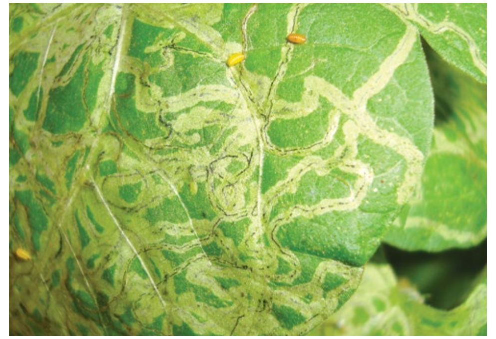

Top: Leafminer flies damage on bean leaves.

Bottom: Creating awareness among farmers on leafminers and their parasitoids before undertaking field release of the introduced parastioids.

parasitoids established in the release areas, and dispersed to more than 50 km from the release points less than a year later. Isolates of entomopathogenic fungi and nematodes virulent to LMF have been identified and tested under field conditions to complement the parasitoids for LMF management in East Africa.

IPM of African indigenous vegetable (AIV) pests

Cowpea, amaranth, and nightshades, represent the three most produced and consumed AIVs in East Africa. The pod borer (*Maruca vitrata*) and aphids (*Aphis craccivora*) are the most important limiting factors for cowpea production. Together with various partners, *icipe* is validating species-specific natural enemies (*Phanerotoma philippiensis*, *Theorophilus javanicus*, *T. marucae*), entomopathogenic fungi isolates, and pheromones against *M. vitrata*. Two isolates of *Beauveria bassiana* (ICIPE 62 and 64) and one of *M. anisopliae* (ICIPE 41) were selected against *A. craccivora* for validation in the field, in combination with a natural enemy, *Aphidius colemani*.

The most damaging pests on amaranth are the lepidopteran defoliators [*Spoladea (Hymenia) recurvalis*, *Udea ferrugalis*, *Herpetogramma (Psara) bipunctalis*, *Spodoptera littoralis*, and *S. exigua*], stem weevils (*Hypolixus* spp.), and aphids (*Myzus persicae*). Local parasitoids (*Apanteles* spp., *Lerus* spp., and *Cotesia* spp.) have been found to be efficient and suitable for augmentative biological control of lepidopteran defoliators, with more than a 60% parasitism rate. Various

Top left: Close up view of the adult bean flower thrips, *Megalurothrips sjostedti*.

Top centre and right: Thrips infestation on beans results in malformed pods and decrease in beans compared to the uninfected crop on the right.

Bottom: Thrips and thrips transmitted *Iris yellow spot virus* results in drying equivalent to 75% of the leaves as seen in this field; and, poor onion yields.

biopesticides, botanicals, and potential resistant varieties are being screened for the formulation of an IPM package against the amaranth pest complex.

Tetranychus evansi and *Aphis gossypii* represent the most devastating pests of nightshades. Predatory mite (*Phytoseiulus longipes*) and *M. anisopliae* isolate 78 are being promoted for control of the mite, while natural enemies, biopesticides, and resistant varieties are being tested for the control of *A. gossypii*.

Private–public partnership for up-scaling IPM technology

icipe has entered in partnership with the Real IPM (Kenya) Ltd., which was founded in 2003, and which mass produces a range of biopesticides, biofertilisers, and predatory mites. Three of *icipe*'s fungal isolates of *M. anisopliae* have been developed as biopesticides. ICIPE 69, marketed as Campaign® and Real Metarhizium are registered and commercialised in Ghana, Ethiopia, Kenya, South Africa, and Tanzania for the control of mealybugs, thrips and fruit flies. *Metarhizium anisopliae* ICIPE 78 is marketed as Achieve® in Kenya, Ethiopia, and South Africa for the control of mites, and is compatible with predatory mites. *Metarhizium anisopliae* ICIPE 62 is registered and commercialised in Kenya for the control of aphids. In 2014, 35,000 ha of crops were sprayed with these biopesticides, and 20,000 growers benefited from the technologies, resulting in a 50% reduction in the use of chemical insecticides.

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 that are effective, selective, non-polluting, non-resistance inducing, and which are affordable to resource-limited rural and urban communities. *icipe*'s mandate further extends to the conservation and utilisation of the rich insect biodiversity found in Africa.

icipe contributes to sustainable food security in Africa through the development of integrated pest management systems for major agricultural and horticultural crops. Such strategies include biological control, and use of behaviour modifying and arthropod-active botanicals. *icipe* emphasises control approaches that have no detrimental impact on the environment. These options are designed to fit the needs of the farmers, and are developed on-farm with their participation. In addition to pests of fruit, other key areas of *icipe*'s research include pests of tomatoes, brassicas, beans, and staple food crops such as maize and sorghum.

COVER PHOTOS

In many countries of Africa, vegetables and fruits have an important role in providing a balanced nutrition. Horticultural production for local and export markets is also one of the most profitable agricultural enterprises in the continent.

DBM Project (Expansion phase) — Collaborators: Malawi: Crop Development Department; Ministry of Agriculture and Food Security. Mozambique: IFAD PRONEA/PSP programme; Plant Protection Department/DSV-MINAG; University of Eduardo Mondlane, Department of Agronomy. Rwanda: National University of Rwanda. Zambia: Zambia Agriculture Research Institute. Donor: IFAD.

African Fruit Fly Programme — Collaborators: Benin: IITA; University of Parakou (UP). Cameroon: Service de Protection des Végétaux (SPV); Institute de Recherche Agricole pour le Développement (IRAD); University of Dschang; University of Douala. Germany: Institut für Oekologie und Evolutionsbiologie; Universität Bremen; Max Planck Institute of Chemical Ecology (MPI). Kenya: MoA; KEPHIS; KALRO. Tanzania: Mikocheni Agricultural Research Institute (MARI); Ministry of Agriculture & Food Security; Plant Health Service (MAFS). Donor: BMZ/GIZ.

Thrips IPM Programme (Phases 1&2) — Collaborators: Germany: Institute of Plant Diseases and Plant Protection; Gottfried Wilhelm Leibniz Universitat, Hannover; Martin-Luther-University of Halle-Wittenberg, Halle (Saale). Kenya: KALRO; Real IPM; KEPHIS. New Zealand: Plant and Food Research (PF&R). Taiwan: AVRDC. Tanzania: HORTI-Tengeru. The Netherlands: Plant Research International (PRI), Wageningen. Uganda: National Crops Resources Research Institute (NaCRRI); Makerere University. USA: Washington State University, Pullman. Donors: BMZ/GIZ and African Union.

Leafminer Project (Phases 1&2) — Collaborators: Germany: University of Hohenheim. Kenya: KALRO; FPEAK; KEPHIS; MoA Horticulture Extension Division; Kenyatta University. Peru: CIP; UNALM; AAC; ISTPC; INIA-Cañete. Tanzania: MoA PHS; HORTI-Arusha. Uganda: Makerere University. Donor: BMZ-Germany.

African Indigenous Vegetable Pests Project—Collaborators: Kenya: KALRO Kandara; Germany: The University of Bonn. Taiwan: AVRDC – The World Vegetable Center: Tanzania: HORTI-Arusha. Donor: BMZ/GIZ.

Tuta absoluta Project—Collaborators: Germany: Julius Kühn-Institut. Kenya; KEPHIS. Peru: International Potato Center. Sudan: Agricultural Research Corporation. Republic of South Sudan: Ministry of Agriculture and Rural Development. Tunisia: University of Sousse. Donor: BMZ/GIZ.

Photos: icipe

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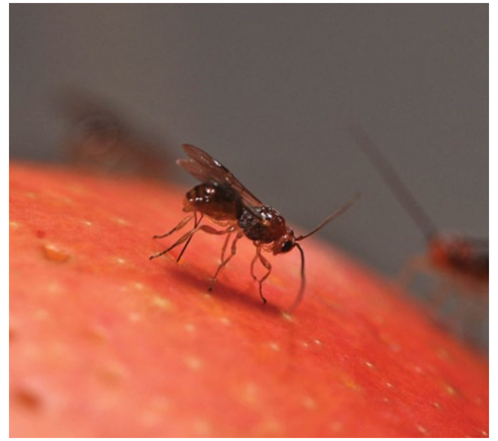
Horticulture

Improving Nutrition, Health and Smallholders' Stake in a Growing Industry

icipe
African Insect Science for Food and Health

Protecting African farmers against native and invasive fruit flies



In sub-Saharan Africa, smallholder farmers grow fruits (such as mango, citrus and avocado), and vegetables targeting the domestic and export markets, thus providing job opportunities and income to the rural poor, especially women and youth. However, fruit flies are a major constraint limiting production of these crops, and can inflict crop losses of up to 40%. The arrival of invasive fruit flies such as *Bactrocera dorsalis* (formerly known as *B. invadens*) has further compounded the problem, as losses are now as high as 90%, and access to lucrative export markets has been hindered due to the quarantine significance of the pests.

Integration of gentle but effective weapons

The *icipe*-led African Fruit Fly Initiative has developed and disseminated in East, West and southern African countries an integrated pest management (IPM) package for fruit flies comprising of food baits to lure adult flies, annihilation of male flies, biopesticide, and proper disposal of infested and fallen fruits using augmentoria (serving the purpose of both orchard sanitation and parasitoids augmentation). The package further includes release of introduced egg parasitic wasps (such as *Fopius arisanus*) and larval parasitic wasps (such as *Diachasmimorpha longicaudata*). Such an IPM approach can suppress fruit flies by 80–90%, and increase mango yields by 30%, valued at US$ 400 to 640 per hectare. Around 21,000 farmers from low-income families, and women, are benefiting from this intervention, paving way towards a more stable mango production, safer ecosystem, and healthier community.

Ensuring invasive fruit fly free fruit exports

Export consignments of fruits and vegetables must be free of fruit flies such as *B. dorsalis*. Eradicating this fruit fly from exports requires effective post-harvest treatments, in addition to integrated pest management (IPM) in the field. Collaborating with partners in export destinations, *icipe* has developed post-harvest cold treatment parameters for citrus and avocado, and has developed hot water treatment parameters for mango. The export horticultural industry can gain access to international export markets to generate foreign exchange, if it implements these treatments.

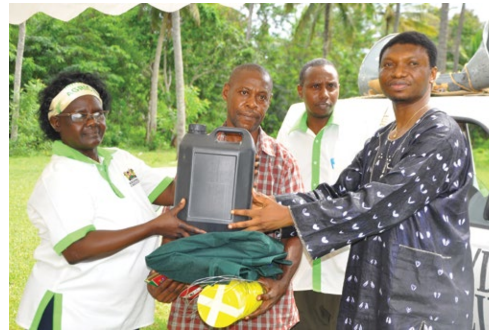
Tackling the menace of the invasive tomato leafminer, *Tuta absoluta,* in Africa

Tuta absoluta, also known as the South American tomato moth, has invaded Africa, and poses a threat to production of tomato on the continent. In Spain and other Mediterranean countries, the pest has caused devastating losses of up to 100% to tomato, and is spreading across the African continent and expanding its host range to attack important indigenous African vegetables (such as nightshades and other solanaceous crops). Cultivating vegetables across political borders,

Left: Egg–larval parasitoid, *Fopius arisanus* parasitising eggs of the invasive fruit fly, *Bactrocera dorsalis.*

Top: An *icipe* fruit fly scientist demonstrates the male annihilation technique to mango growers.

Bottom: An *icipe* fruit fly scientist distributes *icipe* fruit fly IPM starter packs to agricultural extension officers in Kilifi, Kenya.



absence of effective surveillance mechanisms, and lack of phytosanitary expertise for intercepting infested vegetables; coupled with the ever-growing tourism and intra-continental trade, aids the rapid spread of this pest in Africa. Because of the high yield losses, farmers have resorted to calendar use of organophosphates, but these are harmful to humans, bees, and other animals. To strengthen the phytosanitary and surveillance efforts, we have modelled the risk of *Tuta absoluta* invading sub-Saharan Africa. Together with international partners, *icipe* has identified an efficient parasitoid species in the aboriginal home of the pest for management of *Tuta absoluta* in Africa, as well as a potent biopesticide from *Metarhizium anisopliae*. We also encourage farmers to practice farm sanitation, crop rotation, and mass trapping using *T. absoluta* pheromones, for effective management of the pest.

Expanding protection of cabbage from diamondback moth beyond East Africa

Cabbages and kales are among the economically important vegetables in sub-Saharan Africa for the rural and urban poor. However, poor yield due to various factors, mainly pest damage, has prevented smallholder growers from harnessing the economic potential of these cruciferous vegetables. The most devastating pest of cabbage is the diamondback moth (DBM), *Plutella xylostella*, which can destroy the crop to a level where it is no longer marketable. Some strains of DBM are resistant to insecticides, making it difficult to control them.

Top: A close-up view of a pair of *Tuta absoluta* moths on tomato.

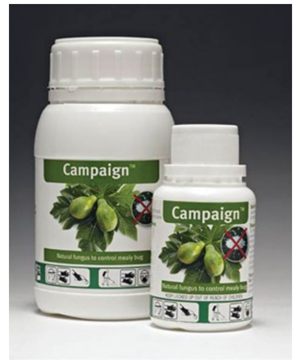
Bottom: Sharing information and knowledge on diamondback moth parasitoids with farmers in Manica district, Mozambique.

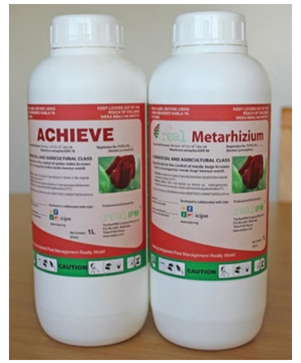
In 2000, *icipe* scientists introduced into East Africa two natural enemies of DBM, tiny wasps known as *Diadegma semiclausum* and *Cotesia plutellae*. While *D. semiclausum* thrives in higher altitudes, the heat-tolerant *C. plutellae* only thrives in lowland and semi-arid conditions. Both parasitoids established and have provided impressive control of the pest, with the estimated economic benefit due to the technology valued at 24 times the value of investment (to conduct the research and implement the technology). In partnership with national research system partners, *icipe* is expanding this technology to other African countries (such as Rwanda, Zambia, Malawi and Mozambique), and has established rearing facilities for DBM natural enemies in Malawi, Mozambique, and Zambia. Farmer field school (FFS) approach has been used to train farmers and extension officers on the use of management strategies compatible with biological control in crucifer-growing regions.

Saving African vegetables from thrips and tospoviruses

Thrips and the tospoviruses they transmit can cause between 20–80% losses to high value crops (such as onion, French beans and tomato), and grain legumes (such as beans and cowpea). Factors such as resistance to synthetic insecticides, invasive nature and cryptic feeding behaviour, coupled with lack of capacity in the region to identify and monitor them, are obstacles to the management of these tiny insects.

Campaign® and Achieve®, outcomes of *icipe*'s private–public partnerships.





In responding to these constraints, scientists in the *icipe*-led Thrips IPM Programme have developed a user-friendly software that is available for free as a Google application to enhance the capacity of quarantine and agricultural extension officers and researchers to diagnose and monitor thrips. The project team also identified a thrips-transmitted tospovirus, the *Iris yellow spot virus,* infecting onions in the region. Prior to this, onion growers had misdiagnosed it as a fungal pathogen, and had resorted to fungicide sprays, but with no improvements. An IPM strategy for thrips and tospoviruses encompassing components such as intercropping, use of biopesticide, host plant resistance, use of agronets, and thrips-attracting plant volatiles, is being demonstrated to vegetable growers across Kenya. More than 100 lead farmers and 15 NARS researchers/extension officers have been trained on monitoring and integrated management of thrips in Kenya and Tanzania through training of trainers courses and field demonstrations in Loitokitok, Mwea, Embu, Kibwezi, Mbita, Wundanyi and Nyeri in Kenya, and Arusha in Tanzania. Further, *icipe* scientists have developed a novel 'lure-and-kill' strategy using an autodissemination device, spot spraying with a biopesticide (*Metarizium anisopliae*), and a thrips attractant (LUREM™). *icipe* scientists have also identified harmless plant-colonising fungi known as 'endophytes' that induce systemic resistance against thrips and thrips-transmitted tospoviruses.

Biological control of *Liriomyza* leafmining flies (LMF)

Liriomyza species, accidentally introduced to East Africa, are among the most important pests of vegetables. Some LMF have quarantine status in Europe, which prevents exports of vegetables from Africa, to the continent. Collaborating with partners from East Africa and South America, *icipe* conducted research on the distribution, damage, and biological control measures of these pests, focusing on release of exotic natural enemies from Peru, which is the aboriginal home of the pest as well as use of biopesticides and botanicals.

Studies revealed that *L. huidobrensis*, the most devastating LMF, is predominant in high, mid and low altitudes in Kenya, whereas *L. trifolii* and *L. sativae* are found in low numbers. Three efficient parasitoids of LMF, *Phaedrotoma scabriventris*, *Halticoptera arduine* and *Chrysocharis flacilla*, identified in CIP, Peru, were introduced and established in *icipe* quarantine facility. Following studies on biology and non-target impacts, and clearing regulatory requirements of KEPHIS, the parasitoids were released in pilot sites in high, mid and low altitudes in Kenya. The three