial repellents were tested, and a passive system developed applying repellents on fabric ribbons fixed on house eaves. • One final Push-pull product was developed that achieved reductions in mosquito biting rates by 50% in the semi-field system. • A field study to test the final product has been conceived and the ethics protocol developed for implementation in June 2018.	• Further basic research required to develop functional Push-pull concept, this includes the identification of odour-oriented behaviour of malaria vectors to spatial repellents, replacement of CO_2 in traps, placement of traps in space for optimal interaction, air sampling to better understand diffusion of chemicals in space and over time. • Need to gain a better understanding of heterogeneous responses of different *Anopheles* species

Expected Outputs as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress observed in Obtaining Outcomes***	***2017 Lessons Learned***
		• Number of publications in peer reviewed journals. • Project progress reports. • Theses.Posters.	• Strong collaborations with private sector partners established for product development. • 2 proposals for funding were submitted to further develop Push-pull technology for malaria control and implement epidemiological trials (1 to BMGF was declined, 1 to Unitaid is under Grant Agreement Development).	to attractive and repellent chemicals. • Urgent need to develop more attractive blends for traps, current blends can not compete with human being in direct comparison.
Innovative application strategies of novel, persistent insecticides for *An. gambiae* developed.	• Optimum concentration of insecticides for malaria control used by the communities in western Kenya by 2020. • An 'attract-and-kill' strategy adapted by combining oviposition attractants with long-lasting larvicides developed and used by communities by 2020.	• Increased interest in larval source management by national malaria control programmes (NMCPs). • Rationalised larval source management strategies for malaria control. • Use of novel insecticides in national programmes. • Number of peer-reviewed publications. • Number of Books.Number of theses produced.	• Insect growth regulators were tested for attract and kill approaches in semi-field settings with limited success. One manuscript submitted. • Increased interest of governments to use larval control tools for malaria control has been indicated by their inclusion of the tool in national strategy guidelines and also increased interest at RBMs Larval Source Management work stream (lead by Dr Fillinger, *icipe*) • Partnership developed with Aquatain Ltd, Australia – formulation of silicone-based surface film combined with oviposition attractant cedrol to test a novel attract and kill strategy – small scale semi-field tests ongoing. • 1 PhD student enrolled in 2017 to work on the association of swamp grasses and habitat selection by gravid malaria vectors to search for novel oviposition attractants for use in attract and kill. • Novel olfactometer bioassays developed.	• Increased interest by donors and governments to use larval source management for malaria control specifically in elimination context. • Need to develop tools that are easy to use and can complement front-line interventions. • Novel product on market that have potential but need rigorous testing.

Expected Outputs as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress observed in Obtaining Outcomes***	***2017 Lessons Learned***
			• New project on oviposition attractant funded by Swedish Research Council and started in 2017.	
Studying the egg-laying behaviour of primary and secondary malaria vectors to develop novel attract and kill strategies (2017-2020)	• Protocols for rearing An. funestus s.s. and secondary vectors developed and colonies established at ITOC by 2019. • Oviposition bioassays implemented in cages and under semi-field conditions to screen for novel oviposition attractants from soil, swamp grasses and water-associated fungal cultures. • Different dispensing mechanisms for potential oviposition attractants tested in traps under semi-field and field conditions. • Field surveys implemented to investigate the correlation between swamp grasses and vector habitat colonization.	• Anopheles funestus s.s. and secondary vector colonies established. • Successful implementation of routine bioassays in cages and semi-field system with gravid female vectors. • Fungal cultures identified for natural vector habitats. • Swamp grass associated chemicals identified from water and headspace. • A number of new infusions and possibly chemicals tested for oviposition attractants. • Dispensers for attractants developed. • Risk factor analyses of field data implemented. • 1 PhD student trained/thesis produced.	• 1 PhD student and 1 MSc student recruited. • Protocols for establishing *Anopheles funestus* s.s. colony developed, and rearing initiated from field samples; to date successful in rearing F1 generation, • Routine bioassays and olfactometer tests developed. • Olfactometer calibration bioassays completed; system ready for testing novel substrates informed by field surveys. • Protocols for field work to identify swamp grasses developed, field work scheduled for May/June 2018.	Rearing of An. funestus s.s. challenging – major issue to resolve is mating to get beyond F1 generation. Need for sending staff to South Africa to learn from group with established colony. Intensive surveys needed to find breeding sites for secondary vectors. Lack of knowledge on ecology of these species makes it difficult to locate them.

Expected Outputs as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress observed in Obtaining Outcomes***	***2017 Lessons Learned***
		• Peer-reviewed publications.		
The symbiotic microbes harboured by mosquitoes as potential tools to control malaria transmission investigated.	• Detailed survey of the symbiotic microbes associated with vector mosquitoes. • Experimental investigation into the effects of harbouring symbiotic microbes on mosquito vector biology. • Discovery of symbionts with Malaria transmission-blocking properties • Investigation into the potential of using microbial symbionts to block disease transmission.	Number of peer-reviewed publications.	• Publication of Spiroplasma results; Chepkemoi ST, Mararo E, Butungi H, et al. Identification of *Spiroplasmainsolitum* symbionts in *Anopheles gambiae* . *Wellcome Open Research*. 2017;2:90. doi:10.12688/wellcomeopenres.12468.1. • Experiments to determine the effect of *Spiroplasma* on Plasmodium transmission are ongoing. • Discovery of a novel microsporidian parasite of Anopheles mosquitoes with transmission-blocking capabilities.	• The logistics difficulties and costs associated with transmission assays can be significantly reduced by collaborating with other research teams that are carrying out similar work.
Comprehensive evaluation of *icipe*'s ongoing integrated vector management (IVM) sub-projects.	• At least two new proposals to mobilise funding for strengthening IVM research and capacity-building in eastern and southern Africa developed by 2016 • An additional two new IVM projects in Kenya and Ethiopia developed by 2019.	• Regular evaluation reports of ICIPE IVM projects in Kenya and Ethiopia • New IVM proposal documents.	• The following project was approved for funding during 2017: Evaluating the feasibility and impact on malaria transmission of community-based winter larviciding or house screening as additional vector control interventions in southern African countries committed to malaria elimination (2018-2021). Funded by GEF/UNEP through WHO-AFRO (US$1,500,467).	• Efforts to systematically and consistently build on strategic sub-themes of human health research and research networks will enable ICIPE to leverage more resources for research and capacity-building , both from domestic

Expected Outputs as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress observed in Obtaining Outcomes***	***2017 Lessons Learned***
				and external sources.
Implementation of integrated vector management (IVM) promoted to improve health and livelihoods of communities in malaria-affected areas of Kenya and Ethiopia.	• At least 60% increased awareness among communities on IVM strategies for vector-borne disease control by 2018. • Adoption of IVM policy for malaria control by the Ministry of Health (Kenya) and Ethiopia by 2017. • At least 60% decrease in malaria prevalence and mosquito densities in target areas by 2018.	• Number of community members trained. • Number of combinations of vector control methods (non-chemical/chemical) being used at community level. • Availability of an IVM decision-making tool for policy makers and vector control personnel. • Number of IVM workshops for policy makers and other key stakeholders. • Levels of malaria prevalence and mosquito relative density. • Improvement in socio-economic status of households. • Number of articles published in peer reviewed journals.	• IVM stakeholder registers were updated on a regular basis in all three project sites in Kenya and Ethiopia. The following community structures and linkages were created: • In Tolay (Ethiopia)**:** 12 Malaria control community working groups formed; District Malaria Control Task Group organized a meeting for all stakeholders involved in malaria control; A total of 12 community meetings and 11 community wide events conducted; A total of 22,757 people received malaria education through different methods. • In Malindi (Kenya): Punguza mbu na malaria Malindi (PUMMA) continued to be a robust and competent community-based partnership with capacity to sustain IVM in Malindi in collaboration with national and county governments; door to door campaigns have reached 17,440 people. • In Nyabondo (Kenya): 27 stakeholders networking forums were conducted aimed at enhancing partnership, collaboration and networking among various departments, ministries and institutions. A total of 8,344 females and 10,909 males benefited from IVM education and awareness creation through engagement with schools, various CBOs, MoH and the community. • To date a total of 105 persons at policy-making level have participated in formal and informal IVM workshops (60 persons in Kenya and 45 in Ethiopia).	• Participation in IVM grew at all the project sites as a result of enhanced engagement of community members and other stakeholders through different participation platforms including new community and county structures. • Considering the dynamic nature of malaria, the participation of an institutional research partner would be necessary on an ongoing basis in order to support and validate with correct information the various educational and advocacy initiatives at community and policy levels. The roles of the

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
			Regarding development of an IVM decision support tool: • In Ethiopia: collation of the national malaria data required for the development of the national models finalised; 15 policy makers and technical personnel trained; a downloadable version of the IVM support tool is undergoing final refinements. • In Kenya: Two different types of Software have been developed (community & national) and shared with the national malaria control programme personnel. Regarding journal publications: • Process of rigorous statistical methodology to comprehensively analyse data collected prior to 2016 initiated with the aim of completing it during 2018. • Several journal papers published including: Kibe LW, Habluetzel A, Gachigi JK, Kamau AW, Mbogo CM (2017). Exploring communities' and health workers' perceptions of indicators and drivers of malaria decline in Malindi, Kenya. *MWJ* 2017, 8:21 Diiro GM, Affognon HD, Muriithi BW, Wanja SK, Mbogo C, Mutero C (2016). The role of gender on malaria preventive behaviour among rural households in Kenya. *Malaria Journal* 15: 14. Available online at: http://www.malariajournal.com/content/pdf/s12936-015-1039-y.pdf	research partner could include conducting rapid situational analyses, organising multi-media campaigns and facilitating policy dialogues at national and county levels. The research partner team would needs to have both IVM and communications specialists.

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
			Demissew A, Balkew M, Girma M (2016). Larvicidal activity of chinaberry, neem and *Bti* to an insecticide resistant population of Anopheles arabiensis from Tolay, South West Ethiopia. *Asian Pacific Journal of Tropical Biomedicine* 6: 554-561.	
Regional and national IVM capacity strengthening for control of malaria and other vector-borne diseases expanded in eastern and southern Africa	• At least 20 staff of national malaria control programmes of Ethiopia, Madagascar and Eritrea trained in IVM in 2016. • *icipe's* role as a regional hub for participatory IVM training in Africa is significantly enhanced from 2016 onwards as a result of increased collaboration with key partners including WHO-AFRO, UNEP, GEF, Stockholm Convention, and Biovision. • IVM training of at least 100 program staff of southern Africa countries dependent on DDT for malaria control achieved by 2019	• Ten-day IVM training course conducted for participants from Ethiopia, Eritrea and Madagascar in July 2016. • *icipe's* ongoing participation as a co-executing partner and lead research organization for evaluation of new innovative IVM interventions in the context of AFRO-II project Global Environment Facility (GEF)/UNEP- through the main Executing Agency, WHO-AFRO	• *icipe* was during 2017 contracted by WHO-AFRO to be the lead institution to conduct research aimed at demonstrating and strengthening of IVM in six southern African malaria elimination countries still using DDT for malaria vector control, in the context of AFRO-II project. AFRO-II involves 14 countries, six of which will evaluate larviciding and house screening as IVM interventions. *ICIPE*'s research protocol for AFRO-II was approved by WHO during the current reporting period.	• *icipe* is now strategically well positioned to regionally play a key advisory role in the institutionalization of IVM for control of malaria and other vector-borne diseases.
Objective. 2. Understanding the risks and benefits of newly developed irrigation schemes in western Kenya in the context of malaria elimination				

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
Specific objective 2.1. How does introducing gravity-fed irrigated agriculture impact land-use, aquatic habitat distribution and vector production?				
Association between irrigation and malaria vector abundance and seasonality and sporozoite infection established over a 3 year period.	Improved awareness of the association between irrigation and vectors by all project stakeholders by end 2020	• Comprehensive dataset on adult malaria vectors, other mosquitoes and changes in species composition, seasonality and biting pattern compiled over 3 years. • Multivariate risk factor analyses implemented annually. • Publications.Stakeholder information sharing meetings.	• Post-doctoral research scientist recruited; • Comprehensive study protocol developed for entire objective 4; • Protocol submitted to KEMRI-SERU awaiting approval. • Study areas mapped with help of remote sensing and study clusters identified.	
Specific objective 2.2. Does irrigation lead to an increase in adult malaria and non-malaria vectors, changes in species composition, seasonality, biting patterns or sporozoite infections?				
Association between irrigation and malaria vector abundance and seasonality and sporozoite infection established over a 3 year period.	Improved awareness of the association between irrigation and vectors by all project stakeholders by end 2020	Comprehensive dataset on adult malaria vectors, other mosquitoes and changes in species composition, seasonality and biting pattern compiled over 3 years.	• Post-doctoral research scientist recruited; • Comprehensive study protocol developed for entire objective 4; • Protocol submitted to KEMRI-SERU awaiting approval. • Supply list compiled, and procurement initiated, initial trap testing completed.	
Specific objective 2.3 Can irrigated agriculture be associated with changes in socio-economic and nutritional status, malaria prevention measures and/or behaviours and prevalence in the population?				

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
1. Association between irrigation and socio-economic and behavioral factors and malaria established over a 3 year period.	Improved awareness of the association between irrigation and socio-economic factors and malaria by all project stakeholders by end 2020.	• Ethical approval granted for study. • Comprehensive dataset on adult household data on socio-economic and nutritional status and behavioural factors compiled over 3 years. • Multivariate risk factor analyses implemented annually. Publications. • Stakeholder information sharing meetings.	• Post-doctoral research scientist recruited. • Comprehensive study protocol developed for entire objective 4. • Protocol submitted to KEMRI-SERU awaiting approval. • • Supplies ordered. Stakeholders mapped and engaged; several community meetings attended.	
Objective. 3 Understanding freshwater pollution and the links to the distribution of Schistosoma host snails in Western Kenya				
Specific objective 3.1. Does the abundance of host snails for human pathogenic trematodes increase with pesticide pollution, and is this increase associated with a decrease of antagonistic macroinvertebrate species?				
1. Risk factor analyses implemented. 2. Pollution associated with abundance of snails, antagonistic invertebrates, and ceracaria infection.	Pesticides bioindicator index developed for the effect of pesticide pollution on macroinvertebrates to tropical freshwater habitats by 2020.	• Filed sites identified. • Two field campaigns .successfully completed. • Dataset compiled for analysis. • Publications. • Donor and other reports. • Thesis chapter.	• 2 PhD students recruited. • Protocols developed. • Field sites identified. • One field campaign completed. • Dataset compiled for first field campaign, data analysis ongoing. • Pesticide analysis completed in Nairobi and sample analysis ongoing in Germany.	• Freshwater habitats in western Kenya polluted by diverse pesticides. • Snail populations challenging to sample and Schistosoma infection low.
Specific objective 3.2. What is the acute pesticide sensitivity of host snails compared to relevant antagonistic species?				

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
Pesticide sensitivity established in comparison to antagonistic species.	Tools available to predict impact of pesticide pollution on snail distribution by 2020.	• Toxicity tests designed and successfully implemented. • Publications. • Donor and other reports. Thesis chapter	• SOPs for toxicity tests developed. • Snail colony established at ITOC.	
Objective. 4 Investigating the disease ecology of tungiasis (sand flea disease) for the development of treatment and prevention strategies				
Specific objective 4.1. Analyzing school- and household-based risk factors associated with disease outcome				
Risk factors associated with disease identified.	• Improved awareness of the association between certain environmental, socio-economic and behavioural risk factors and disease by all project stakeholders (scientists, Ministry of Health, communities) by end 2018.Recommendations for prevention articulated by end 2018.	• Ethical approval for study. • Field surveys completed. • Dataset compiled for analysis. • Statistical analysis. • Publications. • Donor and other reports. • Proposals for prevention trials developed.	• Ethical approval granted. • Field surveys completed. • Data set compiled for analysis. • Risk factor analysis implemented. • Publication drafted. • Two proposals developed (one to DFG under review; one to BOVA network, approved)	• Tungiasis is highly associated with poverty indicators and poor housing conditions. • Simple interventions such as solid floors in home could prevent the disease. • Concrete floors are too expensive for affected, resource poor communities to afford and new technology needs to be developed.
Specific objective 4.2. Testing of herbal remedy used by communities based on neem oil for tungiasis treatment in a clinical trial (phase II)				
The impact of neem oil treatment on tungiasis infestation	Novel treatment recommendations that can be incorporated in the Kenya National Guideline	• Ethical approval for study from KEMRI granted.	• Ethical approval granted by KEMRI. • Study permit issued by Clinical Trials Committee. • Independent clinical monitor contracted.	• Vital training gained in developing a clinical trial

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
and inflammation established.	for Tungiasis Control by end 2018.	• Approval for the study granted by the Expert Committee for Clinical Trials of the Pharmacy and Poisons Board. • Independent Trial monitor contracted. • Trial documentation, forms, SOPs, monitoring plan, etc compiled as per national guidelines. • Project staff training completed. • Field survey completed. • Dataset compiled for analysis. • Statistical analysis. • Report to Expert Committee for Clinical Trials. • Donor report. • Publication. • Proposals for phase III study	• SOPs developed. • Trial dossier developed. • Test products obtained and tested for contamination and chemical analysis for active ingredients. • Staff training implemented in ethical conduct of clinical trial and reporting of adverse effects.	protocol for approval. • Essential expertise gained in clinical trial implementation, monitoring and reporting.
Specific objective 4.3. Developing tungiasis prevention tools				
Impact of novel prevention tools known.	Recommendations for prevention made to Ministry of Health for incorporation in the Kenya National Guideline for	• Proposals developed. • Funding secured. • Ethical approvals from KEMRI granted.	• Two proposals developed, one to DFG under review; one to BOVA network, approved. • Funding secured for developing and testing novel solid floor types for tungiasis prevention.	

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
	Tungiasis Control by end 2020.	• Project staff training completed. • Field tests completed. • Datasets compiled for analysis. • Statistical analyses. • Donor reports. • Publications.	• New collaborations established with Kenya Industrial Research and Development Institute	
Objective 5 – Surveillance of arbovirus and mosquito vector diversities and their blood-meal host populations				
Development of a cost-effective multiplex PCR-HRM assay	• Discovery of Wesselsbron virus and diverse insect-specific flaviviruses in mosquitoes. • Identification of diverse arbovirus infections in mosquitoes, livestock, wildlife and humans.	• Proposals developed • >10 students trained • 5 peer-reviewed publications	• New project	
Development of HRM-based blood-meal host identification	• Unique arbovirus-mosquito host relationships identified	• 2 peer reviewed publications • Additional grant funding obtained based on this work. • 3 students trained.	• New project	
Characterization of larval habitats near Lake Victoria.	• Key effect of fertilizer components found at high concentrations in breeding sites with more *Anopheles* mosquitoes.	• Q peer reviewed publication. • 1 MSc thesis.	• New project	
Specific Objective 5.1. – New Arbovirus transmission blocking strategies				

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
Characterization of endemic insect-specific flaviviruses (ISFVs) in their capacity to affect vector competence of mosquitoes to arboviruses.	• The potential utility of ISFV's for blocking arbovirus transmission identified. • Strategy for arbovirus transmission pursued.	• Funding. • Publications. • Experimental data collection completed.	• New project	
Potential opportunities for RVF control identified.	• Awareness about RVF community based preventive measures.	• Community and stakeholder meetings. • Publications. • Reports.	• New project	
Output: Inter-epidemic circulation ofRVF among humans and livestock in N.E hotspot areas established. Deficiency in knowledge on disease transmission and risk among communities established. Mapping of distribution of RVF vectors along nomadic movement routes generated.	•	• Information shared with the Zoonotic Diseases unit, MOL and MOH through stakeholder meeting and workshop. • Community friendly information on mode of transmission of RVF. and prevention shared in vernacular	• Workshop held with the key stakeholders from the MOH, MOL and the community leadership in Isiolo county to discuss findings and recommendation. • Stakeholder meeting held to share findings and recommendations with the Zoonotic Diseases unit and the MOH/MOL.	

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
Existence and locality of YF, DEN transmission foci in Northern Kenya at border with endemic countries determined.	• Research team confirms presence/absence transmission between primate and human populations.	• Community engagement. • Publications. • Donor and other reports. • Stakeholder information sharing meetings.	• Potential vector presence, abundance and host preference has been established in one rural site. • One paper on the findings currently under review at Acta tropica journal. • Report submitted to NIH on 1st April. • One presentation made at the Medcial and Veterinary Virology conference held in Nairobi.	
Vector species presence and their YF/DEN vector potential in the selected areas assessed.	• Research team detects and maps known and/or other potential YF and dengue vectors.	• Publications. • Donor and other reports. • Stakeholder information sharing meetings.	• Vector presence and abundance in three major Kenya cities has been determined • 2 papers published in peer as follows; • 2017 Aug 17;11(8):e0005858. doi: 10.1371/journal.pntd.0005858. eCollection 2017 Aug. • Parasit Vectors. 2017 Dec 29;10(1):628. doi: 10.1186/s13071-017-2598-2. • Annual report submitted to NIH detailing the findings. • One presentation made at the Medcinal and Veterinary Virology conference held in Nairobi.	
Trapping tools for conducting vector surveillance to improve surveillance of YF and dengue developed.	• The team identifies suitable odours and tools for attracting and sampling YF and DEN vector populations.	• Publications. • Donor and other reports. • Stakeholder information sharing meetings.		
Objective 6: Understanding leishmaniasis transmission dynamics in Kenya and development of control strategies				
Determination of densities, species diversity and host	New vectors of leishmania species identified in Marsabit and Gilgil Vector species of	• Publication. • Project reports.	• Data collected and analyzed. • Data presented at the 6th World leish conference and Gordon Research Conference.	• County engagement was key

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
feeding preference of sand flies	leishmaniasis from various habitats in disease endemics regions documented Sandfly densities recorded Source of bloodmeals established.	• Conference presentations.	• Reports submitted to the counties visited. • 2 manuscript drafts on going.	• Community mobilization was needed prior to trapping • Accessibility of the study sites was a challenge, poor road networks and terrain. This required more time in the field and funds allocation
Leishmaniasis parasite identification.	• Vectors screened of leishmaniasis parasite species.	• Publication. • Project reports. • Conference presentations.	• Data collected and analyzed. • Data presented at the 6th World leish conference and Gordon Research Conference. • Reports submitted to the counties visited. • 2 manuscript drafts on going (included with vector data above).	• Vector parasite infection rates was low thus required more sandlfy sampling.
Development of odour baited sandfly attraction trapping device - the "SanTrap" for the control of leishmaniasis	• Novel approach in the control of sandfly bites developed • Efficacy and efficiency of the attract-and-kill tool on sandflies established	• Publications. • Reports. • SanTrap tool. • Patent.	• Field work and laboratory analyses is on going.	• The concept needed more time to test than allocated.
Vector species for Cutaneous leishmaniasis and parasite transmission in Gilgil, Nakuru County identification.	• Identification and mapping of cutaneous leishmaniasis vectors. • Ecological factors mapping. • Cutaneous Leishmania reservoir identification.	• Publications. • 1 MSc thesis. • Stakeholder information sharing meetings.	• Sample analysis on going. • The student Barrack Omondi is currently at LSTM to finalize on course work and data analysis.	
Correlation of exposure to sand fly bites and the CL	• Identification of exposure to sand fly	• Publications.	• This is yet to be done, awaiting approval by KEMRI.	• Approval process took longer than anticipated at least 4

Expected Outputs as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress observed in Obtaining Outcomes***	***2017 Lessons Learned***
outcome and the risk factors associated with disease exposure in Gilgil.	bites and the associated risk factors.	• Sandfly bite exposure markers.	• Markers of exposure to be tested have been identified	months or more to be factored for this output.

3.5 Environmental Health: RBM Report

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in Obtaining Outcomes*	*2017 Lessons Learned*
Objective 1: Survey, inventory, and description of new species of East African insects published and data made internet-accessible by 2020.				
1.1 At least 10 taxonomists agree to study and publish results of examination of insects collected in Burundi and Kenya.	Taxonomists agree to study East African specimens.	Number of taxonomists agreeing to participate.	17 taxonomists agreed to study East African insects	
1.2 At least 10 manuscripts produced by 2020 exclusively devoted to, or incorporating significant numbers of, East African insect taxa.	Taxonomists study and publish on East African insect taxa.	Number of manuscripts published on generic revisions, species descriptions, and regional checklists.	15 peer reviewed papers published during 2014-2017. Four during the year 2017.	
Objective 2: Collection of one-year Malaise trap sampling in climate-change threatened coastal forest (Kaya Kinondo) made as part of International Barcode of Life's Global Malaise Project and delivered to University of Guelph by 2016.				
2.1One years' worth of preserved insect samples sent to University of Guelph for processing and barcoding by 2015.	Data on threatened insects published online and made available to conservation biologists, taxonomists and interested parties.	Online iBOL Global Malaise Project website	Data for 8,817 specimens collected in Kinondo Forest, 7,133 with barcodes, online in boldsystems.org	As seen previously with other specimens, Hymenoptera had a poor rate of DNA amplification compared to other orders, with the result that the percentage of barcoded Hymenoptera was much lower than that of other insect groups.
Objective 3: Taxonomic information on African insects including major African pests and vectors used by scientists, students and public by 2020.				

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3.1 10,000 DNA barcodes generated for the iBOL database.	• Scientists use the DNA-barcode library for the African pest and vector insects to identify pest species with DNA techniques. • DNA barcoding becomes a routine part of the taxonomic enterprise. • A taxonomic evaluation of poorly understood taxa, like stingless bees and African silkmoth species.	Number of barcodes generated.	Examining the titles of research articles that focus on taxonomy reveals that molecular methods, including barcoding (the most common) routinely accompany morphological data, providing confirmation or questioning of morphological data. Barcoding also has often led to the discovery of cryptic species.	
3.2 Three trainings per year for 10–15 students and staff.	• Students and staff know and apply modern taxonomic techniques, including morphological identification, preparation and DNA techniques to identify insects.	• Number of students and staff members trained.	Two training sessions were carried out during 2017, one on Diptera pollinators and a second on Insect identification with an emphasis on parasitoids. Twenty-five participants were trained.	
3.3 African Insect Taxonomy Toolkit updated by 2015 (http://taxonomy.icipe.org)	• Scientists and others make periodic use of taxonomic literature and tools.	• External access rates are monitored.	none	The original files related to this output have not been accessible.
3.4 At least four donor-funded projects with relevant taxonomic perspective request and receive taxonomic support from the Biosystematics Support Unit by 2015.	• Scientists incorporate taxonomic information into planning and carrying out of projects.	Number of projects funded that incorporate taxonomic data.	Virtually all of the Centre's projects received insect identification services and photographic support during 2017.	
3.5 Aquatic insects of streams in East Usambara area of Tanzania are identified	• Local groups of farmers are capable of identifying these insects, and can monitor the quality of streams.	• Number of community members trained.	During 2017, 506 school children were trained. Since 2015 a total of 8479 community members have been trained in	

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and local groups are trained in their identification by 2014.			identifying aquatic insects and monitoring water quality.	
Objective 4: At least 6 new eco-friendly nature-based products for pest and vector control adopted for improvement of livelihoods of rural and wider community members by the year 2020.				
4.1.1 At least 4 new potential products for mosquito control identified from plants based on efficacy, safety and ease of application. 4.1.2 At least two plant-derived products for mosquito control formulated and packaged. 4.1.3. Community-based cultivation of selected insecticidal plants initiated. 4.1.4. Community-based production and use of plant-derived products for mosquito control initiated in at least one project site. 4.1.5. Atleast 2 PhD and 2 MSc students trained. 4.1.6. At least three papers prepared and submitted to international journals.	• Two plant-derived insecticidal products adopted for use in mosquito control by a local community by 2019. • Three papers or patents on potential mosquito control products published by 2018.	• Number of products produced and used. • Number of community members using the mosquito control products. • Number of reports and publications. • Number of students trained.	• Through efficacy and toxicity evaluation on target and non-target organisms (insects and mammals), and evaluation of its physico-chemical properties, the mosquito larvicide, *Uzimax*, has been shown to be effective, eco-friendly, biodegradable, stable and safe for handling during application at the recommended and even higher dosages. Independent toxicity and efficacy studies were completed for Uzimax and reports submitted to the Pest Control Products Board (PCPB) in Kenya for purposes of registration. The registration is now in its final stage and is expected to be completed in 2018. • A second plant-derived insecticide product, a water-soluble formulation of an additional insecticidal	• There is a major potential for use of plants in vector control, particularly with participation of rural community.

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			and medicinal plant named *icipe*-MedPlant-31 was developed that was very effective as a larvicide against the larvae of the 3 mosquito species, *A. gambiae*, *A. arabiensis* and *C. quifasciatus* in the laboratory and under semi-field conditions. The results indicated that the *icipe*-MedPlant-31 formulation had great potential for practical application in the control of mosquito larvae. Compilation of the dossier for registration is in progress. • Community-based cultivation of 3 insecticidal plants ongoing. • 5 Ph.D. and 2 M.Sc. students trained. • One patent: ○ Lwande W., Ochola J. B., Marubu R. M., Moreka L., Nduguli F.W. and Ligare J., Composition and Method for Controlling Larvae. Patent No: KE/UM/2015/00569. • One manuscript in peer reviewed Journal	

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4.2.1 Two plants with bioactivity against honeybee pests/diseases identified. 4.2.2. One plant-derived product formulated and evaluated for control of a honeybee pest/disease. 4.2.3. The bee pest/disease control product submitted for registration with relevant bodies. 4.2.4. Protocols for production of the bee pest/disease control product established.	• One plant-derived product for honeybee pests/diseases control adopted for production and in use by 2018. • Two publications/utility model/patent on potential honeybee pest control products published by 2018.	• Number of products produced and used. • Number of reports and publications.	• *Apicure,* a shelf-stable plant-based fumigant biopesticide product that was developed for control of bee pests in beehives was further validated in Burkina Faso under semi-field and field conditions, where it was shown to be effective in killing varroa mites and repelling hive beetles in bee colonies. • A detailed study on Apicure as a repellent against hive beetles was undertaken and chemical components responsible for repellency identified. • A total of 18,000 pieces of *Apicure* biopesticide produced for validation in other African countries; • Community-based domestication and cultivation of one repellent plant, *Ocimum kilimandcharicum,* continued to be undertaken by over 1000 households in Kenya and Tanzania. • Two community-based facilities for processing the repellent plant continued to operate in Kenya and Tanzania.	• There is a major potential for use of plants in vector control, particularly with rural Community participation.

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			• Over 15,550 products produced by participating community members. Publications/patents: • Lwande W., Marubu R. M., Ochola J. B., Nguku E. and Raina S., Composition and methods for controlling a bee pest or disease, Patent No: KE/UM/2015/00554 • An international patent application on *Apicure* was filed at the World Intellectual Property Organisation (WIPO): PCT/IB2016/055576.	
Objective 5: Geographic information systems (GIS) are fully integrated as a strategic research tool for *icipe* by 2020.				
5.1 GIS and remote sensing (RS) training courses set up and given to students and resource managers.	• *icipe* seen as an incubator for Earth Observation for insect science and ecology in Africa.	• 10 out of 12 ARPPIS students use a GIS derived map in their work in 2017-2019. • Number of peer reviewed papers on the use of GIS and remote sensing in insect science and climate change studies published.	• Two GIS and RS training courses were given; ARPPIS and DRIP student training was given in April (14 participants), and a VectorBase Workshop in Duduville, 22nd September was given to 12 candidates. • More than 6 ARPPIS/DRIP students used their GIS and RS knowledge to produce maps showing their results in various publications and the thesis itself (i.e. Makori and Kyalo et al).	• *icipe* is on the forefront of cropland and rangeland productivity mapping at landscape scales in Africa, however, little uptake is currently possible/occurring. • *icipe* should link up with large data processing and EO service development partners (for instance European Space Agency) to develop wide-area monitoring

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			• Out of the 134 publications published in 2017 in *icipe*, 10 made extensive use of GIS/Remote sensing data variables or included GIS as a key element • 3 invited talks were given on the use of GIS in *icipe*; one at the Univ. of Bonn, one at the European landscape patterns conference in Ghent and one to DFG partners in Germany.	tools/services relevant to African agricultural productivity constraints. • *icipe* colleagues and ARPPIS students need more specific training and self-help knowledge so that the knowledge gained can be self-sufficiently used (without further help from the GI-Unit).
5.2 Efforts undertaken to increase the use of GIS in new and existing projects.	• Remote sensing and GIS is an integral part of the *icipe* R&D agenda.	• Number of proposals and existing projects that make use of GIS and remote sensing.	• Proposals within icipe that included a GIS and RS part in *icipe* rose from 9 to 15. • Funding was secured for GIS work in an extended phase of the BIOVISION Push-pull scaling project	• Funding efforts need to be more concerted towards large programmes instead of individual projects to increase proposal funding success. • New donors and funding opportunities need to be scouted/sourced
5.3 Remote sensing (ecological) variables are derived and used for disease mapping.	• Disease assessments are localized/more accurate so that interventions can be formulated with more precision.	• Number of projects in *icipe* that use ecological variables derived using Earth Observation(EO) for improved assessments of pests and diseases, i.e. RVF, dengue, malaria, etc.	• A data portal that collates ecological variables from remote sensing and other variables for mapping RVF in central and north-eastern Kenya (Lamu to Baringo County) was further improved by adding livestock migration data from	• Disease mapping is a very competitive field and thus more publications and staff development is needed. • *icipe* needs to develop operational data processing

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			GPS collaring observations. The results were published. • The GI unit was involved in several new proposals that utilize remote sensing variables as part of disease monitoring routines.	routines to develop diseases semi-automatic monitoring for better decision making
5.4 Operational species diversity mapping framework developed.	• *icipe* can use operational shared decision making (SDM) framework for enhanced decision making in IPM and as a marketing tool for funding.	• Number of ecological and remote sensing (RS) models available and significantly understood.	• Innovative seasonality variables were derived from satellite time-series data and two publications were published that shows the pest model improvements using RS variables.	• The GI Unit should develop a continental (Africa) SDM-based bee pest distribution product to maximize visibility and impact
Objective 6: Increasing honey and silk production by 20% in selected African farming communities by 2020.				
6.1 Potential and healthy silk and bee races identified for enterprise development in Africa by 2017. 6.2 Healthy silk and bee races are distributed to 3000 trainers for the farmer groups. 6.3 At least 15 PhD and 10 MSc. students trained. 6.4 At least 50 peer reviewed papers and 5 books/proceedings published in international journals.	60% of the farmers use improved bee and silk races.	• Number of farmers using improved races. • Number of races produced. • Number of manuscripts published.	• 7,918 beekeepers engaged in modern beekeeping in 10 African countries. • 1.04 million silkworm eggs (52 boxes) of ICIPE I and II races distributed to Silk Farmers' Associations in Uganda and 17 households based silk farmers in Kenya. • Efficacy trials were done successfully through the Kenya Plant Health and Inspectorate Service (KEPHIS) and a Research Certificate given. • 6 peer reviewed papers published highlighting issues related to Beekeeping technologies and Pollination.	Impact of research results can be improved by strengthening linkages, synergies and complementarities at national and regional level with relevant research institutions, concerned NARs and Farmers Associations.

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6.5 Training material developed and training sessions held for 2000 trainers.	Knowledge of sericulture and apiculture is applied by at least 750 farmer groups (each 50 to 100).	• Number of farmers trained. • Number of certificates (exam). • Number of farmers applying their new knowledge.	• Fifteen (15) Trainers of Trainers (ToTs) received an intensive 2 weeks training in Nairobi. • Five hundred and fifteen (515) beekeepers, 27% women received first level beekeeping training. • Over 1,500 group members trained. • 106 ToTs trained in bee health related issues. • Beekeeping training manual prepared and shared with ToTs.	TOTs and Farmer-to-farmer extension models are effective training methods.
6.6 Business model developed using value chain approach.	Business model and business responsibility adopted by at least 400 farmer groups.	Number of enterprises registered.	Capacity of registered beekeeper associations in 2 Islands enhanced through training of association officials.	• Linking beekeeper's associations to the private sector offers opportunities for market options. • Strong government support is critical for the establishment and sustainability of the beekeeping industry at national level.
6.7 16 to 20 marketplaces (honey and silk harvesting, processing and selling units) established.	35% increase in honey and silk quantity by 2017.	• DC registry. • Production records.	Four (4) honey processing centres were established and requisite post-harvest equipment procured.	• For successful operation of marketplaces, there is need to engage with the private sector for marketing linkages. • The established marketplaces offer

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				farmers the much-needed central point to sell their hive-based products.
6.8 Modern beehives supplied to farmers and rearing houses (silk moth) established.	500 beehives supplied to farmers by 2017.	Project records.	• 1,820 Langstroth hives have been distributed to beekeepers across five (5) Island Nations. • 200 individual and group apiaries established in 5 Island Nations.	• Integrating traditional practices with modern approaches to project implementation yields results more quickly.
6.9 Internal control system (ICS) training for 3000 trainers conducted.	Percentage of communities producing honey and silk to European Union (EU) standards increases from 20 to 40% by 2017.	Honey and silk quality assessed and certified.	• 59 beekeepers and 26 government extension staff trained in ICS. • Internal Control System (ICS) manuals developed for seven (7) countries.	One way to ensure sustainability is to link organic agriculture to the main Government agriculture agenda and to issues such as the environment, sustainable agriculture and food quality.
Objective 7: Improve bee products and pollination services by 30% through reduced incidence of bee diseases and pests, enhanced markets access, and bee health policy and institutional environment by 2020.				
7.1 Bee health facilities for innovative technologies and provision of pest risk analysis, baselines and benchmarks established.	Documentation of honeybee pests, maps available and utilised by 40% of stakeholders for training beekeepers by 2020.	• Number of stakeholders using maps. • Peer-reviewed publications.	• 9 peer reviewed papers highlighting issues related to Bee Health, Pollination and Beekeeping technologies.	• There is need for regular and continuous monitoring to document disease incidence.
7.2 Development of validated bee disease and pest management modules	• Honeybee–pest interactions understood and applied by 30% of bee extensionists by 2017.	• Number of bee extensionists applying new knowledge. • Peer-reviewed publications.	• 50 government staff trained in extension. • Ten (10) Country coordinators implementing	• Need to develop simplified farmer friendly training

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with efficient field based diagnostic tools.			new technology alongside their extension workers.	modules in local language.
7.3 Innovative integrated honeybee pest control strategies developed.	Use of honeybee integrated pest control strategies increased by 20% by 2017.	• Number of beekeepers trained. • Number of beekeepers applying new knowledge. • Peer-reviewed publications.	• 515 beekeepers trained on integrated honey bee pests control in the Island Nations. • 7,918 beekeepers engaged in modern beekeeping in 10 African countries. • Two (2) publications on honey bee pests.	• Awareness creation on natural resistance as the first line of defense. Not every pest needs to be controlled using chemicals.
7.4 Improved awareness of honeybee health and favourable environment for enhanced bee disease control, access to markets and consumer safety.	Effective multi-stakeholder partnerships and mechanisms for the development of policy, institutional and market options for bee health and pollination services established and functional by 2017.	• At least 75% of participating countries have formulated/reviewed their policies on honeybee health for hive products.	• Three (3) regional policy frameworks and three (3) working groups established (Bee health; Pollination Services & biodiversity conservation; and Production, Marketing and Technologies). • Inventory of Apiculture policy and regulatory completed in Member States (MS). • Validation of continental guideline to minimize the impact of pesticides on honey bees.	• Strong government support is critical for the establishment and sustainability of the beekeeping industry at national and regional level.
7.5 Capacity of beekeeper/farmers' federations, Regional Economic Communities (RECs) and NARS on	• At least 20 beekeepers' associations. supported/strengthened by the end of 2017.	• Project and policy activities report. • Farmers' Federations reports.	• Ongoing strengthening of eleven (11) producer organizations - input supply management and cooperative marketing.	The know-how learned through training and practical experience is an important asset for the beekeepers and for

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bee health management systems and policy options strengthened.	• 80% of the beekeepers' associations actively engaged in bee health policy processes at national level.		• Reference database on bee health and pollination services accessible on ARIS 2. • Interactive online platform (Bee Net Africa - d-group on honey production, bee health & pollination services) is active.	the sustainability of the beekeeping industry.
Objective 8: Promote knowledge and technology-based entrepreneurship through training in beekeeping and silk farming for youth employment in Ethiopia (YESH Project) by 2020				
8.1 In-depth value chain analysis of beekeeping and silk production in the targeted project zones undertaken.	• At least two (2) value chain analysis reports produced and shared with donors and partners by end of 2016. • One (1) scientific publication by end of 2017. • Gender mainstreaming strategy designed by 2016.	• Map the major processes that the raw materials produced (honey, beeswax, cocoons) go through before reaching the final consumption by early 2017. • Identify and map the main actors involved in the processes by end of 2017. • Identify the flows of products as well as information flow and knowledge in the value chain by 2017. • Identify the bottlenecks within the supply chain and where possible identify/refine interventions by 2017. • Quantify the volume of different products in the value chain by early 2017. • Identify relationships and linkages between value chain actors by 2017.	• The two value chain analysis reports produced – one on apiculture and another on sericulture – were finalised, validated and submitted to the Mastercard Foundation for further review. Both reports mapped main actors and the flows of products in the value chain. Baseline production levels quantified as part of the M&E framework. Bottlenecks in the value chains identified. • Gender mainstreaming strategy document finalised, reviewed and submitted to the Mastercard Foundation for further review.	• Both value chains are highly dynamic, and the reports will need to be updated after a few years.

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8.2 The knowledge, capacity and technology-based entrepreneurship within the currently unemployed. youth population increased.	• At least 8,750 youth capable to generate or improve income from beekeeping and silk farming or other businesses from the acquired skills by 2020. • At least 12,500 youth trained in beekeeping and silk farming enterprise development during the period 2016 – 2020. • Gender mainstreaming strategy designed by 2017. • Support at least one (1) egg production facility by 2017. • Develop at least two (2) training manuals by end of 2016.	• Identify, profile and select youth to form groups with a good balance in gender by 2017. • Establish training Centres for beekeeping and silk farming activities by 2017. • Build capacity through training (technical, business and life-skills), provision of starter kits and material support to improve beekeeping and silkworm rearing technologies and post-harvest for high quality production and income by 2020. Increase participatory tree plantation to improve bee biodiversity, provide silkworm feed and enrich the ecosystem by 2020. • Provide technical support using existing egg production facility (grainage) within the region by 2020.	• By end of 2017, a total of 3,600 YESH project beneficiary youth were selected, engaged and trained in entrepreneurship and technical skills development. • The private silkworm grainage identified in 2016 was supported in 2017 to expand its seed production and maintenance activities. The facility was also used to provide practical training for 48 model youth silkworm farmers.	
8.3 The development of youth-led and owned, silk farming and beekeeping enterprises through business development/incubation supported.	• At least 70% of youth using skills acquired from the entrepreneurship training able to build or increase assets during the period 2016 – 2020. • At least 50% of youth engaged in beekeeping and silk farming able to access financial service by 2018.	• Provide training in assessing market information, improving marketing skills and analyzing market linkages in the value chain in the period 2016 – 2020. • Educate the young entrepreneurs in financial management and mediate in acquiring access to appropriate financial services and products by 2020 • Provide a pro-active business development service by mentoring and coaching by seasoned entrepreneurs and advisers as	• By end of 2017 a total of 212 youth led and owned enterprises were established from the Year 1 & 2 cohorts of the YESH project, with 196 in apiculture sites and 31 in sericulture sites. • Each of the enterprises have opened savings accounts with local microfinance institutions in preparation to gain access to their credit services but	• Securing suitable and accessible micro-finance services to support development of the value chains has been more challenging than expected.

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		well as helping to navigate regulatory requirements, standards and compliance by 2020. • Support youth to participate in agribusiness entrepreneur networks, competitions and fairs to promote products, forge partnerships and learn about developments in the industry by 2020. • Assist the young entrepreneurs to gain access to technology information by providing technical training by 2020.	only about six of them have taken loans by end of 2017. • Arrangements were made with local key institutions for availing business development services and mentoring. • A total of 40 experienced local extension staff nominated to provide regular technical supervision to the youth enterprises that have attended one week of intensive training in adult learning skills development.	
8.4 Market opportunities for youth in beekeeping and silk value chains created.	• At least 70% of youth in the project areas employed in the beekeeping and silk farming value chains in the period 2017 – 2019. • Youth led cooperatives established within the period 2017 – 2019. • 25% increase in honey and silk production by end of 2017 of the initial enterprises established • At least two (2) byproducts introduced by end of 2019.	• Facilitate the establishment of legalized Cooperatives and Unions that are youth-led by early 2017. • Develop youth-led marketplaces for harvesting, bulking, processing (value addition) and packaging of quality honey and silk products by mid-2016. • Work with relevant Ethiopian Government organizations and NGOs to increase honey and silk market opportunities – import substitution and export promotion by end of 2020. • Facilitate the use of by-products of the silk and honey industries to benefit youth and their associations by end of 2020.	• By end of 2017, a total of 212 youth led enterprises established, 196 in apiculture sites and 31 in sericulture sites. • Rehabilitation of four buildings to convert them into training and demonstration marketplaces has been underway during 2017. Work on two others will start in 2018.	

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8.5Learning among the project participants facilitated and key project learning captured and disseminated amongst the key stakeholders.	• M&E and outcome mapping strategy developed by end of 2016. • Document the extent to which beekeeping and silk farming are used for solving youth unemployment problem by 2019.	• Develop a M&E plan for the project including a detailed learning plan to ensure uptake of the technologies by 2016. • Implement the M&E plan including baseline data, collection and analysis, review and refinement of methodology after completion of cohort one and subsequent ongoing evaluation including end of project review during the period 2016 – 2020. • Develop an outcome mapping strategy including impact pathways in order to understand and document the impact generated by project implementation process during the period 2016 – 2020. • Monitor different partners (NGOs and Government Ministries) in order to document the extent to which beekeeping and silk farming are used for solving youth unemployment problem by 2020.	• Comprehensive M&E framework and plan developed, reviewed and adopted, with key strategic learning questions of the project incorporated. • Baseline and target production levels quantified based on data generated during baseline surveys. • Year 1 baseline survey report finalized. • Year 2 baseline survey report under internal review. • Progress monitoring survey conducted on the Year 1 cohort of youth enterprises and the report prepared and discussed at various levels.	
8.6Awareness raised and access to the outcomes and information on the project progress and achievements among project partners, relevant key stakeholders and the communities ensured.	• Project website developed by end of 2017. • Annual workshops for dissemination of reports. • A communications plan developed by end of 2016.	• Create a project website for use as a dissemination vehicle for the wider audience, including project activities, progress and results; project publications and presentations by 2017. • Organize conferences and workshops to maximize the impact of dissemination and the	• Project website initiated within the main *icipe* website, and the prototype was finalized for kick off; project communication staff attended brief training about the micro-site. • Project communication plan developed.	

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		sustainability of project outputs by 2020. • Develop a communication plan in order to identify relevant key stakeholders (internal and external) and enhance communication among all parties involved in the project by 2017.	• Project communications officer recruited and engaged to move the implementation forward.	

3.6 Socio-Economic R&D Cross-Cutting Activities: RBM Report

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Objective 1: Increase horticultural and staple food production by at least 30% by 2020 by reducing pre- and post-harvest quantitative and qualitative losses due to pests in *icipe*'s target areas				
Specific Objective 1: Evaluate the spillover effects of mango IPM fruit fly control technology on farm productivity				
Economic spill over effects of Mango IPM fruit fly control technology on farm productivity evaluated	At least 3000 households are aware of the spill over effects of Mango IPM fruit fly control technology on farm productivity Kenya (Embu, Meru, Kilifi) and the results disseminated to other Countries' project's sites and project partners	• One field survey conducted in one of the Kenyan sites • One MSC thesis produced by April 2015 • At least one article produced by end of 2015	Manuscript revised and submitted for peer review (*Food policy journal*). Title "Economic analysis of spill over effects of Integrated Pest Management (IPM) strategy for suppression of mango fruit fly in Meru County, Kenya	Our analysis shows positive and significant cross-commodity spill over effects of the fruit fly IPM strategy on pawpaw and oranges
Specific objective 2: Evaluate the environmental benefits of Mango IPM fruit fly control technology				
Economic analysis and environmental benefits of Mango IPM fruit fly control technology evaluated	At least 3000 households are aware of the spill over effects of Mango IPM fruit fly control technology on environment in Kenya and the results disseminated to other Countries' project's sites and project partners	• One field survey conducted in one of the Kenyan sites • One MSC thesis produced by end 2015 • At least one articles produced by end of 2015	MSc student working "Assessment of health and environmental effects of mango integrated fruit fly management in Meru County" graduated	The analysis show that adoption of IPM strategy reduced environmental impact quotient (EIQ) field use by 6.81%, implying the strategy improved human health and reduced damage on the environment.
Specific Objective 3: Dissemination and Promotion of Mango Fruit Fly Integrated Pest Management (IPM) technologies by 2018				
Socio-economic impact of the introduced fruit fly IPM and classical biological control technologies	•Develop baseline of knowledge, attitudes and practices (KAP) related to mango production and IPM	•Baseline on KAP related to mango production and IPM technologies	• Paper on ex-ante assessment of demand for IPM being drafted.	The preliminary analysis shows that farmers are willing to adopt IPM technologies

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assessed.	technologies using complementary methods including focus group discussions and household surveys with data disaggregated by sex and age. •Undertake an ex-ante impact assessment to assess economic impact of IPM implementation. •Conduct a follow-up ex-post impact assessment of IPM up scaling on smallholder farms with data disaggregated by sex and age	developed in at least two project action sites. •At least one ex-ante study undertaken in at least two project action sites; •At least one ex-post impact assessment study undertaken in at least two project action sites; Income of growers increased by at least 20% in at least two project action sites; Mango rejection reduced by at least 25% in at least two project action sites; Reduction of insecticide use by at least 30% in at least two project action sites.	• Baseline data collected from 662 mango growing households in Elgeyo Marakwet county, Kenya, for a Randomized Control Trial (RCT) study	The Elgeyo Marakwet survey revealed fruit flies as the major mango insect pest in the county, that results to high production losses and few market opportunities for the produce. The project further designed a lottery and distributed IPM materials (289 fruit fly traps and 527- 400ml bottles of protein bait) to 175 mango growers in January,2018.
Specific objective 4: Strengthening citrus production systems through the introduction of IPM measures for pests and diseases in Kenya and Tanzania				
Socio-economic assessment of the importance of the ACP and associated HLB disease, and FCM, and the impact of IPM on target biotic constraints established.	• Baseline data on farmers' knowledge, attitude and practices of ACP, HLB and FCM management collected by end of 2015. • Economic impact of ACP, HLB and FCM on citrus production established by end of 2016.	• Baseline data on farmers' knowledge and management practices (KAP) for ACP, HLB and FCM conducted and information on knowledge, attitude and practices collected in at least one action site by end of 2015.	• Data collected in 2016 cleaned and analyzed. Two (2) Msc thesis synthesized from the data with following titles: ○ Evaluation of Knowledge, Perceptions and Practices of Managing Citrus Pests and Diseases and the Willingness to Pay for an Integrated Pest Management Strategy in Selected Counties	• Results revealed that farmers had good knowledge of the pests and disease, and could correctly identify their symptoms. High reliance on synthetic pesticides was evident in both counties with very little knowledge on alternative options such as IPM, suggesting the need for dissemination and promotion of the developed IPM strategies for controlling FCM,

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in ObtainingOutcome*	*2017 Lessons Learned*
	• Potential impact of IPM interventions evaluated by end of 2016. • Ex-post assessment of implemented IPM management options for target pests and disease conducted by end of 2017.	• Economic impact of ACP, HLB and FCM on citrus production assessed in at least one action site by end of 2016. • Potential impact of citrus IPM intervention assessed for at least one action site by end of 2016. • At least one ex-post assessment of implemented IPM management interventions conducted by end of 2017.	○ Ex- Ante Economic Impact Assessment of The Integrated Citrus Pests and Diseases Management Interventions in Selected Counties, Kenya. • One thesis submitted to the University graduate school for examination • 2 draft articles produced from the thesis and under review by authors	ACT and HLB. Using the economic surplus model, the economic impact assessment showed that farmers incur significant losses due to the target pests and disease. Investing in a citrus IPM strategy was found to be viable with an NPV of 51.3 Million USD over the simulated 15 years, approximately 3.4 million USD annually, IRR of 60.3% and BCR of 16.29%.
Objective 2: Promote the utilisation of insects for food, feed, organic waste recycling and pharmaceutical purposes to enhance food security and income generation capacity in sub-Saharan Africa by 2020				
Specific objective 2.1: Develop and promote insect feed for poultry and fish production in Kenya and Uganda (INSFEED) by 2018				
Market demand analysis for insects as feed ingredient for poultry and fish.		Market demand and cost benefit analysis conducted for at least one insect based feed by 2017. Key market segments described by December 2015.	One MSc student graduated. Topic of study "Gendered analysis of Factors Influencing Demand for Poultry and Fish Feed in Kenya. University of Nairobi, Kenya"	Results show that female livestock farmers were most affected by increase in feed prices in comparison with male counterparts
Economic performance of insect-based feed	Economic viability of insect rearing determined	Comparative costs of at least 3 insect based feeds. assessed by end 2016	Data collection completed; analysis and writing in progress	Preliminary results based on laboratory experiments generate a positive net present value of investing in insect rearing;

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in ObtainingOutcome*	*2017 Lessons Learned*
		Cost efficiency studies of poultry and fish reared on insect based feed evaluated by 2017.		Implying that insect rearing is viable and can be the potential business options.
Specific Objective 2.2: To create awareness and market opportunities in production of insect-based protein for the livestock industry				
Assess perceptions of fish, poultry and pig farmers with regard to use of insect based feed	Perceptions of fish, poultry and pig farmers with regard to use of insect based feed documented	At least one survey report produced	Two reports were generated on "Survey report on Farmer Perceptions of use of Insects as Feed in Poultry and Fish farming in Kenya" and "Survey report on Feed Demand among smallholder Pig, Fish and Poultry farmers in Kenya".	One of the reports captures the current demand of the various feed types used by fish, poultry and pig producers in the four counties. The second reports assess the farmer willingness to pay for insect based feeds in these counties. The reports show that poultry farmers, fish farmers and pig farmers have great interest in the new innovation (of using insect as a source of protein for feed). However, majority (more than three quarters) of the farmers are willing to pay insect based feed at either the prevailing feed market prices or a discounted prices.
Assess consumers' willingness to pay for insect fed meat	Consumer willingness t pay for insect fed chicken determined	One thesis produced One working paper produced	One MSc student submitted a thesis on "Consumer willingness to pay for chicken meat derived from insect based feed in Kenya"	Results show that almost all consumers surveyed would eat insect fed chicken meat; and were willing to pay a price comparable to the premium price.
Objective 3: Assess the impact of the IVM strategies on communities' health, and livelihood				
Impact of IVM strategies on communities' health, and livelihood assessed	At least 3000 community members are aware of the impact of the IVM	At least one (01) research report produced by end of 2015	Community survey was conducted to assess community perceptions of the impact of the	The FGD revealed that households residing in IVM intervention sites have more

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in ObtainingOutcome*	*2017 Lessons Learned*
	strategies on health and livelihood in Nyabondo (Kenya), Malindi (Kenya) and Tolay (Ethiopia) and results of impact study disseminated to project's partners		IVM project interventions in selected villages in Malindi, Kenya. The data was collected through focus group discussions (FGDs) in four IVM intervention villages (Mbogholo, Mikuyuni, Garashi and Mangani) and two control villages (Burangi and Goshi) in Malindi in Kenya.	knowledge of malaria and its prevention. Community perceptions also show general decline in malaria episodes and reduced expenditure on malaria treatment attributed to IVM interventions. As a result, households are perceived to be more productive and food secure. Cases of households having to sell assets to treat malaria, leaving their land fallow due to lack of labor of having to hire outside labor due to malaria were also reported to be decreasing
Specific objective 3.1: Assess and compare the impact of combined 4-H interventions to single H or 2-H or 3-H interventions on household income per capita in Tolay (Ethiopia)				
The impacts of combined 4-H, single H, 2-H and 3-H interventions on household income per capita in Tolay (Ethiopia) are assessed and compared.	One impact assessment report utilised by donor by end of 2014	At least one research report and one draft journal article produced by end of 2014	A manuscript "Multi-intervention impact assessment in Tolay, Ethiopia. " presented at the at the Biovision Foundation Annual Symposium, 19th Nov 2017, Switzerland. And submitted to journal.	The project demonstrated that integration of technologies (Integrated Vector management (IVM) for malaria control, traps for tsetse and trypanosomiasis control, push-pull technology for maize stemborers control and improve soil fertility and beekeeping to improve nutrition and relax financial constraints) substantially increase the net income of smallholder farmers. The combined interventions increase net annual income by 159-226% relative to the baseline scenario and by 34-195% compared to a single intervention

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in ObtainingOutcome*	*2017 Lessons Learned*
				case. The synergetic effects or prompting these interventions together provided an additional per capita income of US$368.
Objective 4: To assess the impact of the Biological Control (BC) programme on productivity, food security, poverty and environment at household level.				
Impact of the biological control programme on productivity, household welfare and environment assessed.	At least one (1) impact assessment report produced and shared with donors and partners by end of 2016.	At least one (1) impact study conducted by end of 2016. One scientific publication by end of 2016.	A manuscript submitted to journal of rural studies in 2017	The BC has productivity increasing and poverty reduction
Objective 5: Assess push-pull technology, IPM and role of women's empowerment in agriculture and adoption of push-pull technology on farm- and aggregate- level welfare impacts				
Assess the impacts of push-pull technology (PPT),	Enhanced evidence on performance of PPT	Two peer reviewed papers on impacts of PPT	One on micro-impacts of PPT in Uganda published	Demonstrate positive evidence on micro-welfare impact of adoption of push-pull technology
Understand role of gender in push-pull technology and other sustainable intensification (SI) technologies adoption	Policy makers, researchers and development partners use research results to enhance capacity and improve gender intervention in agriculture	Peer-reviewed paper on role of gender on PPT adoption and other SI technologies	Gender and adoption of sustainable agriculture practices (SAPs)published in food security journal (https://link.springer.com/article/10.1007/s12571-018-0783-6).	The study found gender to be neutral in adoption of PPT but the heterogeneity was evidence in adoption of some of the other SI technologies/practices.
Analyse the impact of women's empowerment on agriculture productivity	Agricultural productivity impact of Women's empowerment determined	Working paper	One paper on impact of women's empowerment in Kenya agriculture on agricultural productivity submitted to a peer reviewed journal	Results show that women's empowerment significantly increase productivity. Results that female- and male-managed plots experience significant improvements in productivity when the women who tend them are empowered.

Expected Outputs as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Outcome as per RBM framework plan***	***2017 Progress observed in ObtainingOutcome***	***2017 Lessons Learned***
Develop *icipe* wide Planning, Monitoring, Evaluation and Learning (PMEL)	A center-wide PMEL strategy developed	PMEL document M & E workshop participants	*icipe* wide Planning, Monitoring, Evaluation and Learning (PMEL) document produced to measure *icipe's* performance using Centre wide indicators and targets, as well as to guide various *icipe's* projects in terms of proper project planning and M&E.	

3.7 Capacity Building and Institutional Development: RBM Report

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Expected Outcome as per RBM framework plan*	*2017 Progress observed in obtaining Outcomes*	*2017 Lessons Learned*
Objective 1: Increase the number of high quality researchers and middle level practitioners required to respond to arthropod-related research and development challenges in Africa by 2020				
1. Between 2014 and 2020, 60 PhD and 150 MSc postgraduate students (33% women) complete their training in arthropod and related sciences.	• At least 75% of PhD students who complete their training are contributing to research, development and higher education in Africa, dealing with reducing poverty, improving food and nutritional security, improving human, animal and environmental health, and working in Universities, National Research Systems (NARS), sub-Regional Organisations (SROs), International Research Centres (IRCs), and the private sector in Africa, each year during the period 2014–2020. • At least 50% of MSc graduates trained at icipe continue a	• Number of PhD and MSc postgraduate students completing training with icipe each year during the period 2014–2020. • Number of scientists trained at *icipe* engaged in research, development and higher education in Africa. • Number of researchers leading research and development projects or playing a leading role in higher education in Africa. • Number of research activities/projects implemented in African institutions by scientists trained at *icipe.* • Number of graduates leading public & private organisations/ enterprises in Africa.	• In 2017, *icipe* had 84 PhD students and 74 MSc students at various stages of their postgraduate programmes. • In 2017, women represented 47% of all postgraduate students. • In 2017, 18 African countries from all sub-regions of SSA were represented by postgraduate students at icipe; 39 (25%) of postgraduate students were from Southern, Central and West Africa, and 119 (75%) were from East Africa. *[11 new ARPPIS PhD fellows started in September 2017. With 7 African nationalities represented (Benin, Ethiopia, Kenya, Nigeria, Sudan, Uganda, and Zimbabwe) the new cohort represents significant country diversity entering the ARPPIS PhD programme.]* • In 2017, 15 PhD students completed training. Currently, 10 (67%) are in research, development and higher education in Africa; 3 (20%) are in research, development and higher education outside Africa; 1 (6.5%) has returned to her home country in Africa and is currently seeking a research position; information for 1 (6.5%) is unavailable.	Long term tracking of MSc students is lacking.

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Expected Outcome as per RBM framework plan*	*2017 Progress observed in obtaining Outcomes*	*2017 Lessons Learned*
	career in R&D or higher education, dealing with dealing with reducing poverty, improving food and nutritional security, improving human, animal and environmental health.		1 student (0.6%) withdrew from the PhD programme. • We do not have complete records of the number of new research and development activities/projects implemented and/or led by trained PhD level scientists. This will be partially collected as part of routine alumni tracking. However, an ongoing tracer study of all alumni from the *icipe* ARPPIS PhD programme, dating back to 1983, has shown that 74% of all alumni (from when the ARPPIS programme started in 1983 to date) are engaged in R&D or higher education in Africa, 6% are active in similar areas outside of Africa, and 20% are not engaged in R&D, higher education or similar; or are untraceable, or are deceased. • 19 MSc students completed their training in 2017. 10 (53%) are pursuing careers in research, development and higher education (including 2 doing PhD studies in Africa and 3 in Europe); 9 (47%) are currently unemployed. • 145 postgraduate fellows who completed training at icipe since 1983 are in senior positions, contributing to R&D or Higher Education in Africa, although none of those who completed during the project period from 2014 are in senior positions.	
2. Dissemination of research results	Research results disseminated in relevant	• Number of publications that result from research	• In 2017, of the 136 peer-reviewed papers published by *icipe*, 58 (43%)	Although postgraduate student

Expected Outputs as per RBM framework plan	***Expected Outcomes as per RBM framework plan***	***Performance Indicator of Expected Outcome as per RBM framework plan***	***2017 Progress observed in obtaining Outcomes***	***2017 Lessons Learned***
through 420 publications of research results ((including theses, book chapters, peer-reviewed papers, conference abstracts and proceedings, training brochures and manuals, policy documents, print and online media) in the period 2014-2020	formats at scientific community and policy maker levels	conducted by students at icipe during training (theses, book chapters, peer-reviewed papers, conference abstracts and proceedings, training brochures and manuals, print and online media). • Number of students contributing to policy documents. • Quality and relevance of *icipe* led-research results shared with scientific community determined by the number of citations in peer-reviewed publications. • Number of students participating in scientific meetings/conferences	were authored by postgraduate students (47 (35%) as lead authors). • Citation metrics: • Peer-reviewed publications by students had the following average number of citations and downloads for the years given: • *Citations*: 5.75 (2014), 7.45 (2015), 3.7 (2016), 1.3 (2017) • *Downloads*: 50 (2014), 24.97 (2015), 42.7 (2016), 44.5 (2017) • 15 PhD and 19 MSc theses were completed in 2017. • In 2017, 35 postgraduate students participated in 13 international/regional and 13 local scientific meetings & conferences	make a significant contribution to the scientific output of *icipe*, baseline data are required to evaluate the quality of the publications by citations and downloads.
3. Mid-level practitioners and extension workers (200) from 30 national systems in Africa trained in non-degree professional development courses during the period to 2014 - 2020.	• At least 50% of trained middle-level practitioners applying their knowledge and expertise in Africa each year during the period 2014–2020.	• Number of training courses. • Number of trainees. • Number of new technologies produced and adopted. • Training and information.	• 2376 mid-level practitioners and extension workers trained • 54 training courses • 17 countries in Africa • Tracer studies on the number applying their knowledge and expertise in Africa were not conducted.	A plan for monitoring trainees after training should be incorporated into course programmes e.g. the Participant Action Plan Approach (PAPA)
4. Undergraduate interns (150) trained during the period to 2016 - 2020.	• At least 50% of trained undergraduate interns progressing to research and development careers	• Number of interns trained. • Number of internship reports.	• 28 interns were trained in insect and related sciences in 2017. The average duration of an internship was 3.3 months.	Interns are now included in our capacity building database, and tracking interns after

Expected Outputs as per RBM framework plan	Expected Outcomes as per RBM framework plan	Performance Indicator of Expected Outcome as per RBM framework plan	2017 Progress observed in obtaining Outcomes	2017 Lessons Learned
	each year during the period 2014–2020.		• No data is currently available on follow-up of interns.	departure will be included from 2018.
5. Research and training capacities in insect and related sciences strengthened at national and regional research and higher education institutions through the development of an icipe Alumni Network. Institutions will include three ARPPIS sub-regional centres at Addis Ababa University, University of Ghana-Legon, University of Zimbabwe.	• At least 5 new research or training programmes projects developed with national and regional partners each year during the period 2014–2020. • Increased technology uptake and out-scaling in Africa each year during the period 2014–2020.	• Signed MoUs and collaborative agreements. • Number of exchange visits by network partners. • Number of network partners. • Number of research projects started • Number of new training programmes in national systems	• The establishment of the new *icipe* Alumni Programme is still under development. • New online database of all icipe postgraduate and postdoctoral fellows and alumni was developed and is continually updated with new information to support the Alumni Programme.	Managing a network for capacity strengthening in Africa will require a full-time Network coordinator. Funds must be rasied to support institutional development through an Alumni Network.
6. Career development opportunities for 20 early career scientists (short-term visiting scientists and postdoctoral fellowships (PDFs)) implemented during the period 2014–2020.	• At least 75% of PDFs and visiting scientists on completion at *icipe* proceed to contribute to research, development and higher education in Universities, NARS, SROs, IRCs, and the private sector in Africa each year during the period 2014–2020. • At least 50% of fellows attract competitive	• Number of new career development opportunities implemented • Number of postdoctoral fellows and visiting scientists trained. • Number of grants applied for and received by PDFs each year. • Number of research publications in peer-reviewed journals.	• 16 postdoctoral fellows were engaged in research at *icipe* in 2017, including 5 postdoctoral fellows recruited in 2017. • 5 postdoctoral fellows completed in 2017. All are currently employed, contributing to research, development and higher education in Africa. • 36 peer-reviewed articles were published by postdoctoral fellows in 2017 (9 as lead author). • In 2017, *icipe* postdoc fellows made 26 research grant applications. 8 were awarded, 10 were declined, and 8 are currently under review.	

Expected Outputs as per RBM framework plan	Expected Outcomes as per RBM framework plan	Performance Indicator of Expected Outcome as per RBM framework plan	2017 Progress observed in obtaining Outcomes	2017 Lessons Learned
	research grants during their tenure at icipe.			

3.8 Bioinnovate Africa Programme Phase II: RBM Report

Expected Outputs as per RBM framework plan	*Expected Outcomes as per RBM framework plan*	*Performance Indicator of Outcome as per RBM framework plan*	*2017 Progress observed in obtaining Outcome*	*2017 Lessons Learned*
Objective or Specific Objectives: a) Generate bioscience innovations that address the needs of smallholder farmers and agro-processors. b) Evaluate relevant policy options to support scientists in their effort to promote bioscience innovations for smallholder farmers and agro processors. c) Establish Bio Innovate as an independent legally registered a non-for-profit "Eastern Africa regional network for bioscience innovations (EARNBIN).				
Progress towards achieving objective or specific-objective: a) The first cohort of project partners and beneficiaries mainly comprising eastern African universities, research organizations and firms selected competitively. b) Programme Management Structures established (Programme Advisory Committee, Progamme Management Office, Programme Implementation Manual).				
• New scientific knowledge. • Value added products. • Publications. • Graduate students (MSc/PhD). • Pilot demonstration facilities.	• Eastern African universities, research organizations and firms have enhanced capacity to translate modern biosciences into innovations targeting smallholder farmers and agro-process enterprises in the region.	• Percent increase in number of innovative bioscience projects in participating universities, research organizations and firms. • Percent increase in agro process firms linking with scientists in participating universities and research organizations. • Rate of adoption of bioscience technologies by targeted small holder farmers.	• 11 bioscience innovation projects were selected comprising 51 participating universities, research organizations and firms. • 18 agroprocess firms (mainly private companies) are part of selected project teams collaborating with participating universities and research organizations. • None. • None.	• The high demand for opportunities provided by BAP indicate the importance of widely disseminating the call through various channels. • Providing clarity of the call and the transparent process of project selection are key aspects in building trust of stakeholders. • Building collaborations across countries remains a challenge especially in Burundi, Ethiopia and Rwanda. More networking mechanisms are necessary. • Designing innovation projects and the aspect of business development required to link innovations to market is challenging for many scientists. Capacity building

		• Percent increase in applications for patents on value added products.		in these areas is important to align ideas towards innovation. • The peer review process supported by an online submission and review system eased the call selection process. • The requirement for matching support from project partners remains a challenge. Emphasis will be on following up and documenting the in-kind contribution.
• Policy dialogues held. • Policy analysis reports. • Policy incentives. • Market & financial study reports. • Feasibility study reports.	• Eastern African universities, research organizations and firms have enhanced capacity to translate modern biosciences into innovations targeting smallholder farmers and agro-process enterprises in the region.	• Percent increase in number of policy incentives for bioscience innovations	• None.	
• Stakeholder consultations. • BioInnovate Charter developed. • BioInnovate Council inaugurated. • BioInnovate certificate of registration.		• BioInnovate Africa registered as independent legal entity.	• BioInnovate Africa brand registered.	

SECTION 4: List of Refereed Journal Articles

Annex 1: January – December 2017 Publications List

2017 Published (137)

1. *Abdel-Rahman E.M.*, *Landmann T.*, *Kyalo R.*, Ong'amo G., *Mwalusepo S.*, Suleiman S. and *Le Ru B.P.* (2017) Predicting stem borer density in maize using RapidEye data and generalized linear models. *International Journal of Applied Earth Observation and Geoinformation* 57 61–74. doi: 10.1016/j.jag.2016.1012.1008.
2. *Abdel-Rahman E.M.*, Mutanga O., Odindi J., Adam E.M.I., Odindo A. and Ismail R. (2017) Estimating Swiss chard foliar macro- and micronutrient concentrations under different irrigation water sources using ground-based hyperspectral data and four partial least squares (PLS)-based (PLS1, PLS2, SPLS1 and SPLS2) regression algorithms. *Computers and Electronics in Agriculture* 132, 21–33.
3. Abry M.F., Kimenyi K.M., *Masiga D.* and *Kulohoma B.W.* (2017) Comparative genomics identifies male accessory gland proteins in five *Glossina* species [version 1; referees: awaiting peer review]. *Wellcome Open Research* 2, 73. doi: 10.12688/wellcomeopenres.12445.12681.
4. Adam E., Deng H., Odindi J., *Abdel-Rahman E.M.* and Mutanga O. (2017) Detecting the early stage of phaeosphaeria leaf spot infestations in maize crop using *in situ* hyperspectral data and guided regularized random forest algorithm. *Journal of Spectroscopy* 2017, ID 6961387; doi.org:6961310.6961155/6962017/6961387.
5. *Addi A.*, Kelbessa E., Soromessa T., Gallmann P., *Belayhun L.* and Campos M.G. (2017) Proximate composition and antioxidant power of bee collected pollen from moist Afromontane forests in southwest Ethiopia. *Agricultural Science Research Journal* 7, 83 – 95.
6. Adu-Acheampong S., Samways M.J., *Landmann T.*, Kyerematen R., Minkah R., Mukundamago M. and Moshobane C.M. (2017) Endemic grasshopper species distribution in an agro-natural landscape of the Cape Floristic Region, South Africa. *Ecological Engineering* 105, 133–140.
7. *Affognon H.*, *Mburu P.*, Hassan O.A., *Kingori S.*, Ahlm C., *Sang R.* and Evander M. (2017) Ethnic groups' knowledge, attitude and practices and Rift Valley fever exposure in Isiolo County of Kenya. *PLOS Neglected Tropical Diseases* 11(3), e0005405. doi:0005410.0001371/journal.pntd.0005405.
8. *Agha S.B.*, *Chepkorir E.*, Mulwa F., *Tigoi C.*, *Arum S.*, Guarido M.M., Ambala P., Chelangat B., Lutomiah J., *Tchouassi D.P.*, Turell M.J. and *Sang R.* (2017) Vector competence of populations of *Aedes aegypti* from three distinct cities in Kenya for chikungunya virus. *PLoS Neglected Tropical Diseases* 11(8), e0005860. doi: 0005810.0001371/journal.pntd.0005860.
9. *Agha S.B.*, *Tchouassi D.P.*, Bastos A.D.S. and *Sang R.* (2017) Assessment of risk of dengue and yellow fever virus transmission in three major Kenyan cities based on *Stegomyia* indices. *PLoS Neglected Tropical Diseases* 11(8), e0005858. doi: 0005810.0001371/journal.pntd.0005858.
10. *Agha S.B.*, *Tchouassi D.P.*, Bastos A.D.S. and *Sang R.* (2017) Dengue and yellow fever virus vectors: Seasonal abundance, diversity and resting preferences in three Kenyan cities. *Parasites & Vectors* 10, 628. doi: 610.1186/s13071-13017-12598-13072.
11. *Akutse K.S.*, *Maniania N.K.*, *Ekesi S.*, *Fiaboe K.K.M.*, Van den Berg J., *Ombura O. L.* and *Khamis F.M.* (2017) Morphological and molecular characterization of *Vicia faba* and *Phaseolus vulgaris* seed-borne fungal endophytes. *Research Journal of Seed Science* 10, 1–16. doi: 10.3923/rjss.2016.
12. Ali A.M., Salih D.A., Njahira M.N., Hassan S.K., EL Hussein A.M., Liu Z., Yin H., Pelle R. and *Skilton R.A.* (2017) Genotyping of *Theileria lestoquardi* from sheep and goats in Sudan to support control of malignant ovine theileriosis. *Veterinary Parasitology* 239, 7–14. http://doi.org/10.1016/j.vetpar.2017.1004.1005.
13. Assefa Y., Goftishu M., Capdevielle-Dulac C. and *Le Ru B. P.* (2017) Clarifying the source of *Conicofrontia sesamoides* (Lepidoptera: Noctuidae) population in South African sugarcane using morphological identification and mitochondrial DNA analysis. *Phytoparasitica* 45, 45–55. doi: 10.1007/s12600-12017-10566-12601.

14. *Atandi J.*, *Haukeland S.*, Kariuki G.M., Coyne D.L., *Karanja E.N.*, *Musyoka M.W.*, *Fiaboe K.K.M.*, Bautze D. and Adamtey N. (2017) Organic farming provides improved management of plant parasitic nematodes in maize and bean cropping systems. *Agriculture, Ecosystems and Environment* 247, 265–272.
15. Aumer D., Allsopp M.H., *Lattorff H.M.G.*, Moritz R.F.A. and Jarosch-Perlow A. (2017) Thelytoky in Cape honeybees (Apis mellifera capensis) is controlled by a single recessive locus. *Apidologie* 48, 401–410. doi: 410.1007/s13592-13016-10484-13590.
16. *Azrag A.G.A.*, Murungi L.K., Tonnang H.E.Z., *Mwenda D.* and *Babin R.* (2017) Temperature-dependent models of development and survival of an insect pest of African tropical highlands, the coffee antestia bug *Antestiopsis thunbergii* (Hemiptera: Pentatomidae). *Journal of Thermal Biology* 70, 27–36. http://dx.doi.org/10.1016/j.jtherbio.2017.1010.1009.
17. Badshah H., Ullah F., *Calatayud P.-A.*, Ullah H. and Ahmad B. (2017) Can toxicants used against cotton mealybug *Phenacoccus solenopsis* be compatible with an encyrtid parasitoid *Aenasius bambawalei* under laboratory conditions? *Environmental Science and Pollution Research* 24, 5857–5867. doi: 5810.1007/s11356-11016-18293-11356.
18. Badshah H., Ullah F., Zada H., Zeb Q., Shah R.A., *Calatayud P.-A.* and Crickmore N. (2017) Comparison of *Phenacoccus solenopsis* specimens from different regions of Pakistan using COI molecular barcoding (Hemiptera: Pseudococcidae). *Annales de la Société Entomologique de France* 53, 374–378. doi: 310.1080/00379271.00372017.01358666.
19. Bayissa W., *Ekesi S.*, *Mohamed S.A.*, Kaaya G.P., Wagacha J.M., Hanna R. and *Maniania N.K.* (2017) Selection of fungal isolates for virulence against three aphid pest species of crucifers and okra. *Journal of Pest Science* 90, 355–368. doi:310.1007/s10340-10016-10781-10344.
20. Beck J.J., *Torto B.* and Vannette R.L. (2017) Eavesdropping on plant–insect–microbe chemical communications in agricultural ecology: A virtual issue on semiochemicals. *Journal of Agricultural and Food Chemistry* 65, 5101–5103.
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