icipe
Demonstrating Excellence

2007—2012

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African Insect Science for Food and Health

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CONTENTS

ACRONYMS AND ABBREVIATIONS

ABC-PaPoGen	Adaptation in Biological Control - Parasitoid Population Genomics
ACSM	social mobilisation capacities
ADOPT	Adaptation and Dissemination of the Push–Pull Technology
ARPPIS	African Regional Postgraduate Programme in Insect Science
AU-IBAR	African Union-Interafrican Bureau for Animal Resources
AVID	Arbovirus Incidence and Diversity Project
AVRDC	The World Vegetable Center (previously known as the Asian Vegetable Research and Development Center)
BMGF	Bill and Melinda Gates Foundation
BMZ	Federal Ministry for Economic Cooperation and Development
Bti	*Bacillus thuringiensis israelensis*
CCD	Colony Collapse Disorder
CHIESA	Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa project
CIP	International Potato Center
EAAPP	Eastern Africa Agricultural Productivity Project
EID	emerging infectious disease
EPF	entomopathogenic fungi
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GMP	Good Manufacturing Practice
GIS	geographic information system
GPS	Global Positioning System
HAT	human African trypanosomosis
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
IPM	integrated pest management
IRD	L'Institut de recherche pour le développement
IYSV	*Iris yellow spot virus*
IVM	integrated vector management
KEMRI	Kenya Medical Research Institute
KEPHIS	Kenya Plant Health Inspectorate Service
LAMP	Loop-mediated isothermal amplification of DNA
LMF	Leafminer flies
LUBILOSA	Lutte Biologique contre les Locustes et les Sauteriaux
MDG	millennium development goal
NARES	national agricultural research and extension system
NGO	non-governmental organisation
PAN	phenylacetonitrile
PICS	Purdue Improved Cowpea Storage
PSU	Penn State University
RSM	red spider mites
RVF	Rift Valley fever
SAP	super absorbent polymer
SEA	Southeast Asia
SSA	sub-Saharan Africa
ToT	Training of Trainers
WFT	western flower thrips

FOREWORD

Dr Segenet Kelemu
Director General, *icipe*

As a scientist and a scientific leader, my dream has always been to contribute towards the building of an excellent world-class research capacity in developing countries, and in particular in Africa, where such competence is most urgently needed.

It is therefore with great pleasure that, in November 2013, I commenced my appointment as the Director General of *icipe*, an institution that I believe strongly epitomises my vision.

Indeed, since its founding, *icipe* has maintained the idea of excellence at the core of all its activities. Yet, the Centre is aware that as a concept, excellence in science is a compounded issue. Within the international scientific community, excellence is defined by having an international reputation. However, as an organisation based in Africa, *icipe* recognises that excellence must also have another dimension, which is the ability to respond to the critical developmental needs facing the continent.

Among these challenges is a range of dilapidating human and livestock diseases, which include malaria, emerging infectious diseases, the tsetse transmitted human African trypanosomosis, commonly known as sleeping sickness, and the livestock disease nagana.

In addition, the food security and livelihoods of millions of people in Africa is in constant risk due to a variety of factors. For instance, the yields of cereals, the main staple and cash crops for many households in the region, are severely threatened by insect pests, the parasitic weed striga, land degradation and poor soil fertility.

Further, although horticultural crops such as fruits, vegetables, legumes and nuts could enhance the income, employment and nutritional security of many people in the continent, their production is limited by insect pests, which reduce yield and cause the rejection of produce from Africa in export markets.

Moreover, while many people in Africa depend on land-based resources for their livelihoods, factors related to population growth and poverty are bringing about changes that are adversely affecting ecosystems. In addition, the impacts of climate change will most significantly be felt in Africa, possibly pushing communities further into poverty.

As illustrated in this publication, which focuses on *icipe*'s activities between 2007 and 2012, the Centre has strongly responded to the range of developmental challenges discussed above, while adhering to the highest level of globally accepted standards of scientific practice.

This Report showcases *icipe*'s excellence during that period along three themes: providing **better health** for people and livestock, helping to achieve **better yields** for crops and contributing towards a **better environment** for the sustainability of ecosystems and livelihoods.

Dr Segenet Kelemu
Director General, *icipe*

PREFACE

Prof Christian Borgemeister, former Director General, *icipe*

On 30 September 2013, I ended my tenure at *icipe* after eight years as the Centre's Director General.

During that time, we continued to build on the vision set by my predecessors, enhancing *icipe*'s role as a centre of excellence towards ensuring **better health** for people and livestock, **better yields** for crops and a **better environment** for the sustainability of ecosystems and livelihoods in Africa. This publication demonstrates the Centre's success towards these three goals between 2007 to 2012.

On the goal of **better health**, *icipe* has scaled-up its highly successful community-based methods for the control of malaria and mosquitoes to new sites in Kenya and Ethiopia. While addressing the intricate linkage between malaria and livelihoods, the Centre has provided communities with information, education and communication materials, to empower them to make informed decisions and take the right action against the disease.

In addition, *icipe* has utilised its strength in chemical ecology to enhance understanding on the behaviour of mosquitoes, and its expertise in molecular biology to contribute to global advances in genetic strategies to deplete or incapacitate disease-transmitting mosquitoes. This knowledge is critical towards defining innovative methods for controlling malaria and its vectors.

icipe's activities in health have also focused on Rift Valley fever (RVF) as a model for developing strategies to control emerging infectious diseases. In this regard, the Centre is contributing towards enhanced arbovirus surveillance, increased understanding of the ecosystem and sociological parameters that influence RVF outbreaks, and the development of practical early warning and response systems for the disease.

Further, *icipe* is developing integrated and environmentally friendly management strategies for the control of tsetse flies, sleeping sickness and nagana, based on a sound understanding of the biology, behaviour and ecology of the flies.

On the goal of **better yields**, *icipe* has significantly contributed to the improvement of cereal production around three programmes. First, the Centre has made its phenomenally successful push–pull technology accessible to more small-scale farmers across East Africa. Second, *icipe* has conducted extensive collaborative research with the Institut de Recherche pour le Développement (IRD) on stemborers and their natural enemies. Third, *icipe* is spearheading studies on postharvest losses of cereals and other crops, investigating better storage strategies, and helping to compile systematic evidence that will assist decision-makers to optimise post-production policies and strategies.

In horticulture, *icipe*'s activities have been around two goals: the development and implementation of integrated pest management (IPM) strategies that minimise the use of insecticides, and supporting improvement of the marketing of horticultural crops from sub-Saharan Africa (SSA).

icipe's IPM strategies include the use of natural enemies, environmentally safe baits and entomopathogenic fungi (EPF) isolates developed by the Centre. *icipe* is also supporting postharvest methods to ensure that produce from Africa complies with the quarantine security required before export.

On the goal of **better environment**, *icipe* has advanced its strategy of protecting Africa's rich biodiversity resources while improving the livelihoods of the people who live adjacent to them. The Centre has disseminated a variety of tools, which combine modern science, traditional knowledge and practices, partnerships with local communities, development partners and the private sector, for the sustainable exploitation of biodiversity. *icipe*'s activities focus on beekeeping and silk farming technologies, and the domestication and commercialisation of plants with insecticidal, medicinal or aromatic purposes.

These approaches have led to the emergence of thriving community-based, income-generating enterprises, which are improving the livelihoods of thousands of people in a total of 18 countries in SSA, North Africa and the Near East while relieving economic pressure on biodiversity resources.

In addition, *icipe* is taking a leadership role towards securing bee colonies in Africa, through a European Union funded Central Reference Laboratory (CRL), for research and capacity building on bee health, which is under construction at *icipe*'s headquarters in Kasarani, Nairobi, and four bee health satellite stations in Burkina Faso, Cameroon, Ethiopia and Liberia.

Further, *icipe* is coordinating the Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa (CHIESA) project, a four year initiative funded by the Ministry for Foreign Affairs of Finland which commenced in 2011. This initiative will produce knowledge on adaptation to climate change and climate variability, to reduce the vulnerability of communities in Africa.

Within the international scientific community, this excellence is illustrated by the fact that the Centre's scientists have excelled in regard to the number of publications in peer-reviewed journals.

icipe's success has depended on a variety of innovative strategies, which include the incorporation of an interdisciplinary approach. For instance, in 2007, the Centre established a socio-economic unit, which now provides a platform for systematic impact assessments, learning and knowledge sharing across the Centre's activities.

Further, *icipe* has began in earnest to incorporate the use of GIS and Remote Sensing technology, which is opening up new opportunities for the Centre's research, for instance the identification of 'hot-spots' of biological control and the exploration of species habitats under global climate change scenarios.

icipe's excellence during the period covered in this Report is supported by the recognition of the Centre's activities by local and global partners. For instance, organic honey produced by the Mwingi Farmers' Group was awarded the BioFach 2010 trade fair award. In addition, the Muliru Farmers Conservation Group, which, through support from *icipe* and partners, contributes to the conservation of the Kakamega Forest through the domestication of indigenous medicinal and insecticidal plants, won the Equator Prize 2010 and SEED Award 2010.

On a personal level, I am extremely grateful to all colleagues at *icipe*, as well as the national, regional and international development partners, who have made this success possible.

Christian Borgemeister, former Director General

BETTER HEALTH

Photo: *Santiago Escobar*

FOR HEALTHIER ECOSYSTEMS AND LIVELIHOODS

icipe places the health of people and livestock at the centre of all its activities. This is because the pests and diseases that affect people and livestock continue to hold back development in many parts of Africa. For instance malaria, Africa's most deadly and costly disease, impacts heavily on human productivity and the already fragile health care systems in Africa. In addition, emerging infectious diseases (EIDs) such as yellow fever, dengue, Rift Valley fever, o'nyong'nyong virus, Crimean-Congo haemorrhagic fever and the chikungunya virus, are becoming a huge burden in Africa.

Further, most of Africa's population is dependent on livestock for their everyday survival. Yet, livestock diseases, especially those transmitted by blood-feeding insects such as tsetse flies continue to threaten these valuable resources, and therefore the very livelihoods of people.

In this Chapter, *icipe* scientists discuss their activities towards developing integrated strategies for the reduction of malaria, the tsetse transmitted human African trypanosomosis, commonly known as sleeping sickness, the livestock disease nagana and Rift Valley fever.

[redacted]

Photo: *Santiago Escobar*

CONTRIBUTING TO THE WAR ON MALARIA

icipe's malaria research team discusses contribution by the Centre towards fighting malaria in Kenya and beyond.

Q. How has *icipe* linked its IVM strategies for malaria with Kenya's national vision?

A. In recent years, Kenya has taken significant steps to reduce the malaria burden, expressed through the launch of the Kenya National Malaria Strategic Plan, 2009 – 2017. Among the key outcomes of the strategy is the drafting of the integrated vector management policy guidelines by the Ministry of Public Health and Sanitation in 2009. Furthermore, the Kenyan government is utilising a strategy that aims to strengthen advocacy, communication and social mobilisation capacities (ACSM) for malaria control, with the overall goal of ensuring that by 2014, at least 80% of the people living in regions of the country where malaria is prevalent have adequate knowledge on the treatment and prevention of the disease.

Photo caption: *Mosquito scouts, lay people who received intensive and on-going training by icipe and KEMRI scientists on various aspects of controlling these vectors play a critical role in the Centre's war against malaria.*

To contribute towards this goal, *icipe* and the Kenya Medical Research Institute (KEMRI), in partnership with the Kenya Non-governmental Organisations Alliance Against Malaria and the Division of Malaria Control are implementing an IVM strategy driven by ACSM. We are developing and disseminating effective information, education and communication materials, to empower communities to make informed decisions and take the right action against malaria.

One example of our implementation of these activities is in Malindi, coastal Kenya, where we are disseminating an IVM package that includes ecologically, socially and economically sustainable methods for suppressing mosquito larvae. We are using biological larvicides, specifically *Bacillus thuringiensis israelensis* (*Bti)*, and environmental management measures. We are employing four key strategies towards malaria and mosquito control. First, we are developing a comprehensive communication strategy to support essential IVM elements for the achievement of the Millennium Development Goals (MDGs). Second, we are building a range of public and private partnerships in health communications. Third, we are developing local capacity to manage, oversee and co-ordinate the implementation of the communication strategy. Fourth, we are working with key stakeholders, for instance public health departments in Malindi, to ensure that malaria and mosquito control groups are applying the IVM strategies and that the appropriate structures that will guarantee continuity and sustainability are being developed. As a result, the communities in Malindi are now aware of the prevention options for malaria, including readily available tools.

Q. How is *icipe* tackling the linkage between malaria and livelihoods?

A. While it is well known that certain alterations in natural ecosystems aggravate malaria, there is not enough information about the relationship between malaria and livelihoods. Therefore, *icipe*'s approach is to provide evidence on how actions intended to change peoples lives for the better environments in ways that may exacerbate malaria.

For instance, in Nyabondo plateau, western Kenya, our research has shown that brick-making – the main income generating activity in the region – is largely to

Photo: *Santiago Escobar*

Disused brickmaking pits, such as the one in the background, form ideal breeding sites for mosquitoes, thereby contributing to increased malaria transmission.

A community member from Rusinga Island on the shores of Lake Victoria adjusts a solar-powered mosquito trap. Through the Solarmal project, icipe has provided over 4000 households in the region with the technology, which reduces malaria and provides better lighting.

Photo: *Alexandra Hiscox*

blame for increased malaria outbreaks. This is because abandoned brickmaking pits form ideal habitats for mosquito breeding.

Therefore, we have developed communication material which demonstrates the link between brick-making and the occurrence of malaria, and provides information on mosquitoes, malaria transmission and control. Further, our aim is to reduce malaria transmission using an IVM strategy that targets the vector and the disease. Working with community members, we have identified alternative income generation activities, for instance fish farming.

In Rusinga Island, Lake Victoria, we are investigating the risk of malaria that is directly related to a variety of livelihoods, for instance fishing and small-scale farming. Our aim is to determine malaria prevalence among individuals associated with different activities out of these two categories, for instance fish traders, boat owners, fishing crew and subsistence farmers. We can already identify a higher risk of malaria among fishermen, because fishing activities take place outdoors at night, when transmitting mosquitoes mainly bite. In addition, most commonly used malaria vector control tools are designed to mitigate mosquito bites indoors.

We are also developing communication tools to share the knowledge that is generated from our studies with local communities and to develop an outcome mapping model to measure changes in behaviour among collaborating boundary partners, who include community based organisations, women's groups and the local public health office.

Q. **Please discuss the vision behind *icipe's* Solarmal project.**

A. Solarmal is a new innovative project, which is being implemented by *icipe* in collaboration with Wageningen University, The Netherlands, focusing on the use of solar power to develop environmentally friendly strategies for malaria eradication. The initiative builds on the gains made in Africa in recent years in reducing the malaria burden, which are largely attributed to insecticide-treated bednets, indoor residual spraying and the use of potent anti-malarial therapies.

The sustainability of these accomplishments is being undermined by increasing resistance by mosquitoes to insecticides, the changing feeding behaviour of the vectors and their growing ability to transmit malaria to people when they are outdoors.

Previous studies by *icipe* have shown that odour baits that attract as many malaria vectors as human beings do can be used to capture and kill mosquitoes without the use of insecticides. Our aim is to use insecticide-treated nets and case management, augmented with mass trapping of mosquito vectors to demonstrate proof-of-principle for the elimination of malaria in Rusinga Island.

We will provide 4000 households in Rusinga Island with solar panels to power traps that will catch malaria-transmitting mosquitoes before they gain access into houses. This strategy will reduce mosquitoes in the environment and limit their chances of biting people, therefore reducing malaria transmission. In addition, this approach will improve the quality of life by providing lighting and reducing the risk of contracting respiratory diseases associated with inhaling soot from kerosene lamps.

Q. How is *icipe* using its strength in chemical ecology in the fight against malaria?

A. We are using chemical ecology in the exploration of compounds and their blends to disrupt malaria transmission. Using semi-field experiments at the *icipe* Thomas Risley Odhiambo Campus, we are evaluating attractive odours that significantly affect mosquito behaviour to assess their competitiveness against human odours. We are then conducting field tests of the odour blends that show attractiveness or repellency to mosquitoes to assess their efficacy. So far, we have secured several blends of mosquito attractants, as well as further funding to study their potential towards developing odour-baited traps for mosquitoes.

Further, we are using chemical ecology to explore what we are referring to as the floral dimension of African malaria. These studies, which started in 2011, are based on previous exploratory research conducted by the Centre, which obtained extensive evidence that certain plants are part of the nutritional ecology of *Anopheles gambiae*. We are investigating four special features of the

Photo: *Vincent Nyasembe*

Malaria vector Anopheles gambiae *probing on host plant* Parthenium hysterophorus.

An Anopheles gambiae *mosquito. icipe and partners are conducting studies on the population biology and molecular genetics of these malaria-transmitting mosquitoes, integrating the reproduction, immunity and population biology of the vector.*


Photo: *Georg Georgen, IITA*

plant–mosquito relationship: host–plant attractants, host–plant learning, anti-*Plasmodium* secondary plant compounds, and the plants' role in promoting the behaviour of a jumping spider species, which is an *Anopheles*-specific predator.

So far, we have identified host plant attractants for the malaria vector from three plants and have developed a synthetic blend, which is currently undergoing field evaluation. We have also discovered candidate anti-*Plasmodium* compounds, and identified plant volatiles that attract the *Anopheles*-specific predator.

Q. How has *icipe* been involved in the global advances in genetic control of mosquitoes?

A. In the last five years, researchers based in institutions in the North have made significant progress in developing gene modifications of mosquitoes, which include the interference with the ability of the *Anopheles gambiae* and *Aedes aegypti* to transmit malaria, and dengue and yellow fever, respectively. Such gene modification could facilitate the implementation of control measures, for instance the sterile insect technique.

However, it has been difficult to translate these scientific achievements into mosquito control measures, mainly due to the fact that the European laboratories do not combine molecular biology and genetics expertise with mass rearing of mosquitoes, population genotyping, access to confined field facilities and detailed knowledge of population biology and regulatory approval procedures.

icipe aims to increase interactions and enhance capacity for the expansion of the understanding of mosquito biology and the translation of this knowledge into vector control measures.

The Centre is also conducting studies on the population biology and molecular genetics of *Anopheles gambiae* mosquitoes. With partners in West Africa, and Europe, we have, for the first time, integrated three crucial aspects of biology of *An. gambiae*, which are the reproduction, immunity and population biology of the vector. Currently, we are addressing the molecular bases of reproductive biology of the vector, and the ways in which it affects immunity to the transmission of *Plasmodium*.

Q. How is *icipe* contributing to the discovery, development and utilisation of biological insecticides for mosquitoes?

A. The increasing resistance to synthetic insecticide by mosquitoes means that novel, affordable and environmentally safe tools for the control of malaria are urgently needed. *icipe* is testing the use of entomopathogenic fungi (EPF), by developing formulations and delivery methods which are efficacious, long-lasting and capable of suppressing malaria transmission. In studies in western Kenya, we have observed that EPF is capable of infecting and killing adult malaria mosquitoes.

We have also started exploring the development of simple, affordable mosquito repellents based on African plants, with the aim of assisting communities to sustainably produce such products for personal use and for local and international markets.

So far, we have identified a number of plant-derived products that show high repellent activity against *Anopheles gambiae* and *Aedes aegypti* adult mosquitoes in laboratory tests. Two mosquito repellent product formulations have been developed, with activity comparable to diethyltoluamide, more commonly known as DEET, the most widely used commercial mosquito repellent ingredient.

Q. Has *icipe* expanded its IVM strategies beyond Kenya?

A. Utilising the principles that we have developed through our projects in Kenya, we have expanded our activities to Ethiopia, in the Tolay settlement scheme, an area that has a heavy malaria burden.

We are incorporating an IVM strategy into the overall development programme of the area, addressing interlinked issues of poverty, environmental degradation and crop pest damage, while strengthening institutional linkages with partnering organisations, community groups and other stakeholders.

Photo: *Melaku Girma*

icipe *is contributing to the discovery, development and utilisation of biological insecticides for mosquitoes. Here, Mr Kassahun Mammo, a member of the* icipe *staff in Ethiopia, and a mosquito scout from the Tolay settlement scheme, are pictured testing the efficacy of biopesticides developed by the Centre to control mosquitoes.*

icipe has expanded its malaria and mosquito IVM strategies to Ethiopia. Here, community members from the Tolay settlement scheme receive practical training from icipe researchers on how to sample mosquito larvae from breeding sites.

Photo: *Melaku Girma*

In close collaboration with the country's Ministry of Health, we are creating awareness and compiling data on malaria prevalence, training, distribution of bednets, etc. Our efforts also include mobilising community members towards the implementation of the IVM approaches. In the beginning, about 2000 households were participating in the activities. However, at the request of various stakeholders in Tolay, we have now scaled-up our activities.

So far, our efforts in Tolay have led to an increase in the distribution of bednets, as well as the destruction of most mosquito breeding sites, for instance through the draining of irrigation canals. We have also contributed to the replacement of DDT with deltamethrin and of temephos with *Bti*. By 2008, the prevalence rate of malaria had declined by 49% in adults and by 35% in children below five years of age.

In addition, we are promoting the use of plant-based biopesticides for control of disease vectors and crop pests, and income generation. Among the plants that we are investigating in Ethiopia are neem, vetiver grass, *Jatropha curcas* and cabbage tree (*Moringa stenopetala*), for larvicidal, insecticidal and repellent activity, identification of active and other constituents, evaluation of the safety of the constituents and standardisation. Two plants have already shown effectiveness in an inert base laboratory formulation, and we are now testing their efficacy against mosquitoes in semi-field and field tests. Efforts to establish a facility for production of biopesticides in Tolay are already in place.

Photo: *James Wauna*

RIFT VALLEY FEVER

Since 2008,* icipe *has been building capacity in emerging infectious diseases (EIDs) in eastern Africa, using Rift Valley fever as the initial model. Rosemary Sang, Baldwin Torto and Hippolyte Affognon discuss* icipe*'s three main projects on RVF, which include studies to enhance arbovirus surveillance, increase understanding of the ecosystem and sociological parameters, and develop practical early warning and response systems for the disease.

icipe started its research on RVF in 2008, with an ambitious project known as the Arbovirus Incidence and Diversity (AVID). Funded by Google.org, the philanthropic arm of Google, the three-year project brings together a consortium of experts from the health, veterinary, wildlife and vector-related sectors, to develop an integrated approach to arbovirus surveillance and research.

In the past four years, we have directed most of our efforts towards the setting up of operations in the field sites and have made progress in the procurement of facilities

Photo caption: *A herd of cattle resting in a homestead in northeastern Kenya. Severe outbreaks of RVF in the region have devastating impacts on people, animals and overall livelihoods.*

and supplies to collect, store and process samples of viruses. Through AVID, we have acquired diagnostic platforms that make it possible to conduct high throughput arbovirus detection screening and sequencing, which include a Genome Sequencer FLX system donated to *icipe* by Roche in 2010.

A significant accomplishment has been the construction of a GMP-compliant enhanced biosafety level 2 Emerging Infectious Diseases Laboratory at *icipe*. This facility is a great step towards enhancing the preparedness and response to EIDs in the region. It also puts *icipe* on the path towards becoming a centre of excellence in EID, joining the few existing laboratories on the continent to provide such a resource.

This infrastructure has enabled the AVID researchers to acquire a unique collection of bio-surveillance samples from a diversity of hosts, from which we have isolated and detected a number of viruses that we are currently characterising. We are continuing with the screening activities to detect arbovirus agents and determine their diversity.

In 2012, *icipe* began a second set of studies on RFV, this time geared towards enhancing the understanding of the ecosystem and sociological parameters that surround the disease. We initiated this research based on the observation that the spread, increasing scale and frequency of RVF epidemics seems to be connected to changes in the environment, climate variability and demographic pressure. However, a comprehensive understanding of the ecology of RVF is still lacking, which has made it difficult to explore the whole range of adaptation and mitigation strategies that could be applied to prevent epidemic outbreaks.

Our research is being conducted by a multidisciplinary team of virologists, ecologists, social anthropologists, epidemiologists and health geographers in a study area in northeastern Kenya. Our aim is to improve prevention and identify new options that can be used effectively by communities to control RVF and similar arboviruses.

We are using GPS collars to monitor five herds of cattle, bringing together close to five thousand animals, as they migrate from one area to another in search of pasture. We will also track one sedentary herd, to obtain comparative data.

We will obtain a baseline sample at the start of the project and once every quarter during dry and wet seasons from the cattle, to test for RVF antibodies in order to assess

Photo: *James Wauna*

A calf being fitted with a GPS collar. icipe *and partners are tracking over 5000 cattle using the technology as part of their strategy towards monitoring potential outbreaks of RVF in northeastern Kenya.*

A technician secures a light trap to a tree, to trap mosquitoes.

Photo: *James Wauna*

the seroprevalence dynamics of the virus. We will also obtain samples for the same purpose from people and mosquitoes.

We are also monitoring daily rainfall, temperature, relative humidity and the speed of wind, through our own recordings and from the national weather stations.

We are also investigating the social, cultural and economic perspectives of RVF in northeastern Kenya. Currently, data relating to the economic effects of RVF during and beyond the time of outbreak is inconclusive, as it is often collected in an *ad hoc* manner and is largely based on approximations. For instance, although it is generally assumed that pastoralists consider RVF to have a negative economic impact, there is no clear understanding on their perceptions about the disease, and how they affect their support for mitigation measures.

We will also provide empirical evidence on the impact of RVF on livestock sales by establishing the norms and the value associated to livestock in northeastern Kenya and explore the underpinning issues behind decisions on whether or not to sell cattle in the event of RVF outbreak.

There has been much emphasis on public education and campaigns for vaccination, ban of livestock trade and animal slaughter during RVF outbreaks. In our studies, we want to go further, towards understanding the extent to which these measures resonate with the social and economic circumstances of the pastoralists. Our aim is to understand how communities can be motivated to support these efforts, for their utmost benefit.

We also intend to map out the views of decision makers in the Ministry of Livestock Development, which is exclusively mandated to predict, control and treat RVF in Kenya, as a process towards creating the appropriate policy measures and programmes for mitigating the disease. The factors that we will assess include allocation of resources for RVF, for instance finances, the size and distribution of staff, tools and equipment, and frameworks for engaging communities. Our overall objective is to implement a multidisciplinary surveillance, research and response system to enhance the prediction and prevention of emerging infectious diseases.

Photo: *icipe*

David Tchouassi, a postgraduate scholar at icipe*, is pictured in a homestead in Naivasha division, one of the areas of Kenya that are prone to RVF outbreaks, in the course of the research that led to the development of a lure for improved trapping of mosquito vectors of RVF.*

icipe's third research focus is on developing early warning systems and appropriate response measures for RFV. Most of the strategies that are currently used to model the outbreaks of the disease are based on flood predictions and satellite-based information, using observations on amounts of rainfall, changes in temperature and signs of thriving vegetation. However, these strategies have not been entirely reliable. For instance, in 2006 alerts on an eminent outbreak of Rift Valley fever were only issued after the rainfall and flooding had already occurred.

Therefore, our model will be based on epidemiological and demographic data, as well as knowledge on environmental factors and ecology of the RVF virus. We intend to enhance understanding on pathogen, vector and host dynamics, and link this information to decision support tools to improve early warning and rapid response.

To develop tools for improved mosquito vector surveillance, we have identified semiochemicals mediating mosquito attraction to four hosts of the disease; sheep, goats, cows, donkeys and humans, and shown them to be similar. Through studies in the field, we have made a ground breaking demonstration that a lure developed from these chemicals can improve trap captures of mosquitoes by threefold. This trapping system is not only of scientific interest but could also serve for mosquito population monitoring by national programmes in RVF endemic areas during the inter-epidemic period.

Photo: *icipe*

TOWARDS A TSETSE AND TRYPANOSOMOSIS FREE CONTINENT

Rajinder Saini, Baldwyn Torto and Dan Masiga discuss* icipe*'s activities towards developing integrated and environmentally-friendly tsetse control and management strategies based on a sound understanding of the biology, behaviour and ecology of the flies.

Over the years, *icipe* has developed a variety of technologies to control tsetse flies. In our activities, we realised that pastoralist communities, for instance the Maasai of eastern Africa, require a mobile technology that can move along with them, in their search for pasture.

icipe's efforts to address the unique needs of the pastoralists led to the development of a tsetse repellent technology from synthetic sources, and from natural blends of

Photo caption: *Cattle protected by* icipe *repellent collars grazing freely in Shimba Hills, coastal Kenya.* icipe*'s goal is to help smallholder farmers across Africa reclaim 'green deserts', which are lying uninhabited due to tsetse menace.*

animals which are common in tsetse habitats, but which are not preferred hosts of the insects, for instance waterbuck. We also developed dispensers for the repellents, which, when worn around the neck of cattle, slowly dispense the chemicals in them, thereby protecting the animals from the flies.

During field trials, we noted that the tsetse repellent technology was also popular with sedentary livestock keepers, and therefore found it necessary to expand its dissemination to as many farmers as possible. In 2010, we obtained funding from the European Union (EU) to validate and disseminate the tsetse repellent technology through large-scale field trials. This support has enabled us to develop new dispensers, which are currently being tested in farmers' fields on the outskirts of the Shimba Hills Game Reserve along the Kenyan coast, involving over 300 livestock keepers and 1600 head of cattle.

Our trials indicate that despite their prototype nature, the tsetse repellent technology provides substantial protection to cattle, enabling farmers to graze their animals for longer periods, including in the early morning and evening hours when tsetse are most active, and near the park fence, where the density of the flies is highest. The cows are also more settled when grazing or ploughing while the disease incidence has gone down significantly.

As a result, farmers are now obtaining more income, since the healthier cows produce more milk, meat and traction power, and sell for significantly higher prices. The tsetse repellent technology has also contributed to environmental conservation, as the farmers use trypanocides less frequently and they no longer light fires to smoke away the flies. We believe that once fully optimised and commercialised, the tsetse repellent technology will significantly benefit a variety of smallholder farmers in Africa.

In 2007, we started studies to explore the use of entomopathogenic fungi (EPF) to control tsetse flies. Because this pathogen infects target organisms through the cuticle, it has been possible to develop a device that can deliver and auto-disseminate inoculum among tsetse in the field. However, the use of EPF will only be successful if there is effective horizontal transmission of the inoculum between insects. Although horizontal transmission of EPF in tsetse flies has been conducted in the laboratory,

Photo: *Georg Georgen, IITA*

Glossina fuscipes fuscipes *(pictured), which is a riverine species of tsetse, is one of the major vectors of human sleeping sickness, and is responsible for epidemics of the disease in Angola, DR Congo, South Sudan and Uganda.*

icipe *has discovered that odours from monitor lizards, such as the one pictured here, mediate attraction of one of the key vectors of the disease. This knowledge will contribute towards developing attractant odour baits and repellents for this tsetse species.*

Photo: *Santiago Escobar*

so far it has not been possible in the field. Our studies therefore investigated the transfer of inoculum between infected and uninfected flies under cage conditions. Since auto-dissemination is achieved mainly through mating, we also investigated the mating behaviour of fungus-infected flies and the possibility of using sterile males to disseminate spores of EPF. Through this research, we have demonstrated horizontal transfer of fungal conidia between flies and established that the infection does not affect the mating behaviour of tsetse.

icipe has also been investigating the feeding patterns of tsetse flies, to identify the bloodmeal sources that the insects are attracted to as well as the animals that they tend to avoid. This study has contributed to the development of a dichotomous key for identifying the sources of tsetse fly bloodmeals, which we have applied on tsetse fly species from Kenya, Uganda and Tanzania. Our studies have led to requests for collaboration with the National Livestock Resources Research Institute (NaLIRRI) in Uganda, and Tsetse and Trypanosomiasis Research Institute (TTRI), Tanzania.

Further, we are conducting studies on vector competence, to investigate whether local populations of trypanosomes and tsetse are co-adapted to each other. Previous studies have shown that populations of tsetse are strongly differentiated genetically. In particular, there is considerable variation in *Trypanosoma congolense*, for instance in regard to the ability of the species to undergo genetic recombination. Therefore, understanding the existence and extent of co-adaptation is a critical aspect in the design of tsetse control strategies.

We are conducting field studies in two ecosystems: in Nguruman in southwestern Kenya, a dry savanna region and in Shimba Hills National Park in coastal Kenya, which is a humid dense forest. Our study is focusing on *T. congolense*, a trypanosome in which no laboratory demonstration of mating has been conducted, limiting the investigation to key phenotypes such as drug resistance and virulence. We have isolated trypanosomes from both sites, in preparation for the genotyping activity. We have also developed a genotyping protocol which provides a platform for understanding the genetics of tsetse flies and trypanosomes.

In partnership with three UK-based institutions: The University of Liverpool, Natural Resources Institute and Rothamsted Research, we are developing attractant odour baits and repellents for tsetse fly species that are vectors of HAT. We have discovered that odours from monitor lizards mediate attraction of one of the key vectors of the disease, *Glossina fuscipes fuscipes*.

Further studies led to the identification and screening of a number of host-derived candidate chemicals, either alone or in a blend. However, these assays gave mixed results suggesting the involvement of missing essential components in the blend to improve trapping of the vector. Although we did not come up with an effective odour bait, we were able to develop a low cost effective vector trapping system based on visual cues, which has been successfully evaluated in a tsetse endemic area in western Kenya, showing in controlling HAT in other parts of Africa.

BETTER YIELDS

FOR CEREALS AND HORTICULTURAL CROPS

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

In addition, there is an urgent need to increase the yields of vegetables, fruits, legumes and nuts in SSA, to improve the nutrition, household incomes and national economies. Yet, the production of these crops is constrained by insect pests, which reduce yield and cause rejection of produce from Africa by export markets.

This chapter focuses on *icipe*'s efforts towards improving cereal production in Africa, through three programmes: the push–pull technology, joint research with the Institut de recherche pour le développement (IRD) on insect pests and studies on postharvest losses. It also discusses the Centre's activities to develop integrated pest management (IPM) strategies for pests that constrain the production of horticultural products.

Photo: *icipe*

ADVANCING PUSH–PULL

Zeyaur Khan discusses* icipe*'s activities in the past five years towards advancing the Centre's phenomenally successful push–pull technology, which addresses most of the key constraints faced by smallholder cereal farmers in Africa.

The push–pull technology, which was developed in the past 20 years by *icipe* and partners from Kenya and the United Kingdom, involves intercropping cereals with a repellent plant, such as desmodium, and planting an attractive trap plant like Napier grass as a border crop around this intercrop. Stemborers are repelled or deterred away from the target food crop (push) while, at the same time, they are attracted to the trap crop (pull), leaving the food crop protected. In addition, desmodium stimulates the germination of seeds of the parasitic weed striga and inhibits their growth after germination.

Initial field trials in Kenya and Uganda showed that push–pull also has additional significant benefits for dairy farming, since desmodium and Napier grass are both high

Photo caption: *Ms Rachel Agola, a push–pull farmer from western Kenya who was awarded the One World Award for 2010, is pictured in her thriving farm. She was among the first farmers to adopt the technology.*

quality animal fodder plants. Furthermore, since both plants are perennial, push–pull conserves the soil's moisture and improves its health.

Between 2007 and 2012, we continued to build on push–pull's immense opportunities, while addressing some of the challenges towards its advancement. To make push–pull accessible to more small-scale farmers across East Africa, amidst significantly constrained national extension systems, we re-assessed our information and knowledge dissemination strategies and collaborated with several partners, in particular the Swiss-based Biovision Foundation, to test a variety of pathways such as the use of the mass media, information bulletins, video and computer communication tools, field days, farmer teachers and farmer field schools.

As a result, we increased the ability of smallholder farmers to learn, adopt and communicate ideas on push–pull. We also raised the awareness of key stakeholders such as farmers' organisations, extension services, non-governmental organisations (NGOs) and research institutions, on the potential of the technology in increasing cereal production. Our efforts also enhanced linkages between them, leading to the refining and more intense efforts to deploy push–pull, as well as the lobbying for policies to improve the food security of smallholder farmers.

To strengthen the ability of women farmers to utilise push–pull, we conducted studies to understand the processes and the socio-economic factors that affect their ability to adopt technologies. As a result, we developed cost-effective dissemination channels that now enable them to use push–pull, regardless of the size of their farms. Moreover, some of the women farmers involved in the project have integrated other initiatives, for instance organic farming, into their agricultural systems.

To resolve the issue of low availability of desmodium seed, a major constraint for farmers implementing the push–pull technology for the first time, we partnered with a private seed company to commercialise production and developed structures for community-based seed production as well as vegetative propagation techniques. The seed and plants are now more readily available in East Africa than before.

In addition, we conducted laboratory studies to determine the possibility of introducing the genes of the striga growth inhibitor, known as isochaftoside, which is found solely in *Desmodium* spp., through breeding into food legumes such as cowpea. Our studies

Photo: *icipe*

Aside from addressing the constraints of cereal production, push–pull offers immense opportunities to farmers, for instance the keeping of dairy goats, such as the ones pictured here feeding on Napier grass.

An icipe *technician explains the push–pull technology to farmers during a field day. The Centre organises such sessions to increase the ability of farmers to learn, adopt and communicate ideas on the technology.*

Photo: *icipe*

provided new insights into the interactions that take place below the ground between striga and desmodium, leading to methods for large-scale screening of the metabolome of food legumes.

In the past five years, we have formed strategic partnerships with like-minded organisations towards improving cereal production and overall livelihoods of small-scale farmers in Africa. One such partnership is with the Gatsby Charitable Foundation through its Kilimo Trust East Africa. Together, we conducted on-farm trials of push–pull involving more than 7000 farmers in 20 districts in Kenya and Uganda, which confirmed the effectiveness of the technology in controlling stemborers and striga, and the impact of push–pull on the food security and income of smallholder farmers.

Through further support from these partners we intensified our activities in western Kenya, eastern Uganda and northern Tanzania. To optimise the establishment of desmodium in these regions, we identified drought-resistant lines, which are now available to farmers. Moreover, we expanded our focus to include upland rice and developed push–pull intercrops for its cultivation. Finally, we determined the effectiveness of cotton in striga control and its potential utility in push–pull, while identifying its major pests in the region.

As part of this initiative, the Swiss Intercooperation conducted a participatory impact assessment study and published a report which broadly confirmed that the push–pull technology is widely accepted and adopted by smallholder farmers in East Africa because it addresses their major production constraints.

icipe also partnered with the International Institute of Tropical Agriculture (IITA), as part of a Bill and Melinda Gates Foundation (BMGF) funded project, aimed towards sustainable striga control in Africa. The project partners established demonstration and training sites for striga control technologies in Nigeria and Kenya to create awareness of the range of control options, including push–pull, imazapyr resistant (IR) maize, legume rotation and groundnut intercropping.

icipe's specific role is to promote push–pull for striga control in both countries. We are deploying new tools and methodologies towards a better understanding and more effective control of striga. Further activities include the introduction of community-based desmodium seed production systems and an assessment of drought-tolerant desmodium species in different agroecologies of the two countries.

The collaboration between *icipe* and IITA has catalysed linkages between farmers' groups and the private sector, for instance by encouraging seed companies and agro-dealers to take advantage of the business opportunities within push–pull, such as the production of desmodium seeds. The involvement of the private sector has contributed towards the improvement of market value chains. Moreover, the partnership created a model for scaling out push–pull to other regions with similar ecologies in SSA, and a foundation for national programmes to identify, develop and implement strategies for striga management.

Due to climate change, some cereal-growing regions of Africa might become increasingly dry and hot in future. Therefore, in 2011, with support of the European Union (EU), we launched a new project known as Adaptation and Dissemination of the Push–Pull Technology to Climate Change (ADOPT), to ensure the sustainability of push–pull in the context of changing agroecologies. We are utilising a conservation agriculture approach to identify crops that are grown in dry areas, mainly sorghum and millet, and the companion crops that can be integrated into a more drought resilient push–pull. The companion crops will be selected on the basis of suitable chemistry in terms of stemborer attractancy and repellency, and striga suppression in addition to their ability to improve soil fertility, moisture retention and organic matter.

So far, ADOPT has contributed to strengthening the research linkages that already existed between *icipe* and key partners. We estimate that by the end of the ADOPT project in 2014, over 50,000 additional households will be utilising this adapted push–pull technology. We believe that the project will also strengthen the capacity of local, national and regional stakeholders to establish forums where they can utilise the research results.

In the past five years, *icipe* has enhanced the application of push–pull, leading to improved cereal productivity, dairy farming and overall livelihoods of farmers in Africa. By 2012, almost 60,000 smallholder farmers in East Africa had adopted the technology, increasing their cereal yields on average more than threefold. Farmers involved in push–pull have also reported increased household nutrition and income through additional dairy farming. In western Kenya alone, our aim is to reach 1 million small-scale farmers by 2020.

Photo: *icipe*

An ADOPT pilot site at the icipe TRO Campus, Mbita, dedicated to testing more drought resilient push–pull companion crops, to ensure the sustainability of the technology in the context of climate change.

Photo: *Paul-Andre Calatayud*

UNDERSTANDING STEMBORERS AND OTHER INSECTS

icipe *and the Institut de Recherche pour le Développement (IRD) have conducted extensive collaborative research on stemborers and their natural enemies, as a key component towards addressing the constraints of cereal production in Africa. Bruno Le Ru and Paul-André Calatayud discuss the progress made by the two organisations in the past five years in these studies.*

Despite their economic importance, little information is available on the diversity of stemborers and their parasitoids in their natural habitats in sub-Saharan Africa (SSA). Where available, the knowledge appears fragmented and it mainly focuses on East Africa. For instance, only two studies have been conducted on host plants of stemborers in southern Africa, yet the region is probably the centre of origin of many different stemborer species, as it is one of the zones with the highest diversity of noctuid borers in Africa.

Photo caption: *In many African homes, such as the one in this photo, maize farming is one of the most important activities. Studies by* icipe *and IRD will generate key information, which will benefit numerous households across Africa.*

In 2003, *icipe* and IRD started to evaluate the diversity, abundance and distribution of stemborers and their natural enemies in wild habitats around cultivated grasses. The studies were conducted in different agroecological zones in SSA, leading to the discovery of a huge number of previously unreported species of stemborers. Significantly our studies extended beyond the traditional focus on economically important stemborer species like *Busseola fusca*, *Chilo partellus* and *Eldana saccharina*, mainly on cultivated crops.

Previous studies have indicated that stemborers and their associated parasitoids find refuge in wild hosts bordering cultivated crops. However, our research showed that compared to non-pest species, economically important borers are less abundant on wild host plants. Moreover, until recently, it was assumed that parasitoids of stemborers can survive, and indeed thrive, off-season, i.e. when no cultivated cereal crops are in the fields, by taking refuge in natural habitats. Our findings highlight the importance of natural habitats as refugia for sustaining parasitoid diversity, which in turn can affect stemborer parasitism in the cereal cropping system.

Therefore, we predict that due to the destruction and fragmentation of wild habitats as a result of increasing demands for more agricultural land, some current and future stemborer pests of grasses will, and indeed are already originating from wild host plants. These findings have implications for the development of IPM strategies, such as push–pull and cultivation of *Bt* maize.

icipe and IRD have also investigated the likely impact of climate change on agricultural production, and in general, on the livelihoods of farmers in Africa, especially in regard to changes in the abundance of insect pests and their existing and potential natural enemies.

In collaboration with IITA, the International Potato Center (CIP), the University of Hohenheim in Germany and NARES partners in Africa, we are utilising innovative phenology modelling and risk mapping techniques, to understand and predict the effect that rising air temperatures caused by climate change will possibly have on the future distribution and severity of major insect pests on important food crops in Africa.

Photo: *George Ong'amo*

icipe-*IRD studies have found that sheds such as the one shown here, which are used to store cereal crop residues provide refuge to stemborers between seasons.*

A farmer ploughing his field in readiness for maize planting. Controlling stemborers and other insects that constrain cereal yield is critical for many smallholder farmers.

Photo: *Paul-Andre Calatayud*

The project builds on CIP's experience on insect simulation modelling and risk mapping, utilising the Insect Life Cycle Modelling (ILCYM) software, which will be further improved and adapted to cover a wide range of insect pests and the needs of the different stakeholders.

The activities will also include training scientists from African NARES in applying simulation methodologies to assess the climate change induced vulnerability of agricultural systems to major pests, and to identify adaptation strategies to cope with future pest problems.

Further, *icipe* and IRD are undertaking studies as part of the CHIESA project on ecosystem services and food security in eastern Africa, which focuses on the Eastern Afromontane biodiversity hotspots. Due to climate and land use changes, exacerbated through high population increase, the goods and services provided by the ecosystems in the region are under significant threat.

Through a project known as ABC-PaPoGen, we are investigating the inter-relation between climate change and wild habitats and the adaptation ability of natural enemies in new environments. Our activities include conducting laboratory and field studies on the mechanisms of adaptation of biological control agents against agricultural pests, for behavioural and physiological traits of adaptation to host and habitat.

The studies will consider adaptations at two time scales: in the long term between locally adapted host populations and in the short term against new hosts or new environment in experimental selection or in operations of biological control by acclimatisation.

The samples, characterised for fitness traits on the host, will be genotyped through high throughput sequencing methods. The adaptation genes and adaptation statistics will be identified using existing and newly developed bioinformatics tools.

Photo: *Joseph Manono*

MITIGATING POSTHARVEST LOSSES OF CEREALS

Baldwyn Torto and Hippolyte Affognon outline* icipe*'s initiatives towards improving postharvest storage of cereals and other crops in Africa.

icipe, in partnership with Purdue University in the US and NARES partners in Kenya, Uganda, Malawi and Mozambique, is investigating the possibility of using the triple-bagging technology known as PICS (Purdue Improved Cowpea Storage), for alternative uses.

The technology, which is simple, low-cost, practical and effective, was developed to enable low-resource farmers in West and Central Africa to preserve cowpea after harvest, by providing security against storage pests. We are investigating the possibility of using PICS bags on more crops, including maize and other cereals, in eastern and southern Africa for expanding their impact and benefits.

Photo caption: *A PICS bag containing grain, awaiting sealing for storage.* icipe *and partners are investigating the possibility of using the bag on more crops, including maize and other cereals, as a way of mitigating postharvest losses in Africa.*

Photo: *Duncan Mbuge*

icipe *is designing improved structures for storing and drying maize. Here, super absorbent polymers (i.e. the powder at the bottom of the bottles) are being tested for their potential in drying maize in an enclosed environment with temperature control in an oven.*

Specifically, we are evaluating the performance, costs and benefits of PICS bags and raising awareness on their use. We have already initiated experiments in Kenya, Uganda, Mozambique and Malawi to collect the relevant data. In addition, we have trained close to 30 NARES scientists and several collaborators from the private sector in the four countries on how to evaluate PICS bags.

Poor postharvest storage is also implicated in aflatoxin contaminations, arising from high temperatures, humidity of the surrounding air and the moisture content of the grain. In Africa, these conditions are particularly intensified by increasingly unpredictable weather, where the rainy seasons often start when the maize is ready for harvest but not adequately dry for storage.

icipe, in partnership with the University of Nairobi and the Swiss Federal Institute of Technology, is also designing improved structures for storing and drying maize, for small-scale farmers in SSA, by determining the effectiveness and utilisation of super absorbent polymers (SAPs). Our aim is to identify and select three suitable SAPs for drying maize on the basis of mechanical and drying properties. We also plan to determine the efficiency of the selected SAPs in controlling aflatoxin contaminations. So far, we have identified and are currently optimising three SAPs candidates and have developed analytical methods for quantifying aflatoxin contamination.

icipe is also addressing the lack of systematic evidence on postharvest losses of several commodities in SSA, among them maize, to assist decision-makers to optimise post-production policies and strategies along the different parts of the supply chain.

Globally, the estimates regarding the proportion of food that is lost due to poor post storage and waste vary widely. *icipe* and partners are conducting analytical reviews and will produce guidelines for rigorous and systematic assessment of postharvest losses along the different value chains, with an aim of generating action plans for research and interventions.

Photo: *icipe*

SAVING THE ELEPHANT GRASS

Zeyaur Khan and Dan Masiga discuss* icipe*'s efforts towards developing an IPM for the stunt disease which is threatening Napier grass, one of the key resources for smallholder farmers in East Africa.

Napier, also known as elephant grass, is a tall fast-growing indigenous plant, which is an important crop in eastern Africa, with over 80% of smallholder dairy producers in the region relying on it as a source of cattle fodder. The grass is also a key crop in *icipe*'s push–pull strategy.

Unfortunately, Napier is currently threatened by a stunt disease, which, as the name suggests, inhibits the growth of the grass. Once infected by the disease, shoots of Napier turn a pale yellow–green colour and become completely dwarfed. In some cases the grass dies altogether, and many smallholder farmers have lost their entire Napier crop to the stunt disease. Most varieties of Napier grown in the region appear to be susceptible to the disease. There is also a potential risk that the disease might spread

Photo caption: *Zeyaur Khan, leader of* icipe*'s push–pull programme and Mr Remjus Asewe Bwana, a push–pull farmer in Kisumu, Kenya observing stemborers trapped in a Napier grass border crop. Due to the importance of the crop, the Napier stunt disease poses a huge threat to many smallholder farmers in East Africa.*

to Gramineae food crops, for instance sugarcane, rice, millet and sorghum. As such, the Napier stunt disease is becoming a major threat to the smallholder farmer dairy industry in East Africa, and to the adoption and expansion of push–pull.

In the past five years, *icipe,* in cooperation with the Eastern Africa Agricultural Productivity Project (EAAPP), has been developing an IPM strategy for the Napier stunt disease in East Africa. We have identified the cause of the disease, which had remained elusive for a long time, to be a phytoplasma and discovered a leafhopper known as *Recilia banda* Kramer to be one of its vectors in Kenya. Currently, we are evaluating 11 species of leaf and planthoppers associated with Napier grass for their possible role as vectors of the phytoplasma of the stunt disease.

We have also developed a molecular based diagnostic tool for screening Napier grass for the phytoplasma. The assay, which is known as the loop-mediated isothermal amplification (LAMP) of DNA, replaces the nested polymerase chain reaction (nPCR) which is laborious, costly and technically demanding. LAMP has also proved to be 20-fold more sensitive than the nPCR, and allows the detection of phytoplasma in settings with limited infrastructure.

Utilising this protocol, we have identified the phytoplasama in plants several months before the appearance of any symptoms of the Napier stunt disease. The tool has also facilitated the discovery of genotypes of Napier grass that are resistant to the phytoplasma of the stunt disease, which we will recommend to farmers. This knowledge will also be useful in future breeding strategies of Napier grass.

At present, we are identifying suitable management strategies to stop further spread of the Napier stunt disease in East Africa. We hope to put in place an approach that effectively controls the stunt disease, enabling the continued use of Napier as fodder in East Africa. These measures will also help to curb the current losses being incurred by farmers, which include additional labour and expenses incurred dealing with the disease, and in seeking alternative fodder for their cattle. We also hope to remove the over-reliance on Napier, by assisting farmers to use other high yielding and climatically adapted fodder plants.

Photo: *icipe*

icipe *has identified the long-elusive cause of the Napier stunt disease to be a phytoplasma and discovered a leafhopper known as* Recilia banda, *pictured here, to be one of its vectors in Kenya.*

Once infected by the Napier stunt disease, the grass turns a pale yellow–green colour and becomes completely dwarfed. In this picture, the infected shoot contrasts sharply with the healthier stand in the back. icipe *has developed a LAMP protocol that makes it possible to identify the phytoplasma of the disease several months before the appearance of any symptoms.*

Photo: *icipe*

Our studies on the Napier stunt disease have led to a range of strategic collaborations with local and regional stakeholders in Kenya, Uganda and Tanzania, leading to a network of institutions conducting research on the Napier stunt disease in the region. As a result, we have trained staff from universities and research institutions in the three countries on the use of the LAMP protocol and application of integrated management strategies of the stunt disease.

icipe has also contributed towards strengthening the organisational, management and communication skills of smallholder farmers, therefore improving their capacity for technology uptake and integration within their other livelihood strategies. Moreover, the Centre's expertise on the phytoplasma of the Napier stunt disease has become globally renowned leading, for instance, to funding from BMZ, Germany for further studies on the phytoplasma of the Napier stunt disease.

Overall, our studies on the Napier stunt disease will help stabilise and increase dairy and cereal production, resulting in improved incomes, nutrition and livelihoods.

Photo: *Santiago Escobar*

SECURING A FRUITFULL FUTURE FOR AFRICA

Sunday Ekesi describes how* icipe *is contributing towards a more sustainable fruit production, through its integrated pest management (IPM) package.

Q. What has been *icipe's* strategy in addressing the pest constraints of fruit production, in the past five years?

A. *icipe's* activities have revolved around two goals: the development and implementation of an IPM strategy that minimises the use of insecticides and their residues, and the exploration of opportunities to improve the marketing of fruits from sub Saharan Africa (SSA).

In collaboration with partners from Africa, Asia, Europe and USA, we developed an IPM package for exotic and native fruit flies in Kenya, Tanzania, Cameroon, Benin and Mozambique, which would facilitate compliance to the standards set

Photo caption: *Fruits ready for sale in a market in Kenya. The cultivation of such produce provides income, employment and nutritional security to many people in Africa.* icipe *has developed an IPM package for the effective management of fruit flies.*

by export markets. The package includes tools based on locally available protein bait, soft pesticide and fungal-based biopesticides, male annihilation techniques and the use of augmentorium for orchard sanitation and conservation of natural enemies. This package was initially tested in pilot sites in the three countries and personnel from national agricultural research organisations (NARES), and over 9000 mango growers were trained on how to apply it.

We also conducted extensive studies on the biology and ecology of *Ceratitis* fruit flies, which are native to SSA, and *Bactrocera invadens*, *Sternochetus mangiferae* and *Rastrococcus iceryoides,* which are exotic pests from Asia. Our studies showed, for the first time, the abundance, distribution, pest status, seasonal occurrence and host plants of these pests and also determined the level of parasitism of the pests by indigenous natural enemies.

We also conducted explorations in the aboriginal home of two invasive pests, *B. invadens* and *R. iceryoides,* in Sri Lanka and India respectively, and found a great diversity of natural enemies of these pests. However, due to regulations related to the Convention on Biological Diversity (CBD), we were not able to import any of the natural enemies. Instead, we imported two natural enemies, *Fopius arisanus* and *Diachasmimorpha longicaudata* from Hawaii for biological control of *B. invadens*.

Q. How have you advanced the application of the IPM package?

A. In 2011, we started implementing and validating the IPM package with partners in different agroecologies in Kenya, Tanzania, Benin, Cameroon and Mozambique. This process also included open field releases of the two imported parasitoids, *F. arisanus* and *D. longicaudata,* in the five countries, with an encouraging establishment rate.

In collaboration with the Swiss-based Biovision Foundation, we implemented further dissemination of the IPM package to smallholder farmers in eastern and coastal Kenya. In partnership with farmers and NARES, we have established learning sites, through which we distributed IPM starter packs consisting of traps and baits and provided hands-on training to 1500 mango farmers. Our activities

Photo: *AFFP Team*

A farmer inspects an icipe fruit fly trap in his mango orchard, which is part of the IPM package developed by the Centre to assist farmers obtain maximum yields from the cultivation of fruits.

icipe scientists, Samira Mohamed (second right) and Sunday Ekesi (right) presenting fruit fly IPM starter packs to farmers in coastal Kenya. Over 1500 farmers in Kenya, Uganda, Tanzania and Benin have received the packs, which consist of traps and baits.

Photo: *AFFP Team*

also included the installation of 100 augmentoria for orchard sanitation and parasitoid conservation and large-scale releases of *F. arisanus*, and extensively monitored the establishment of the parasitoid.

In 2009, the government of Mozambique invited *icipe* to provide technical oversight within the country's efforts to manage and mitigate the impact of *B. invadens*. The horticultural sector in Mozambique could generate revenues of more than $ 20.75 million per year through commercial and smallholder production in just two provinces, Maputo and Manica. However, the possibility of fully exploiting the potential of horticultural farming in the country is significantly constrained by *B. invadens* infestation, which causes loss in yield as well as loss of market, due to strict restrictions by major trading partners such as South Africa.

*icipe'*s role was to provide surveillance and appropriate IPM measures in areas where the pest has fully established. We conducted surveys, to determine the distribution of the pest and its prevalence on economically important fruits. These studies established the pest status of *B. invadens* and delimited the infested and non-infested areas, providing the country's decision makers with a basis for negotiations with trading partners. As a result, some export markets removed the restrictions on fruit and vegetables from pest-free areas in Mozambique. Efforts are also being made to maintain the regions that are free of pests as such. We also assisted in the implementation of IPM and domestic quarantine measures in parts of the country. Our activities included training NARES and quarantine personnel and raising public awareness on the management of fruit flies. Overall, we contributed towards a stronger horticultural export system in Mozambique and improved the income and nutrition of smallholder farmers.

Q. What other strategies has *icipe* initiated in managing pests of fruit?

A. The IPM package developed by *icipe* can effectively suppress fruit flies by 80–90%, and mango seed weevil by 92–100% in the field. It has increased mango yields by 30% in the project benchmark sites, with significant spin-off in other areas. The mango yield increment amounts to US$1000 to 1440 per hectare, representing an additional income of US$400 to US$640 per hectare. About 9000 farmers, majority of them low income families and women, are currently benefitting from the IPM package, resulting in improved household income, nutritional and environment health.

However, to completely eradicate fruit flies and provide the quarantine security required for fruits and vegetables before export, additional regulatory measures, such as postharvest treatments, are necessary. Since no postharvest treatment facilities are available in SSA, *icipe* conducted studies to develop appropriate protocols.

We started with studies on citrus, due to its importance as an export fruit in many African countries and its significant susceptibility to *B. invadens*. Our objective was to determine whether the postharvest fruit disinfestation cold treatment protocol T107-a, established by the United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS), would be adequate for *B. invadens* on Valencia orange. Our studies showed that the parameters of the protocol, which stipulates that fruits should be treated at a temperature of 1.1 degrees centigrade for 14 days, are ineffective for the third instar of the larvae of *B. invadens*, the most cold tolerant stage of the pest. We found that to achieve quarantine security level for *B. invadens* larvae in citrus fruits, a phytosanitary treatment protocol of 0.9°C or lower should be applied to the fruit pulp for 16 consecutive days.

We also conducted studies to establish a treatment protocol on avocado. We recommend that the fruit should be placed under a cold treatment of 20°C over a period of 18 days to disinfest it of *B. invadens*.

Photo: *Robert Copeland*

icipe has recently initiated studies on Bactrocera cucurbitae, *pictured here, based on its significance to fruit and vegetable production in Africa.*

The use of icipe IPM packages, for instance this fruit fly trap secured in a farmer's avocado orchard in Kenya, will contribute to the ability of smallholder farmers to cope with the impacts of climate change.

Photo: *Kelah Kathure*

Q. How has *icipe* addressed the potential impact of climate change on fruit production?

A. Our main activity on the interlinkage between fruit production and climate change is through work package five (WP5) of the CHIESA project, which focuses on ecosystem pest management and pollination. Using avocado as a case study, we are devising measures that will assist farmers in East Africa to adequately prepare for any climate change-induced alterations, for instance in composition and abundance of pests, their natural enemies and other organisms that contribute to ecosystem services.

We are also investigating the contribution of avocado plantations to carbon sequestration, to assist policy makers in East Africa to encourage cultivation of the crop as a component of climate change mitigation.

Q. What other fruit fly pests has *icipe* focused on aside from *Bactrocera invadens*?

A. Aside from *B. invadens,* the other most prevalent and destructive *Bactrocera* species is *B. cucurbitae*. In 2010, we started studies on *B. cucurbitae* to comprehensively document its host plants, as a guide towards its management. Although the host range of *B. cucurbitae* is primarily cucurbits, which include cucumbers, pumpkins, luffas and watermelons, the pest has also been recorded on several non-cucurbit hosts such as tomato. Despite the economic importance of *B. cucurbitae*, there has been no comprehensive study on its host range in Kenya.

We are also investigating the latest invasion of the *Bactrocera* genus into Africa, *B. latifrons*, which was detected for the first time in 2006 in Tanzania. Based on the frequent movement, as well as the cultivation of vegetables across the Kenyan–Tanzanian border, there is a high risk that the pest could also invade Kenya. Therefore, our aim is to establish the pest status in Kenya and advice the quarantine authorities accordingly so that they can develop a strategy for its management. So far, we have established the geographical distributional range of *B. latifrons* and characterised its host–plant relationships. We have also tested the food baits and native parasitoids against it. Kenya's quarantine officials have enforced restrictions on movement and planting of the main host plant of *B. latifrons*, *Solanum aethiopicum*. As a result, the number of incursions of this fruit fly species from Tanzania into Kenya has been minimal.

Further studies have included efforts to unravel the identity of the two populations of *Ceratitis rosa*, which belong to what is known as the FAR complex, whose members are morphologically very similar and belong to the same subgenus, *Pterandrus*. Recent genetic analysis has shown that the FAR complex is probably five entities. *Ceratitis rosa* has been observed to split up into two different groups – the lowland and highland populations – which can be differentiated genetically as well as morphologically, at least in the males, probably that they might also both have different physiological patterns with one entity being more cold tolerant than the other and with the potential for varying invasive powers. Our aim is to establish colonies of the two populations of *C. rosa* in Kenya and study their mating compatibility and establishing their thermo-tolerance.

Photo: *Subramanian Sevgan*

CONTROLLING THRIPS AND TOSPOVIRUSES

In Africa, thrips – tiny, slender insects which get their name from their fringed wings – cause extensive damage to a wide array of crops either directly by feeding on them, or indirectly by transmitting tospoviruses. As Subramanian Sevgan observes below, icipe has made great progress towards controlling the dual threats of thrips and tospoviruses.

In eastern Africa, thrips and tospoviruses transmitted by them cause between 20–80% losses in key high value crops such as onion, tomato and French bean, and in grain legumes such as bean, cowpea, dolichos, etc.

The management of thrips and tospoviruses is constrained by various factors for instance, the ability of most thrips species to resist synthetic insecticides, the invasive nature of some thrips, difficulties in targeting thrips that attack crops from cryptic locations and

Photo caption: *In many African countries, the cultivation of vegetables provides nutritional security, as well as employment and income for a range of people along the value chain, such as these women trading tomatoes in a market in Uganda.*

the lack of capacity to identify and effectively monitor thrips. As such, there is an urgent need to develop environmentally-friendly integrated pest management (IPM) strategies for thrips that are less reliant on externalities like synthetic insecticides.

In 2008, *icipe* started studies towards the development of integrated pest management (IPM) strategies for thrips in eastern Africa, with financial support from the Federal Ministry for Economic Cooperation and Development (BMZ) of Germany. Our initial activities focused on enhancing the understanding of the diversity and ecology of thrips and tospoviruses, as well as building capacity for effective, accurate and timely diagnosis of thrips and thrips-transmitted tospoviruses.

Towards this end, we conducted extensive surveys in over 250 locations in Kenya and Uganda. As a result, we have produced and made available occurrence maps of over 60 species of thrips and some of their natural enemies. Significantly, we reported the presence of several species of thrips for the first time in East Africa, namely *Frankliniella williamsi*, *F. borinquen*, *Ceratothripoides claratris*, *Gynaikothrips uzeli* and tospoviruses namely the *Iris yellow spot virus* infecting onions and *Tomato yellow ring virus* infecting tomatoes in the region. Further, in partnership with Prof. Gerald Moritz of Martin Luther University in Germany, we have developed a user-friendly software, which will greatly enhance the capacity of quarantine agencies, agricultural extension officers and research organisations to identify and monitor thrips and their natural enemies in the region.

A key element of our new IPM package for thrips and tospoviruses is the use of need-based applications of entomopathogenic fungi (EPF). *icipe* reached an agreement with Real IPM Ltd., a commercial biopesticide producer, for the commercialisation of *Metarhizium anisopliae* ICIPE 69 under the brand name of Campaign®. The biopesticide is currently registered in five countries in Africa. Further, our studies showed that LUREM-TR, a thrips attractant developed by our collaborators at the Plant Research International, Netherlands, and Plant and Food Research, New Zealand, can enhance thrips attraction by two- to sixfold in French beans. We also completed a proof-of-concept for the development of a 'lure-and-kill' strategy combining Campaign® with LUREM-TR.

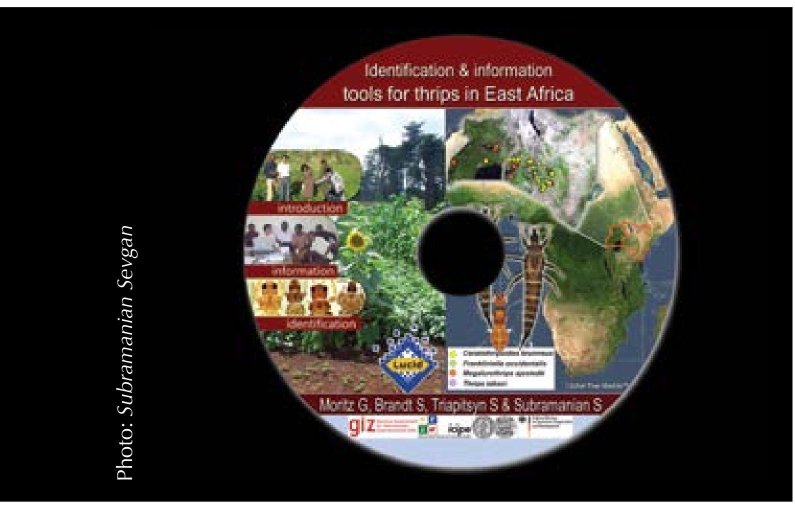

Photo: *Subramanian Sevgan*

An image of the user-friendly software developed by icipe and partners for enhancing the knowledge and capacity of quarantine officers and agricultural extension officers in East Africa on thrips monitoring and management.

Campaign®, an entomopathogenic fungi based biopesticide developed by icipe has been shown to be effective in the management of several crop pests, including thrips.

Photo: *Courtesy Real IPM*

The IPM package also consists of intercropping, use of host plant resistance and conservation biological control approaches. For instance, we have observed that intercropping of French beans with baby corn or sunflower significantly reduces thrips infestations, increasing the marketable yield by over 50%. We also found that Bombay Red and Texas Grano onion cultivars are moderately resistant to thrips and IYSV infestation.

Through a series of Training of Trainers (ToT) courses, we enhanced the capacity of more than 100 representatives of collaborating organisations, NARES and quarantine agencies from Kenya, Uganda, Tanzania, Zanzibar, Somalia and South Sudan, in the monitoring and integrated management of thrips and tospoviruses.

In 2011, with support from BMZ, we conducted a pest risk assessment for invasive western flower thrips (WFT), *Frankliniella occidentalis* in Africa through innovative phenology modelling. This thrips species was first reported in Kenya in 1989, and is now widespread in Kenya, posing serious problems for vegetable production.

WFT management under the current and future climate change scenarios will only be effective if there is a better understanding of the pest's potential spatial distribution and its host association, information that is currently lacking in East Africa. We established phenological models in relation to temperature based on life cycle data, also known as life tables, and used them to develop potential WFT distribution maps for 2000 and 2050 scenarios, which indicated wider distribution of WFT in Africa due to climate change. The predictions need to be further refined with other biological and ecological parameters.

In order to effectively deploy Campaign® in different eco-climatic regions, it is important to understand the impact of varying weather parameters, especially temperature on pathogenicity of EPF to WFT. Therefore, we investigated temperature influences on the biology and virulence of Campaign® against WFT in the laboratory. As a result, we established a model to predict the efficacy of EPF in relation to temperature, which enabled us to predict the potential effectiveness of the fungus in different agro-

Photo: *icipe*

icipe scientist, Sevgan Subramanian (third left), is pictured with participants of a field-based training course on the application of IPM strategies for the control of thrips.

ecologies. Through training activities, we enhanced the ability of staff from NARES, students and researchers to use ILCYM and other tools for phenological modelling.

In 2012, *icipe* in collaboration with partners from Kenya, Uganda, Tanzania, Germany, The Netherlands, New Zealand and the US, commenced a second phase of this research, to validate and implement the IPM strategies developed earlier utilising a community-based approach involving farmers, community leaders, and NARES and agricultural extension workers. Our aim is to further strengthen the capacity of stakeholders in thrips and tospoviruses management and establish the socio-economic impact of these pests and diseases in the region.

Our efforts to validate and implement IPM strategies on thrips were further boosted by funding from the African Union (AU) in 2012, which has enabled us to undertake further studies on the severity and impact of the pests in grain legume production in eastern Africa in order to implement IPM strategies using tools such as EPF, intercropping and attractants. For the first time, we are also investigating the presence of an aggregation pheromone of bean flower thrips. The focus would be to eventually disseminate these tools to smallholder grain legume producers in East Africa.

UNDERMINING LEAFMINER FLIES

***Liriomyza* leafmining flies (LMF) are invasive pests of great importance in the production of horticultural crops and potatoes in the tropics and subtropics. For example, vegetables worth up to $ 10 million destined for export markets from Kenya are rejected every year because of LMF infestations.**

icipe commenced research on LMF in East Africa in 2006. Through economic assessment studies, we established that the current strategies used by farmers in the region are incompatible with the Good Agricultural Practices (GAP) most often required in international export markets. Moreover, in Kenya, we found that none of the insecticides that are commonly used by farmers are efficient against LMF larvae. In addition, with the exception of one product, all insecticides are detrimental to LMF natural enemies.

Therefore, our objective has been to improve LMF management in major horticultural and food crops, with biological control as one of our key strategies. Through surveys

Photo caption: *A* Liriomyza *leafmining fly feeding on a tomato leaf. These flies pose a significant threat to a variety of crops which are grown in Africa.*

and literature review, we observed that in East Africa, the diversity of LMF parasitoids is much lower than in other regions where the pests are prevalent. As such, we found it viable to search for LMF natural enemies in the pests' original home. As a result of these efforts, we introduced three parasitoids from Peru into Kenya, namely *Phaedrotoma scabriventris*, aimed for releases in the highlands and regions at mid altitude, *Halticoptera arduine* which is specific to lowlands and highlands and *Chrysocharis flacilla*, a species that is ideal for the lowlands.

After promising performances under quarantine conditions at *icipe* against the three most important LMF species in Kenya, *P. scabriventris* was approved by the Kenya Plant Health Inspectorate Service (KEPHIS) for field releases in the country.

We also tested the application of various EPF from Kenya. However, although the pathogens were effective against LMFs, they had a negative effect on the parasitoids. In contrast, we found botanicals such as neem and pyrethrum not to be detrimental to *P. scabriventris,* meaning they can be safely used for LMF control. Further, we observed that intercropping and complexities in the landscape reduced LMF infestation and damage.

In 2010, we commenced a second phase of activities, to implement earlier findings, including releases of *P. scabriventris* in fields. The ability of the natural enemy to control LMF has improved considerably, from less than 5 to 77% parasitism, depending on cropping season, altitude and pesticide use in specific sites. The natural enemy has substantially contributed to a reduction in LMF damage, leading to a gradual decline in insecticide use.

Following a promising performance in laboratory studies at *icipe*, we obtained a KEPHIS release permit for *H. arduine* at the end of 2012.

The third exotic natural LMF enemy *C. flacilla* initially failed to establish at *icipe*'s quarantine facility and had to be reimported from Peru. Currently, we are conducting more laboratory studies with an aim of future field releases. Finally, we are also considering introducing a fourth natural enemy known as *Diglyphus websteri*, which has been found to be highly effective against LMFs in Peru.

Photo: *icipe*

Caroline Foba, a PhD researcher, uses GPS technology to record the location of leafminer samples obtained from farmers' fields for further laboratory studies.

Researchers from icipe conduct training in GAP and IPM techniques for the management of LMF. Over 500 farmers and staff from NARES have been trained so far.

Photo: *icipe*

Based on the adverse effect of EPF on parasitoids, we are exploring the possibility of using the pathogens as endophytes. So far, we have identified eight fungal isolates that are endophytic, which are also highly virulent against LMF.

In surveys in Kenya, Uganda and Tanzania, we determined the LMF species composition and that of their associated natural enemies, as well as the infestation and parasitism level at different altitudes. We were able to show that *Diglyphus isaea* and *Opius dissitus* are the two most abundant indigenous parasitoids in the three countries.

More than 500 farmers and staff from agricultural ministries in East Africa have been trained in GAP and in IPM techniques. Key elements of the training were precise identification of LMF and their natural enemies, and techniques for environmentally friendly pest management to reduce the use of broad spectrum insecticides and improve biological control. This capacity building will contribute to reduction of LMF damage and increased yield in crops affected by the pest.

Photo: *Santiago Escobar*

TESTING THE MIGHT OF SPIDER MITES

Komi Fiaboe and Nguya Maniania discuss icipe's efforts to control the red spider mite (RSM),* Tetranychus evansi*, an invasive pest of tomatoes which causes severe yield losses in smallholder production systems in East and southern Africa.

RSM is believed to have originated from South America and since its introduction in Africa, it has rapidly spread across the continent. As there are no effective RSM natural enemies in Africa, farmers largely rely on expensive synthetic acaricides to control the pest. However, in studies in Kenya and Zimbabwe, *icipe* found that most of the acaricides that are commonly used to combat RSM are actually completely ineffective. There is also growing concern about environmental and health risks associated with their use.

Therefore, our research aims at increasing tomato production by developing environmentally friendly RSM management methods in smallholder tomato production

Photo caption: *In Africa, thousands of kilogrammes of tomato are consumed every day. Through its research on IPM strategies to control spider mites,* icipe *will enable smallholder farmers reap ultimate benefit in the cultivation of the crop.*

Photo: *icipe*

icipe *has established that the use of an isolate of* Metarhizium anisopliae *ICIPE 78 in combination with a predatory mite imported from Brazil is effective in the management of RSM, as shown in this tomato plot.*

systems in eastern and southern Africa. We started our activities with surveys for RSM natural enemies in Africa, which did not yield promising results. Therefore, we expanded the exploratory studies for RSM natural enemies to regions of South America that have similar climate to those affected by the pest in Africa.

We found three promising biological control agents in Brazil: the predatory mite *Phytoseiulus longipes*, the acarophagous ladybird beetle *Stethorus tridens* and the entomopathogenic fungus *Neozygites floridana*. Of these, *P. longipes* was introduced into Kenya where it performed well in laboratory and greenhouse tests, and, after receiving a KEPHIS release permit, we tested the predator in field trials in early 2007 in Kenya. However, the predatory mite was not found during initially recovery surveys, probably because of pesticides used by farmers to control other pests and diseases in their tomatoes. Yet from 2011 onwards, we repeatedly recovered *P. longipes* from nearby fields, indicating a gradual establishment of the natural enemy. Although we still need to conduct more surveys to assess the abundance, spread and effectiveness of the predator, these initial indications give us hope that additional releases could lead to effective control of RSM.

We also identified an isolate of *Metarhizium anisopliae* ICIPE 78 to be virulent against RSM, which has now been developed as a biopesticide and is being commercialised under the name of Achieve™ by Real IPM (Kenya) in Kenya, Ethiopia and South Africa. The fungus does not have negative effects on *P. longipes*, meaning that it can be used in combination with the predator. Therefore, we are evaluating the potential of combining EPF and the predatory mite to manage RSM in tomato crops as well as in African nightshade, an important indigenous vegetable in Africa. We also found some resistance to RSM in tomato accessions, opening up the opportunity to develop commercial varieties that are pest resistant.

Further, we will conduct studies on the migratory behaviour of RSM and the two-spotted spider mite *Tetranychus urticae*. We have also assessed the efficacy of eco-friendly nets for protecting tomatoes in different agroecological zones in Kenya. The technology is now available for farmers, and can contribute to a significant decrease in synthetic pesticide use.

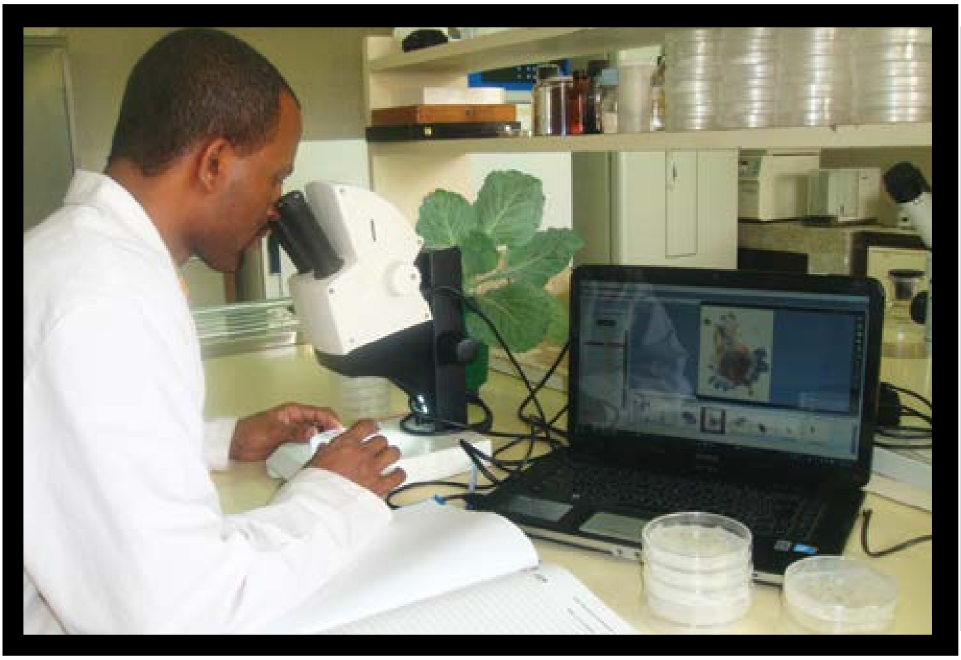

Photo: *Tanga Mbi*

DESTROYING 'PLANT LICE'

Aphids, small sap-sucking insects, which are also known as 'plant lice', are among the most destructive insect pests in temperate climates, causing huge losses in the yield and quality of crops through direct damage and transmission of viral diseases. Sunday Ekesi describes* icipe*'s progress in developing integrated pest management strategies for the aphids in Africa.

In 2012, *icipe* joined a three-year multi-institutional programme whose aim is to develop, test and adapt sustainable and environmentally-friendly options for the management of aphids on okra, kale and cabbage, while reducing the synthetic pesticide load on these crops in Cameroon and Kenya.

Our aim is to determine the level and dynamics of aphid infestations as well as the diversity and prevalence of aphid-transmitted viruses and their damage on the three crops. In addition, we will investigate the diversity and impact of predators, parasitoids and pathogens on these pests. An additional objective is to establish the identity and

Photo caption: *Bayissa Wakuma Hundessa, a researcher at* icipe *is pictured conducting studies on aphids, as part of the Centre's contribution to finding sustainable and environmentally-friendly options for the management of these pests.*

prevalence of aphid-transmitted viruses on the three vegetable crops and on associated vegetation.

We are developing appropriate user-friendly tools for identifying and monitoring aphids and their associated natural enemies, their species composition and abundance while identifying windows of opportunity for interventions. This process will include the development of geo-referenced maps of the distribution of aphids and their viruses as well as guides for their diagnosis. The studies will also involve the determining and modelling of the role of biotic and abiotic factors affecting the dynamics of aphids on the three crops.

Further, the studies will involve detailed evaluations of promising natural enemies, and possibly the introduction of new species or new strains to complement existing ones. We have already identified one major parasitoid, *Diaeretiella rapae*, of aphids in East Africa, which we have now introduced for redistribution in West Africa.

icipe is also testing conservation biocontrol and alternatives to synthetic insecticides based on biopesticides and natural products. In addition, we want to identify the varieties of the three crops that are tolerant or resistant to aphids and have good horticultural traits. Our aim is to develop and test new tools based on existing and newly identified entomopathogens and natural products.

Overall, our objective is to increase aphid management options that are available to smallholder farmers in the cultivation of okra, kale and cabbage in the two target countries. In effect, this research will contribute towards enhancing the yields of these crops, and by ensuring greater sustainability of the production systems, improve the livelihoods of the smallholder farmers as well. Finally, these studies will also enable NARES to conduct appropriate research and transfer technologies more effectively.

Photo: *Tanga Mbi*

Aphids seen through a microscope feeding on a cabbage. These sap-sucking insects cause huge losses in the yield and quality of crops through direct damage and transmission of viral diseases.

Photo: *Venansio Tumuhaise*

FOCUS ON THE VORACIOUS POD BORER

Baldwyn Torto discusses* icipe*'s contribution towards controlling* Maruca vitrata *(Mv), a voracious pod borer that intensely attacks and ruins crops during the flowering and pod-forming stages of cowpea and other legumes.

icipe is a partner in a project led by AVRDC, the World Vegetable Centre, whose goal is to reduce *Mv* losses on vegetable legumes in Southeast Asia (SEA) and sub-Saharan Africa (SSA). The overall goal is to improve income generation and livelihoods of small-scale vegetable legume farmers in SSA (in Kenya and Benin), and in SEA (in Thailand and Vietnam). Our approach is to refine components of a simple, economical and environmentally sound IPM strategy for *Mv*.

Specifically, *icipe*'s role is to improve existing technologies that are based on *Mv* sex pheromones, entomopathogens and botanicals, while exploring for specific natural enemies in the aboriginal home of *Mv* for subsequent introduction in the selected countries.

Photo caption: Maruca vitrata *larva feeding on cowpea flower.* icipe *and partners have already made progress towards developing strategies that will help alleviate the extensive losses caused by the pest in SSA and SEA.*

The refining of the *Mv* sex pheromones is a novel endeavour. Although previous researchers have attempted to develop sex pheromone lures for the pest, the responses of the moths to the lures have been highly variable across regions. We aim to determine these causes which centre on the population structure and genetic differences of *Mv* in different regions of Asia and Africa.

So far, we have confirmed previously identified sex pheromone components and revealed for the first time an additional candidate pheromone component detected by males from the odours of the insect. These findings indicate that the refining of the sex pheromone and its exploitation for control of the pest is an achievable goal.

Further, our studies have revealed, for the first time, the influence of host plant volatiles on *Mv*'s sexual behaviour. They have also shown the identities of the candidate chemical components involved.

Already, we have identified two potent fungal isolates. In collaboration with Real IPM Ltd, these isolates have been formulated for field application, and the results obtained from trials so far are very encouraging. In addition, commercial products based on *Bacillus thuringiensis* and neem have been identified. We will subject these products to large-scale field validation trials before recommending them to farmers.

Based on these two sets of findings, an *Mv* management strategy can be developed utilising a combination of either sex or plant attractants together with the entomopathogens and/or botanical.

Mv parasitoids that are currently found in the target countries are either generalistic – meaning that they attack a variety of host species – or their ability to control the pest is low. Therefore, we will explore the occurrence of parasitoids that are specific to *Mv* in SEA, which is believed to be the pest's centre of origin. Once identified, these parasitoids will be introduced in classical biological control programmes in SSA and other SEA countries.

As a result we will increase and widen the *Mv* management options for smallholder cowpea and bean growers in Africa and Asia. We will also contribute towards improved food availability, income and nutrition of smallholder farming communities in SSA and SEA.

Photo: *Santiago Escobar*

THWARTING LOCUSTS

Baldwyn Torto and Nguya Maniania discuss* icipe*'s activities towards controlling locusts in the Sahel region and in Madagascar.

For thousands of years, locusts, one of about a dozen species of grasshoppers, have caused mankind untold anguish. In Africa, the countries of the Sahel region which include Algeria, Burkina Faso, Chad, Ethiopia, Eritriea, Mauritania, Mali, Niger, Nigeria, Senegal, Somalia and The Sudan, are particularly susceptible to outbreaks of the desert locust, *Schistocerca gregaria*. In Madagascar, outbreaks of the gregarious phase of the Malagasy migratory locust, *Locusta migratoria capito,* are a recurring problem and a major threat to agriculture.

The commonly-used control methods for locust outbreaks, which are based on the use of synthetic insecticides, are extremely costly. In addition, the large amounts of non-specific toxicants that are sprayed over affected areas pollute the environment and threaten the biodiversity.

icipe's overall objective has been to develop components of a preventive, eco-friendly and cost-effective locust control system, based on benign, bio-rational, semiochemical-

Photo caption: *A solitary desert locust, such as the one pictured above is completely harmless. By understanding and contributing strategies to disrupting their ability to aggregate,* icipe *is contributing towards minimising the massive destruction caused by adult swarms of locusts.*

Photo: Santiago Escobar

Locusts being reared for laboratory trials in Madagascar. Studies by icipe *have shown that fungal-based biopesticides and Green Muscle® are effective against the pests.*

based control tools and tactics. We have developed a preventive strategy for locusts based on an adult locust pheromone phenylacetonitrile (PAN), which is effective against juvenile stages of the insect.

PAN has been tested in large-scale field studies in Sudan on small bands of locust juveniles, in collaboration with the national locust control agency and observers from Egypt, Mauritania, Niger and Senegal. These trials demonstrated the effectiveness of the pheromone, whether applied alone or in combination with the grasshopper specific entomopathogen (EPF) *Metarhizium anisoplaie var. acridum*, also known as Green Muscle™, a fungal biopesticide developed through the LUBILOSA programme. The field trials facilitated the registration of PAN combined with Green Muscle™ for use in locust control in the Sudan, which is now part of Locust Preventive Strategy of the Food and Agriculture Organisation (FAO) of the United Nations and Sudan's Plant Protection Department.

Further, we found that PAN is also effective in sub-lethal doses of conventional synthetic locust control insecticides, and in sub-lethal doses of insect growth regulators when compared to the recommended dose of conventional insecticides for locust control. A similar study, which was conducted under controlled laboratory conditions in Niger by Centre Regional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationnelle (AGRHYMET), confirmed the results that we obtained through our trials in Sudan.

icipe, in partnership with FAO, has instituted an awareness campaign for this strategy through several joint workshops in African countries affected by locusts. These activities have intensified efforts to build capacity in preventive locust control tactics in 14 countries that are affected by locusts.

icipe has also developed effective control agents for the malagasy locust, *L. migratoria*, based on pheromones and fungal-based biopesticides and Green Muscle®. We tested the virulence of these biopesticides against *L. migratoria* and non-target organisms in the laboratory under quarantine conditions in Kenya. We then introduced the products into Madagascar for further laboratory tests and large-scale trials. As a result, Green Muscle® is now registered and available in Madagascar for the control of *L. migratoria*.

Photo: *icipe*

CASHING IN ON CASHEW

Cashew is an important source of livelihood, food security and income for more than five million smallholder farmers in sub-Saharan Africa (SSA), contributing 50–90% of their total farm income. In West Africa, the crop is the second major source of foreign exchange next to cocoa butter, with exports amounting to $ 414 million. As Nguya Maniania narrates below* icipe *is helping to maintain the crop's importance in Africa.

In the 20 years between 1970 and 1990, SSA's earnings from cashew crashed from a global share of 70% to a mere 17%. This decline is attributed to a combination of biological, agronomic and socio-economic factors. The biological constraints, which include damage by coreid and mirid bugs such as *Pseudotheraptus wayi* and *Helopeltis* spp. respectively, and powdery mildew, can lead to 60–100% yield losses in the crop.

Often, in a bid to control these pests, farmers resort to large-scale application of synthetic pesticides usually at doses beyond the recommended rate, endangering their

Photo caption: *Moses Olotu, an ARPPIS PhD student based at Mikocheni Agricultural Research Institute observing ants in the laboratory as part of* icipe*'s research towards identifying biological control agents for the pests of cashew.*

Photo: *Moses Olotu*

The African weaver ant, Oecophylla longinoda, *which has been identified by* icipe *as an effective biocontrol agent of sap-sucking pests of cashew.*

own health and that of consumers because of pesticide residues in the fruits and nuts and, in general, in the environment.

icipe is aiming to develop, validate and implement sustainable cashew IPM technologies that will enhance productivity and quality of the crop. The research focuses on understanding the bioecology of the key insect pest complex and their natural enemies in diverse habitats and landscapes.

We are exploring strategies that minimise or eliminate the use of excessive sulphur dust, the most commonly used fungicide for powdery mildew management. We have also assessed the effects of sulphur alternatives on beneficial insects like pollinators, and the natural enemies of the bugs.

icipe and partners have provided a better understanding of the dynamics of cashew pests and their interactions with natural enemies. They have also identified the weaver ant, entomopathogenic fungi and antagonist fungi as components of IPM to minimise the use of synthetic pesticides.

Our studies have led to new knowledge of chemical and sex attractants of coreid and mirid bugs. Once fully validated, the sex attractants can be used for monitoring purposes on cashew and other crops that are known to infest coconut, cocoa and macadamia. In addition, these two sets of attractants can be used to develop lures as part of an IPM package.

We are also conducting an assessment of current socio-economic pathways of cashew production and marketing information, on potential cashew IPM strategies.

BETTER ENVIRONMENT

Photo: *icipe*

FOR HEALTHIER ECOSYSTEMS AND LIVELIHOODS

icipe believes that a healthy environment is vital for sustainable development in Africa, where many people depend on land-based resources for their livelihoods. Yet, factors related to population growth, poverty and climate change, are bringing about changes that are adversely affecting the services that people obtain from ecosystems. For instance, alterations in the environment reduce the availability of fresh water, affect soil conditions, contribute to air pollution and flooding, and negatively affect useful insect species, such as bees and silkworms.

In this chapter, *icipe* researchers discuss their strategies towards addressing the complex links between improving human well-being and environmental protection, by enabling communities to sustainably exploit useful insects and control their current and potential threats. The Centre also bioprospects natural resources to provide communities with alternative income generating options while developing environmentally safe products, for instance biopesticides. Further, *icipe* is leading climate change research, to counter Africa's vulnerability to the phenomenon.

Photo: *Boniface Ngoka*

BEES, SILKWORMS AND SUSTAINABLE LIVELIHOODS

Suresh Raina, Programme Leader of the* icipe *Commercial Insects Programme (CIP), discusses the Centre's strategies and accomplishments towards creating a convergence between honeybees, silkmoths, forest and biodiversity conservation, and sustainable livelihoods.

Q. Please give an overview of the CIP programme.

A. The CIP programme has been in operation for about two decades with activities focusing on three main thrusts: the development of technologies for beekeeping and silk farming, the conservation of forests and fragile ecosystems and the improvement of the socio-economic conditions of the communities that live adjacent to them.

CIP commences its activities with baseline surveys on the livelihoods and income levels of communities, and an evaluation of the constraints towards

Photo caption: *A customer admires a display at the Taita honey marketplace, where* icipe *is assisting community members to improve their livelihoods while protecting the natural resources around them.*

the adoption of new technologies in general. This baseline knowledge guides CIP in its research towards developing, validating and implementing tools for beekeeping and silk farming.

Our baseline studies have confirmed that majority of the people who live close to forests or in the semi-arid and arid areas are often poor, landless or marginalised. Therefore, they usually over-rely on the resources around them for their livelihoods. In addition, such communities often lack the incentives to support, and in some cases the opportunity to become involved in conservation efforts. Therefore, our overall aim is to increase the awareness of communities and national institutions regarding the relation between conserving ecosystems and the improvement of their own livelihoods.

As the projects proceed, CIP continues to assess the factors influencing the adoption of the technologies for beekeeping and silk farming. We conclude our activities with an evaluation of the impact that CIP has had towards improving the livelihoods of communities and in the conservation of ecosystems.

Q. What tools and strategies has CIP developed so far for beekeeping and silk farming?

A. In many countries in Africa and the Near East and North Africa (NENA) region, beekeeping is a traditional activity, which has remained stagnant due to poor production and harvesting methods. Therefore, CIP's strategy is to develop modern technologies to advance beekeeping to a level where communities can obtain meaningful income from it.

We have produced new knowledge on rearing various species of bees, including stingless species, and on enhancing the management practices in the production of honey and hive products. Further, our research has focused on ways to scale-up beekeeping, for instance by promoting pollination services and other livelihood options to strengthen farming systems.

Since silk farming is a relatively new venture especially in Africa, CIP's activities have focused on establishing the basics of wild and mulberry silk farming in

Photo: *Suresh Raina*

icipe *is promoting sericulture in several African countries. Here, community members in Ethiopia receive training in mass rearing of old age mulberry silkworm.*

The development of products from commercial insects provides livelihood options especially for women, for instance these ones pictured receiving training in the silk reeling process in The Sudan.

Photo: *Jael Lumumba*

different agroecological regions. We have also undertaken research towards the development of various apiculture and sericulture products, on the basis of the quality regulations of the European Union, Organisation for Economic Co-operation and Development (OECD) and other trade agencies.

Q. What are some of the sites that CIP has implemented its tools and strategies in, in the past five years?

A. Between 2007 and 2012, CIP implemented beekeeping and silk farming technologies in sub-Saharan Africa (SSA) and the Near East and North Africa (NENA) region. In total, our activities cover about 18 countries: Algeria, Botswana, Burundi, Congo, Ghana, Ethiopia, Egypt, Libya, Madagascar, Morocco, Yemen, Rwanda, Sudan, South Sudan, Tanzania, Tunisia, Uganda and Zambia.

In Kenya, CIP advanced projects in Kakamega and Arabuko Sokoke forests and in Mwingi county, a dry woodland area in eastern Kenya. Further, we continued activities in West Pokot, a marginalised, semi-arid area in northwestern Kenya.

CIP also initiated new projects, in the Lake Naivasha Basin, in Isiolo county, a semi-arid region in northern Kenya and in Rachuonyo County, in western Kenya. We also integrated beekeeping into the rehabilitation programme of orphans and former street children at the Mully Children's Family Homes in Machakos District, Kenya.

Q. What progress did CIP make in Kakamega and Arabuko Sokoke forests?

A. Kakamega forest, the easternmost fragment of the Guineo–Congolean rainforest, is world-famous for its unique biodiversity, which includes a variety of flora and fauna, while Arabuko Sokoke is the largest remaining portion of the East African coastal dry forests. These two forests are an invaluable resource for the people who live around them, who depend on them for firewood, timber, herbal medicine, food and new land for agriculture and settlement. However, human and economic pressure has resulted in haphazard, excessive, wasteful and unsustainable harvesting of their resources.

The activities of CIP were, therefore, geared towards providing the communities that live adjacent to the forests with alternative sources of income, so as to conserve the biodiversity. We identified tree species in the two forests that harbour silkmoths and bees, and assisted the communities to cultivate them on their farms and the forest buffer zone, and assisted them with the necessary expertise in sericulture and apiculture.

Q. How did CIP advance its work in Mwingi?

A. One of CIP's main objectives in Mwingi was to increase the number of community members, especially women, and their overall involvement in the development and implementation of beekeeping and silk farming. By 2012, close to 50% of the people involved in the CIP projects in Mwingi were women. We also wanted to enhance the alignment and sustainability between our activities and community needs. Therefore, we focused on creating leadership skills amongst the community members, through training of trainers in various parts of the county. To assist the farmers build their capital base, so as to increase production of bee and silk products, we identified six financial institutions through which the farmers could access credit services.

Further, we found that the farmers were trying to market their products individually, an approach that left them vulnerable to exploitation by middlemen. We therefore supported them to launch the Mwingi honey and silk marketplace, which now serves as a collective marketing centre for honey and silk.

In June 2007, CIP started a process towards the organic certification of Mwingi honey and hive products, based on the European Union ISO65 (EU-ISO65). This effort started with the registration of farmers, the selection and training of field officers, leaders of the various groups, the association's management staff and producer groups. It also involved the mapping out of the bee and silkworm habitats and forage resources in the area.

The EU-ISO65 organic regulations require the development of an internal control system (ICS) as the mechanism for enabling certification of producer

Photo: *Rolf Gloor*

The CABESI project is enabling community members in the marginalised West Pokot region to merge modern technology with their rich traditional culture, to improve their livelihoods.

icipe is assisting communities across Africa to adapt to the impact of climate change by providing the strategies and tools for alternative livelihood options such as beekeeping. Here, farmers from Mt Kenya region harvest honey from Langstroth hives provided by the Centre.

Photo: *James Ng'ang'a*

groups. Therefore, our process also involved the restructuring of the groups, further detailed training, the development of appropriate recording systems and extension framework.

After inspection by the Institute of Marketecology (IMO) of Switzerland, the Mwingi Beekeepers Association was awarded an organic certification for their honey in 2009. Aside from becoming the pioneers of organic honey in Kenya, Mwingi beekeepers are now able to attract international trade partners who are interested in issues of fair trade. In addition, the strategies that were instituted as part of the certification process have improved the management of the natural resources and land practices in Mwingi, with benefits beyond beekeeping.

Q. What were the activities of CIP in West Pokot?

A. In West Pokot, natural resources are largely underutilised due to lack of technologies, market access and means of transportation. When CIP started its activities in the region in 2005, it sought to utilise the area's vegetation and camels, through a project known as CABESI (*Ca*mels, *Be*es and *Si*lk).

Through CABESI, CIP's goal is to enable communities, and especially women in West Pokot, to improve their livelihoods. During the first and second phases of CABESI we introduced modern technologies of beekeeping and silk farming, and opened marketplaces for honey and silk products in the region.

Between 2007 and 2012, our main aim was to ensure the sustainability of these activities, along three main goals: to introduce more income generating activities, to reduce the incidence of malaria and to contribute towards reduction of the challenges regarding the management of arid land, for instance soil erosion. The community is now able to oversee the honey business, from production to sale. They have also generated enough money to venture into further development projects, for instance the cultivation of *Jatropha* and *Aloe*. The malaria cases in the region have also gone down significantly.

Q. What has been the progress in the new project sites?

A. The new project sites have all had different challenges. As the only inland freshwater lake of economic importance in Kenya, Lake Naivasha is a vital source of water in a semi-arid environment, supporting a flourishing business in horticulture and floriculture. However, the basin is under threat from unsustainable land-use which has led to deforestation, siltation and pollution by agro-chemicals used by farmers along its course. In collaboration with the World Wildlife Fund (WWF), our aim was to improve the sustainable use of natural resources and the livelihoods of low income farmers in the Lake Naivasha basin, through beekeeping and mulberry silkworm rearing.

Like many other communities in the northeastern region, the communities in Isiolo have traditionally practised pastoralism. However, in recent years frequent droughts have had disastrous results on livestock. Therefore, our goal was to introduce beekeeping and silk farming as alternative income sources. We provided the community members with equipment, training and exchange programmes, culminating in the establishment of the Isiolo Honey Refinery and the Isiolo County Beekeepers Association as community based initiatives.

At the Mully Children's Family Home, we established a beekeeping resource centre consisting of posters, books, bee specimens, hives, honey extractor, protective clothing, smokers and hive tools, to benefit the facility as well as the adjacent communities. We also helped to restart a beekeeping club, which is now a training platform on bee biology and behaviour, conservation and colony management.

In Rachuonyo District, CIP restored and scaled-up silk production, with the aim of empowering women silk farmers while protecting the environment.

Q. What has been the focus of the CIP work in the NENA region?

A. In NENA region, our project area covered the protected forests and poverty-stricken semi-arid zones of Egypt, the Sudan and Yemen.

We aimed to reduce poverty through improved food security and income levels of farmers, by scaling-up of apiculture and other income generation technologies

Photo: *Loise Kawira*

icipe *takes a holistic approach towards promoting the sustainable exploitation of useful insects. Here, beekeepers in Tolay, Ethiopia, receiving training on how to inspect hives for bee diseases and pests.*

Community members living around Kakamega forest tilling a plot on which *icipe* is helping to implement a trial on crop pollination using stingless bees.

Photo: *Kiatoko Nkoba*

within projects funded by IFAD through participatory agroforestry management (PAFM).

We have conducted the appropriate activities regarding beekeeping and silk farming, including training of farmers and development of marketplaces. Currently, we are extending capacity development for these activities to all levels of stakeholders, from community members, local administrators to forestry officials. CIP also facilitated the inauguration of honey and silk marketplaces and marketing linkages for the products. Our activities have contributed to poverty reduction and environmental conservation strategies being implemented by various governments in the region, as well as the improvement of management practices for better crop yield through pollination services.

In addition, we assisted in the rehabilitation of the beekeeping industry after severe flooding in Hadramawt and Al-Mahara governorates, Yemen. We also explored constraints including the bee diseases and pests, affecting the beekeeping industry and pollination services in the two regions.

Our activities in the NENA region have empowered communities, including women and youth, through ownership and operation of honey businesses. We helped the farmers to eliminate middlemen and generate more income at the community level. The value added to bee products through quality control, processing and packaging to national and international standards has also enhanced the income generated from beekeeping. Based on these accomplishments, the communities are now motivated to increase agricultural productivity and maintain forest biodiversity. Their economic well-being has also improved.

Q. What are the future plans for *icipe* and CIP?

A. The most significant plan for the future is the construction of the African Reference Laboratory (ARL) for research and capacity building on bee health at *icipe*'s headquarters in Kasarani, Nairobi, and four bee health satellite stations in Burkina Faso, Cameroon, Ethiopia and Liberia. The ARL, which is a collaborative initiative between *icipe* and the African Union (AU-IBAR), will

Photo: *Brian Mwashi*

Lodewijk Briët (centre), Head of EU Delegation to Kenya and Ahmed El-Sawalhy (left), Director AU-IBAR, taste icipe *honey, offered to them by the Centre's head of the Commercial Insects Programme, Suresh Raina (right), during the official signing ceremony for the establishment of an African reference laboratory (ARL).*

provide a coordinated process for bee health in Africa, through research and development, policy advocacy, capacity building, and strategic networking. We have obtained funding from the European Union (EU) and *icipe* core funds, which will go towards the purchase of equipment and bee apiary setting and beehives, and refurbishing the satellite stations and ARL, and capacity building.

The *icipe* ARL will generate new knowledge on bee diseases and pests across Africa and, through extensive capacity building efforts, it will propose and disseminate new and effective measures for their control. In collaboration with AU-IBAR, *icipe* will also provide the infrastructure and technical support to the four African satellite stations, and guide the incorporation of strategies, harmonised procedures and legislation on bee health into national development agendas across the continent. Ultimately, these activities should lead to an African framework on bee health.

Photo: *Robert Copeland*

PROTECTING HONEYBEES

Although honeybees provide critical pollination services, nutrition and income for small shareholder farmers and rural families in Africa, there is limited understanding regarding their key threats. Baldwyn Torto discusses how* icipe *has utilised its extensive expertise in chemical ecology to enhance knowledge on bee pests.

In 2008, *icipe* launched a programme towards the utilisation of semiochemicals to develop monitoring and control programmes for invasive pests of bees. Through extensive nation-wide surveys of hive beetles, we discovered two related scarabs, *Oplostomus haroldi* and *O. fuligineus,* to be the key pests of African honeybee colonies.

Our studies on the biology and chemical ecology of the beetles have led to the generation of DNA barcodes based on a section of their mitochondrial genome, which will aid morphological taxonomy and identification of origin, should these pests become threats to honeybee colonies of a different race outside Africa.

Further, we explained the chemistry on the interaction between the two beetles and

Photo caption: *A honeybee pictured on a flower. These insects are hugely important, not least in Africa, where, in addition to other benefits they provide vital pollination services for crops.*

honeybees, and developed a trapping system, and tested its performance in capturing the small hive beetle in African honeybee colonies, before expanding it to other species. We also identified the alternate hosts of the beetles, to understand factors that could contribute to the spread and distribution of the pests. The findings from our studies have provided the basis for developing policy guidelines for the movement of honeybee colonies within and outside Kenya, to reduce the introduction of pollinator pests into new geographic and agricultural areas.

icipe is also involved in an international collaboration whose aim is to understand the biology, ecology and management of African bees, within the context of the colony collapse disorder (CCD), which is causing significant decline of honeybees in Europe and USA.

The project aims to verify whether the maladies affecting European bees are present in African bees. The goal is also to understand the mechanisms that allow African bees to tolerate these problems and the management techniques employed by beekeepers to minimise their impact.

The factors that have so far been identified as the most likely contributors to CCD include varroa mites, diseases, particularly viruses vectored by varroa, pesticide exposure and stresses associated with modern beekeeping practices, like the movement of hives and poor nutrition.

Our studies have shown that African bees in Africa are less vulnerable to brood diseases, parasites such as varroa mites and pests like the small hive beetle. In addition, in the US, Africanised bees, many of which are hybridised crosses with European species, tolerate these maladies better, and do not often succumb to them.

icipe's evaluation of the health of honeybee populations led to the discovery of varroa mites for the first time in honeybee colonies in Kenya, Uganda and Tanzania. This finding facilitated a new initiative between *icipe* and Penn State University (PSU), funded by the Bill and Melinda Gates Foundation and the National Science Foundation Basic Research to Enable Agricultural Development (NSF BREAD) project. We will conduct outreach programmes to beekeepers in East Africa, towards sustainable honeybee management practices that are not dependent on pesticides and miticides.

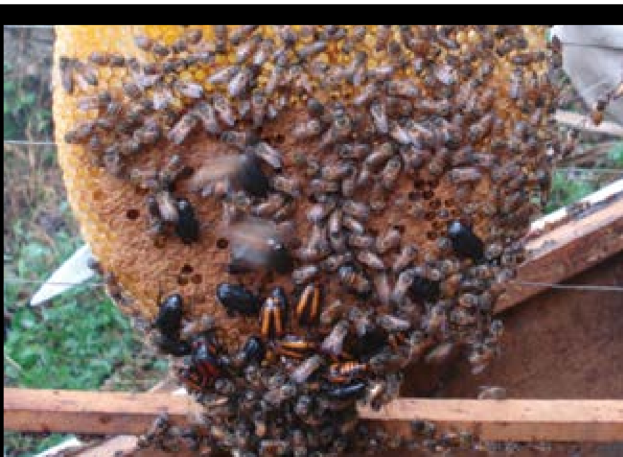

Photo: *Ayuka Fombong*

Studies by icipe *have led to the discovery of key pests in African honeybee colonies, including* Oplostomus haroldi *shown in this picture.*

As part of their studies on bee health, icipe researchers are using GPS technology to assess and map land cover and resources such as flowering trees.

Photo: *Tobias Landmann*

Further, we are conducting research towards understanding the factors and mechanisms that mediate the interactions of varroa mites and diseases with honeybees. We also want to explore the factors that contribute to the resistance of bees to these pests and pathogens. In addition, we aim to deliver critical knowledge and skills in beekeeping to farmers.

We have established three research apiaries on the campus of one of the project collaborators, Southeastern Kenya University (SEKU). Our studies have led to the description of the occurrence of varroa mites in honeybee colonies, and the determination of their pathogen loads. We have also documented the hygienic behaviour in honeybee colonies. For the first time in Kenya, we detected bacterial pathogens, in this case the genus *Nosema*, and viruses such as black queen cell virus. Through farmer education forums, we have transferred this knowledge as well as skills towards improving beekeeping practices to beekeepers.

Based on the success of our activities so far, the BREAD project has been extended for one more year. We intend to use this extension to compare the performance of three types of beehives, Kenya top bar, Langstroth and the traditional log, using the apiaries established at SEKU. Through this comparison, we will obtain data regarding the productivity of honeybees, foraging behaviour and response to pest and disease threats. We will also document the contribution of honeybees to ecosystem services in a dryland region where beekeeping is also beneficial for biodiversity conservation.

Photo: *Kassahun Mammo*

EXPLORING AND PROTECTING AFRICA'S BIODIVERSITY

Biodiversity and traditional knowledge, two of East Africa's most important resources, are currently threatened by various factors, which include rapid population growth and poverty. Wilber Lwande discusses* icipe*'s efforts to sustainably exploit and protect these rich resources in the region.

In the past five years, *icipe* has continued its activities towards protecting East Africa's rich biodiversity resources while improving the livelihoods of the people who live adjacent to them. Our strategy is to combine modern science, traditional knowledge and practices, and partnerships with local communities, development partners and the private sector.

One of our key focus areas is the bioprospecting for commercial products from plants that have traditionally been used for insecticidal, medicinal or aromatic purposes. We have introduced on-farm cultivation of such plants and provided communities

Photo caption: *Ethiopian women farmers and their daughters receiving tree seedlings to plant on their farms, a strategy that contributes to the protection of East Africa's rich biodiversity resources.*

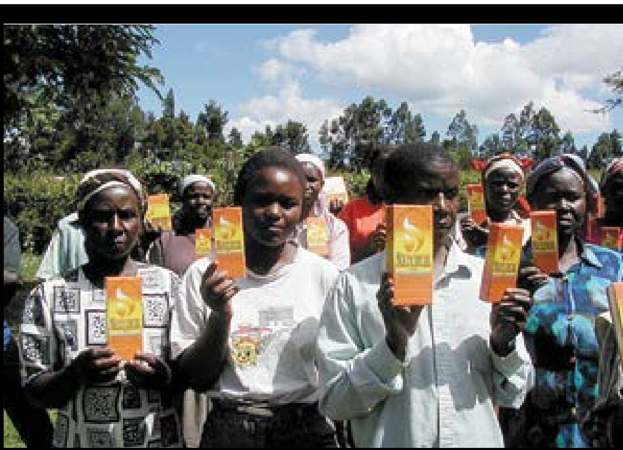

Photo: *icipe*

Members of the Muliru Farmers Conservation Group (MFCG) which contributes to the conservation of Kakamega Forest through the domestication of indigenous medicinal and insecticidal plants, pictured with samples from their Naturub range of products. MFCG, which is supported by icipe and partners, has received several international awards.

with the scientific back-up and the necessary skills for the production and marketing of products derived from them. As a result, we have contributed to the emergence of thriving community-based, income-generating enterprises, which provide income and employment while relieving economic pressure on biodiversity resources.

By 2012, over 1789 households in Kenya, Tanzania and Uganda were involved in such nature-based enterprises, and seven products had been developed, which are now available in the marketplace. Of these, the most notable are Naturub®, a range of medicinal products developed from *Ocimum kilimandscharicum,* and Mondia tonic, which is produced from *Mondia whytei*.

icipe is also working with traditional healers and community members to safeguard the knowledge and practices, safety, quality and availability, so as to enhance the use and effectiveness of selected traditional medicines. Our efforts have contributed to the improvement of a traditional healers' forest school, at Buyijja village (Mpigi District) and the enhancement of selected income-generating enterprises for the traditional healers.

Between 2005 and 2008, we implemented sustainable nature-based businesses for communities living adjacent to the Eastern Arc Mountains and Coastal Forests (EACF) of Kenya and Tanzania, one of the 25 global biodiversity hotspots. Among the projects that we introduced is the improved production of beehive products and the cultivation and processing of *Ocimum kilimandscharicum*. Two products have been developed for the community-based enterprise adjacent to the East Usambara Mountain forests in Tanzania, and are now awaiting registration.

icipe's activities also include the search for plant-derived pesticides for disease vectors such as mosquitoes, and for postharvest and storage pests, from randomly and ethno-botanically selected plants in East Africa. So far, we have identified a range of mosquito larvicidal extracts and compounds, which are now undergoing further investigation.

We have particularly promoted the use of plant-derived pesticides in the Tolay settlement scheme in Ethiopia, where we have evaluated six plants for effectiveness against mosquito larvae and maize weevils. We have now assisted over 170 households in the region to start the commercial farming of these plants.

Photo: *CHIESA Team*

MITIGATING AFRICA'S VULNERABILITY TO CLIMATE CHANGE

Although climate change is a global phenomenon, predictions are that its impact will most significantly be felt in sub-Saharan Africa (SSA). Through the Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa (CHIESA) project, a four year initiative funded by the Ministry for Foreign Affairs of Finland and coordinated by* icipe*, the Centre is producing knowledge on adaptation to climate change and variability, so as to reduce the vulnerability of SSA countries. Below, Tino Johansson gives an overview of the project.

Photo caption: *Mount Kilimanjaro's Kibo Peak, as seen from Moshi, Tanzania. SSA consists of a mosaic of landscapes which include valuable ecosystems that are likely to be more sensitive to the impacts of climate change and climate variability.*

Q. What is climate change?

A. Climate change refers to any significant change in the statistical distribution of weather patterns lasting for an extended period of time, from decades to millions of years. Therefore, climate change includes changes in average weather conditions, such as temperature, precipitation and evapotranspiration among other effects. In combination with human induced changes in land use and land cover, climate change directly impacts the health of ecosystems and as a result the services derived from them. In its Fourth Assessment report, published in 2007, the Intergovernmental Panel on Climate Change (IPCC), confirmed that human induced temperature increase is on the rise with measurable and rising effects.

Q. What are the specific issues of climate change in regard to Africa?

A. Although climate change is a global phenomenon, the magnitude of its impacts varies significantly across different regions. According to the IPCC report cited above, the impacts of climate change will be most intense and adverse in SSA. This is because most people in the region depend heavily on land-based resources and in particular on agriculture. As such, their food security and overall livelihoods are supported by various ecosystem services, such as the availability of fresh water, regulation of floods, nutrient cycling, pest control and pollination. The short and long term impacts of climate variability and change will affect these services, and therefore sustainable development as a whole. In addition, rising population density in SSA is increasing the competition between agriculture, forestry and biodiversity conservation, further complicating matters. Therefore, there is an urgent need for knowledge on adaptation to climate change and variability, so as to reduce the vulnerability of countries, and that of people on a household level.

Q. What is CHIESA's objective?

A. Currently, the available models and predictions on the impact of climate change on agriculture and food security have not sufficiently addressed issues regarding crop diseases, insect pests and pollinators. In addition, there is general lack of information on the impacts of climate change on sensitive and unique ecosystems and on their services in Africa.

Photo: *CHIESA Team*

icipe GIS specialist, Tobias Landmann conducts a training course on how to use the technology. The use of GIS in land cover and land use monitoring is one of the research gaps being addressed by CHIESA.

The main beneficiaries of the CHIESA project will be smallholder farmers, who are likely to be most vulnerable to the impacts of climate change, such as this family pictured in their coffee farm in the Jimma Highlands, Ethiopia.

Photo: *CHIESA Team*

CHIESA aims to increase the knowledge on the impact of climate change on ecosystem services in the Eastern Afromontane Biodiversity Hotspot (EABH), through research, training and the dissemination of results obtained through the project. Specifically, we are implementing activities in the Taita Hills in Kenya, in the Didessa River Basin in Jimma Highlands, Ethiopia, and along the southeastern slope of Mount Kilimanjaro in Tanzania. These areas adequately represent well the agriculture–forest mosaics in EABH. We have selected four key crops (maize, crucifers, avocado and coffee) for on-farm studies.

CHIESA's activities focus on four main pillars – research, monitoring, capacity building and development of adaptation strategies towards climate change impacts, which are being undertaken by a multidisciplinary team of scientists from several universities and research institutes in East Africa and Europe. Our goal is also to develop and build capacity for adaptation to climate change in eastern Africa through training activities for the staff members of local and regional stakeholder organisations, and supporting the establishment of weather stations in the target areas.

Q. Who are the beneficiaries of CHIESA?

A. The beneficiaries of the CHIESA project are first and foremost, the farming communities whose livelihoods depend on the ecosystem services in the selected areas. We hope to provide them with the information, options and adaptation tools to manage risks related to climate change. We plan to engage them in the planning, design and implementation of the identified adaptation options through wide dissemination of the project results and public awareness campaigns. Beyond the study sites, the wider general public will also benefit from the outputs of CHIESA. We hope to partner with extension officers in agriculture, livestock, environment, forestry and hydrology sectors in the formulation of the adaptation tools and in training farmers to use them.

Further, our strategy is to disseminate the results and outputs of the project to other stakeholders working on climate change adaptation across eastern Africa. In this regard, we will target government institutions which could use the outputs from our research, for instance downscaled climate models and vulnerability risk maps, for land use planning and policy formulation. We also expect national research institutes, universities and non-governmental organisations (NGOs) in eastern Africa to benefit from the project findings and from our capacity building efforts.

The ultimate goal of the CHIESA project is to contribute to local and regional development by utilising scientific knowledge in order to design, develop and implement adaptation options and strategies to climate change.

Photo: sxc.hu

COFFEE, COFFEE BERRY BORER AND CLIMATE CHANGE

Coffee is the world's most valuable tropical export crop, with an annual retail value of approximately US $ 90 billion. The coffee berry borer,* **Hypothenemus hampei** *is the most important biotic constraint of commercial coffee production worldwide. In addition, climate change and its forecasted impact on coffee production will have huge implications for coffee production throughout the tropics. In the article below, Juliana Jaramillo explains icipe's efforts to fill in critical knowledge gaps in these two areas, so as to safeguard the livelihoods of millions of small-scale farmers who depend on coffee farming.

In spite of many decades of research, the coffee berry borer, *Hypothenemus hampei,* remains the most important pest of coffee throughout the world, causing serious

Photo caption: *Research by* icipe *and partners has made significant progress towards securing future production of coffee, one of the most important cash crops for millions of farmers globally.*

economic losses to more than 100 million people in the tropics. Among the main reasons for this, are the still poorly understood biology and ecology, and especially the chemical ecology of the insect.

In the past five years, we have conducted basic research in these areas, to unveil key cues used by *H. hampei* during its host location and colonisation phases. We are investigating three important aspects of the biology and chemical ecology of the coffee berry borer. First, we are studying the major host location cues used by the females during their dispersal and colonisation phases, including the search for a possible aggregation pheromone of *H. hampei*. Second, in collaboration with Prof. Bill Hansson, Max Planck Institute Jena, Germany, we are conducting the functional characterisation of the olfactory system in *H. hampei*. Third, together with Dr Aaron Davis of the Royal Botanic Gardens, Kew, UK, we are investigating the possible alternative host plants or non-host plants among wild Rubiaceae in East African forests, and the chemicals in them that possibly attract or repel the beetle, *H. hampei*.

This knowledge, and the clarity that it will provide on the major attractants or repellents of *H. hampei*, will open up new and innovative possibilities to effectively control the pest. For instance, the information could be used in the development of IPM programmes, ideally based on a push–pull strategy.

Our second series of studies is in regard to the effect that climate change will have on the coffee berry borer. We are conducting thermal tolerance studies and modelling the pest's distribution in East Africa under current conditions and future climate change scenarios.

In collaboration with colleagues from CIRAD in France, Central America and CIAT in Colombia, we are also mapping compounded coffee pests and diseases suitability under climate change scenarios and agroecosystem types in Central America and East Africa.

Within the framework of the CHIESA project (WP5), which focuses on ecosystem pest management and pollination, we are undertaking further studies on the responses of the pests and natural enemies of *Coffea arabica* L. to changes in climate in southwestern Ethiopia and along Mt. Kilimanjaro, Tanzania.

So far, our studies have found that climate change will make coffee production more difficult and unpredictable, resulting in alternating periods of over- and underproduction. In particular, our studies estimate serious consequences in areas where the high quality *Coffea arabica* is produced. Our model forecasts that a 1–2°C increase could lead to an increased number of generations, dispersion and damage by the coffee berry borer. We have also observed that a rise in temperature of 2°C and above could lead to shifts in altitudinal and latitudinal distribution of the pest.

These results indicate that, theoretically, future arabica plantations in East Africa would need to move to higher areas. However, increasing population pressure and growing food insecurity makes this approach not feasible. Moreover, soil conditions at higher altitudes might not be suitable for arabica coffee. We therefore suggest that a more practical way to adapt to the rising temperatures is to introduce shade trees in coffee plantations as this considerably improves the microclimate and favours the growth of coffee.

icipe – Working in Africa for Africa

icipe – African Insect Science for Food and Health – was established in 1970 in direct response to the need for alternative and environmentally friendly pest and vector management strategies. Headquartered in Nairobi, Kenya, *icipe* is mandated to conduct research and develop methods for pest control that are effective, selective, non-polluting, non-resistance inducing, and affordable to resource-limited rural and urban communities. *icipe*'s mandate further extends to the conservation and utilisation of Africa's rich insect biodiversity.

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

Cover photos

Top left: A honeybee pictured on a flower. *icipe* is safeguarding the importance of these insects in Africa, which include vital pollination services for crops.

Top right: Mosquito scouts, lay people who received intensive and on-going training by *icipe* and KEMRI scientists on various aspects of controlling these vectors, play a critical role in the Centre's war against malaria.

Bottom left: Through its research on IPM strategies to control spider mites, *icipe* is enabling smallholder farmers to reap ultimate benefit in the cultivation of tomato.

Bottom right: *icipe* has discovered that odours from monitor lizards, such as the one pictured here, mediate attraction of one of the key vectors of trypanosomosis.

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