The *Feed the Future Innovation Lab* for

Integrated Pest Management

Technical Workplan

Fiscal Year 2018

IPM IL | Integrated Pest Management
Innovation Lab

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Vegetable crops and mango IPM in Asia

PI: George Norton

Co PIs: Megan O'Rourke and Maria Elisa Christie, Virginia Tech; Edwin G. Rajotte and Cristina Rosa, Penn State; Sally Miller, Ohio State; Naidu Rayapati, Washington State; Yousuf Mian, BARI; Luke Colavito and Lalit Sah, iDE-Nepal; Michael Roberts and Seng Kim Hian, iDE-Cambodia

Collaborating Institutions: U.S Universities: Virginia Tech, Penn State, Ohio State, Washington State; Bangladesh: Bangladesh Agricultural Research Institute (BARI), Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh Agricultural University (BAU); Nepal: iDE-Nepal, Agricultural and Forestry University (AFU) of Tribhuvan University, Himalayan College of Agricultural Sciences and Technology (HICAST), National Agricultural Research Council (NARC), Center for Environmental and Agricultural Policy Research, Extension, and Development (CEAPRED); Cambodia: iDE-Cambodia, General Directorate of Agriculture (GDA) of the Ministry of Agriculture, Forestry and Fisheries (MAFF), Royal Agricultural University (RUA).

Objective 1: Undertake adaptive research in each country to tailor existing and new vegetable and mango IPM practices and packages to local conditions

Activity 1: Continue crop/pest monitoring (pests defined as insects, diseases, weeds, nematodes, etc.) in Nepal

PIs: Norton, Sah, Rajotte, Miller, Rosa, Rayapati

Site/Location: Nepal

Status: Continuing

Description: This activity will involve:
a) Crop/pest monitoring for *Tuta absoluta* will continue for tomato, especially in the Feed the Future districts.
b) Crop/pest monitoring for other existing and potential pests (see pest definition above) will continue for cucumbers, tomato, onion, chili peppers, okra, eggplant, and beans, especially in the Feed the Future districts and with special attention to identifying potential viruses.
c) Survey of vegetable viral diseases.

Expected outcomes: (1) Increased knowledge of *Tuta absoluta* distribution and its damage in Nepal (2) increased knowledge of other major pests affecting the targeted crops

Activity 2: Continue crop/pest monitoring (pests defined as insects, diseases, weeds, nematodes, etc.) in Bangladesh

PIs: Norton, Mian, Rahman, Rajotte, Miller, Rosa

Site/Location: Bangladesh

Status: Continuing

Description: This activity will involve crop/pest monitoring (pest defined as insects, diseases, weeds, nematodes, etc.) for *Tuta absoluta* and other existing and potential pests will continue for tomato, mango, and other vegetable crops, especially in the Feed the Future districts.

Expected outcomes: Increased knowledge of major pests affecting the targeted crops.

Activity 3: Continue crop/pest monitoring and analyze farm-level baseline survey data and data from crop/pest monitoring in Cambodia

PIs: Norton, Kim Hian, Rajotte, O'Rourke, Miller, Rosa

Site/Location: Cambodia

Status: Continuing

Description: This activity will involve:
a) Selected crop-pest monitoring will continue to verify crop-pest priorities. Special attention will be devoted the collection of plants with viral symptoms and to nematode data. Data collected will be summarized.
b) Data from the previous farm-level baseline survey data will be analyzed to assess which pest management practices are currently being applied on crucifers, cucumber, tomato, long bean, chili peppers, sweet peppers, bitter gourd, and eggplant, and the extent of IPM adoption.

Expected outcomes: Survey results summarized with information on major pests by vegetable crop, current pest management practices, and extent of IPM practice adoption.

Activity 4: Collaborative, on-farm research will be undertaken to design, test, adapt, and evaluate IPM practices in Nepal

PIs: Norton, Sah, Rajotte, O'Rourke, Miller, Rosa

Site/Location: Nepal

Status: Continuing, but practices to be tested will be new for the Nepal site and are designed to fill in gaps in IPM packages.

Description: Collaborative, on-farm research will be undertaken to design, test, adapt, and evaluate IPM practices in replicated on-farm trials with randomized treatments and farmer's practice as a control. Those practices will include:

a) Testing of a fruit and shoot borer package that includes: area-wide lures, clipping shoots, and applying Spinosad and Coragen in 3 week intervals after first symptoms. These practices will be tested in on-farm trials in Banke and the successful ones included in the eggplant IPM packages in subsequent years. NARC entomology scientists will be involved in monitoring and feedback on the trials.

b) Testing tomato pith necrosis IPM practices under polyculture that include removing infected pith and painting wounds with copper oxychoride, reduced nitrogen, and sanitizing tools with bleach during clipping. In this experiment, the existing IPM tomato package will be tested with and without this set of pith necrosis components in on-farm plastic houses. NARC plant pathology scientists will be involved.
c) Trapping of fruit flies with protein bait and cuelure will be tested on farm for cucumbers and bitter gourd. Especial attention will be given to assessing the economic benefits of the protein bait. NARC entomology scientists will be involved in the trial sites.
d) A chili package will be tested on farm that includes raised beds, compost amended with Trichoderma and Pseudomonas, and resistant varieties. One treatment will include grafting as well. NARC plant pathology scientists will be involved.
e) Testing on-farm, a combination of neem and *Bt* to manage *Tuta absoluta.* In addition, there will be an efficacy test of chemical pesticides and biopesticides for the management of *Tuta absoluta*. These trials will occur in an area where Tuta is a major problem. NARC entomology scientists will be involved in the trials.
f) Testing on-farm an IPM package (per our protocols) to manage Tuta absoluta. This trial will occur in an area where Tuta is a problem (Lalitpur, Kavre, Bhaktapur, Kathmandu, Banke and Surkhet). NARC entomology scientists will be involved in the trials.
g) On-station testing of anaerobic soil disinfestation.
h) Test virus management strategies for tomato production under greenhouse conditions. NARC plant pathology scientists will be involved.

The U.S. Asian vegetable and mango IPM IL team will visit the Nepal site during the winter growing season to review progress with local scientists and plan adjustments and future trials.

Expected outcomes: Additional IPM practices on tomatoes, eggplant, chili, cucumber, and bitter gourd will be evaluated for efficacy and cost effectiveness. Recommendations will be made for their future testing in IPM packages and diffusion.

Activity 5: Collaborative, on-farm research will be undertaken to design, test, adapt, and evaluate IPM practices in Bangladesh

PIs: Norton, Mian, Rajotte, O'Rourke, Miller, Rosa

Site/Location: Bangladesh

Status: Continuing, but practices to be tested will be new for the Bangladesh site and are designed to fill in gaps in IPM packages.

Description: Collaborative, on-farm (on-station in some cases) research will be undertaken to design, test, adapt, and evaluate IPM practices in replicated on-farm trials with randomized treatments and farmer's practice as a control. Those practices will include:

a) Test management approaches (cloth bagging for fruit on the tree and bagging with brown paper bags) against mango fruit fly *Bactrocera dorsalis* in three locations: Gazipur, Khagrachari, and

Chapainawabgonj. Demonstrations will also be set up for field days that will assist with dissemination of mango bagging with brown paper under objective 2 below. In addition, treatment for mass trapping with protein-bait for the females and cuelure for the males (combined with picking fruit from the ground) will be continued in northern Bangladesh. (BARI Co-PIs: M.S. Hossain, M. Hossain and B.C. Sarker.

b) Testing on farm of mango leaf hopper IPM practices that include yellow sticky traps and biopesticides (BARI Co-PIs: M.S. Hossain, M. Hossain, B.C. Sarkar).

c) In addition to the monitoring for *Tuta absoluta* severity that will be conducted under Activity 1 above in Panchagorh, Jessore, Comilla, Sylhet and Gazipur, a bio-ecological study will be conducted on *Tuta absoluta* (BARI Co-PIs: M.S. Hossain, A.K. Das). On-farm testing an IPM package to manage *Tuta absoluta* will be conducted by BARI but will not use IPM IL funds.

d) Test IPM management practice using a biocontrol agent to suppress white mold (*Sclerotinia sclerotorium*) on country bean in Bogra and other locations using an on-farm trial with randomized and replicated treatments. In addition, we will explore mycelial growth, sclerotia formation, ascocarp development, ascus and ascospore production and identify physico-chemical and soil ecological factors that influence white mold disease development (in-vivo). (BARI Co-PIs: M. S. Nahar, L. Yasmin, M. N. Naher, M. J. Hossain, M. J. Alam).

e) Test suitable rootstock (at BARI station and in Bogra) for grafting with tomato to combat bacterial wilt disease and develop IPM package for insect, disease, and virus management of summer tomato production in Bangladesh. Viruses will be monitored to identify prevalent ones (BARI Co-PIs: M.A. Goffar, M. M.M.R. Salim, S. Hossain, M.S. Nahar).

f) Test eggplant IPM package a) with grafting and with bacterial resistant hybrids and b) with and without *Bt* eggplant varieties released by BARI with the Cornell-BARI *Bt* eggplant project. (BARI Co-PIs: M.S. Hossain and AKM Qamruzzaman)

The U.S. Asian vegetable and mango IPM IL team will visit the Bangladesh site (security permitting) during the winter growing season to review progress with local scientists and plan adjustments and future trials.

Expected outcomes: Additional IPM practices available for on tomato, eggplant, mango, country bean, and bitter gourd will be evaluated for efficacy and cost effectiveness. Recommendations will be made for their future use in IPM packages and diffusion. IPM recommendations for *Tuta absoluta* in Bangladesh will be based on results of field testing of an IPM package by BARI. The first test of *Bt* eggplant in an IPM package.

Activity 6: Collaborative, on-farm research will be undertaken to design, test, adapt, and evaluate IPM practices in Cambodia

PIs: Norton, Kim Hian, O'Rourke, Rajotte, Miller, Rosa, Rayapati

Site/Location: Cambodia

Status: Continuing

Description: Collaborative, on-farm (in Siem Reap) and on-station (at RUA) research will be undertaken to design, test, adapt, and evaluate IPM practices in replicated trials with randomized treatments and farmer's practice as a control. Many of the practices to be adapted have been developed and applied in other countries such as Bangladesh, India, Nepal, Indonesia, and the Philippines. This year the practices will include, at a minimum:

a) Test cucumber IPM package on farm in Siem Reap. That package includes: Trichoderma seed/seedling/soil treatment, nursery nets, Pheromone traps – Fruit fly bait + Cuelure and Kairomone for fruit fly, Yellow traps, scout for pumpkin beetle; chemical pesticide at threshold; scout for downy mildew – apply fungicides as soon as it appears, staking, roguing for virus, and mulch
b) Test on farm in Siem Reap a Chinese Kale IPM package that includes: Hot water treatment + Trichoderma seed/seedling/soil treatment + Nursery nets + Pheromone traps (DBM, Spodoptera) + Yellow traps + Microbials Bt + Scout for larvae; Bt at threshold + Roguing for virus + Mulching
c) Test on-farm in Siem Reap and on station at RUA a long bean IPM package of Trichoderma, Orange Oil, *Bacillus subtillus*, *Beuvaria basiana*, *Bacillus thuringiensis*, cuelure, sticky traps and pheromone trap for bean pod borer (*Maruca vitrata*).
d) Tomato rootstock evaluation for *Ralstonia* resistance at RUA
e) Monitoring tomatoes for *Tuta absoluta* using pheromone traps at various locations
f) Monitor vegetables (cucumbers, tomatoes, chili peppers, eggplant and long beans) for viruses in all project sites and identify prevalent viruses.
g) Lab test the quality and efficacy of *Trichoderma* spp.

The U.S. Asian vegetable and mango IPM IL team will visit the Cambodia site during the winter growing season to review progress with local scientists and plan adjustments and future trials.

Expected outcomes: Additional IPM practices available for tomatoes, cucumber, beans, and Chinese kale will be evaluated for efficacy and cost effectiveness. Recommendations will be made for their future use in IPM packages and diffusion.

Objective 2: Work with public and private sector partners to diffuse IPM practices and packages to farmers using gender-sensitive approaches to scaling up IPM adoption

Activity 1: a) Implement technology transfer plan developed in year 2 for IPM vegetable and mango.

PIs: Norton, Kim Hian, Mian, Sah, Rajotte, O'Rourke, Miller, Rosa

Site/Location: Cambodia, Bangladesh, Nepal

Status: Continuing

Description: This activity will involve:

a) Conduct IPM farmer field days with NGOs and other partners to raise awareness of horticultural IPM, disseminate IPM practices to farmers in a gender sensitive way, improve local capacity to diagnose IPM problems and conduct IPM research, and spread IPM knowledge more broadly. In Nepal, bulk IPM solutions will be passed through bulk SMS, training of the "Last mile supply chain actors" such as CBF in coordination with other iDE projects.

b) Coordinating with the relevant agricultural value chain projects in Nepal, Bangladesh, and Cambodia such as Harvest II, iDE-Codes, AVRDC home garden projects, and other USAID-supported IL projects, by providing them information on vegetable IPM packages that relate to crops with which those projects are working and giving demonstrations to growers; and supporting them in encouraging market actors to promote information and products that support IPM practices.
c) Coordinate with government agencies such as the PPD in Nepal, PPSP in Cambodia, and DAE in Bangladesh through collaborative workshops, IPM training and promotional materials.

Expected outcomes: (1) Increased vegetable and mango IPM knowledge and diffusion plan in each country, (2) Farmers receive IPM information, (3) Market actors receive IPM information.

Activity 2: Developing specific training aids for use with IPM vegetable and mango technology transfer and pest diagnostics.

PIs: Norton, Kim Hian, Mian, Sah, Rajotte, O'Rourke, Miller, Rosa

Site/Location: Cambodia, Bangladesh, Nepal

Status: Continuing

Description: This activity will involve:

a) Developing IPM training aids and help train trainers using fact sheets, pest identification guides [including pest diagnostic cards for each pest (insect, disease, nematode, virus, weed) for each relevant vegetable crop in each country], and other guides based on IPM research results. The trainers trained to use these aids will come from groups such as the public agricultural extension services in each country, NGOs, USAID value chain projects, and input supply firms.
b) Initiating a program to expand the use of mobile phones to transfer IPM solutions in Nepal through bulk SMS.

Expected outcomes: Training aids developed for IPM diffusion in each country.

Objective 3: Improve the human and institutional capacity for developing and diffusing horticultural IPM in Nepal, Cambodia, and Bangladesh

Activity 1: Graduate degree training in IPM in the United States and in host countries in entomology, plant pathology, agricultural economics, and gender studies

PIs: Norton, O'Rourke, Christie, Rajotte, Rosa, and Miller, Kim Hian, Sah and Mian

Site/Location: Cambodia, Bangladesh, Nepal

Status: Continuing

Description: Graduate training will include one PhD student in agricultural economics and an MS student in geography and gender studies at Virginia Tech, a PhD student in entomology at Penn State, one in plant pathology at Ohio State, and a PhD student in agricultural economics at Tribhuvan University in Nepal. In addition, undergraduate and/or MS thesis research will be supported for 3-5 students at RUA in Cambodia and two at HICAST in Nepal.

Expected outcomes: Eventually the students listed above will complete PhD or MS degrees and return to their home countries (each student, except the gender studies student and the new Ag Econ Ph.D. student, is from the host countries).

Activity 2: Short-term training/workshops for scientists and others on IPM research, practices, and pest diagnostics.

PIs: Norton, O'Rourke, Christie, Rajotte, Rosa, Rayapati, Miller, Kim Hian, Sah and Mian

Site/Location: Cambodia, Bangladesh, Nepal

Status: Continuing

Description: a) Use two-week review and planning visit by U.S. scientists to the countries as time to conduct an IPM research workshop, b) Conduct insect pest and disease diagnostics workshop.

Expected outcomes: Information on research-based IPM packages and methods for pest diagnostics spread among scientists.

Objective 4: Evaluate outcomes and impacts (economic, environmental, gender) of the IPM program

Activity 1: Summarize data from farm-level surveys and IPM trials and assess factors affecting IPM adoption and pesticide use

PIs: Norton, O'Rourke, Christie, Kim Hian, Sah and Mian

Site/Location: Cambodia, Bangladesh, Nepal

Status: Continuing

Description: Yield, cost, income, and environmental (pesticide-related) impacts of IPM activities will continue to be assessed. Survey and other household data from each country program will used in the analyses along with data from the various on-farm trials. Farm-household- and market-level benefits will be calculated for IPM practices and packages where appropriate. These studies will be conducted as part of theses and dissertations and eventually published in papers. Papers based on completed theses, will be submitted to journals. One Cambodian scientist will participate and present the results of IPM trials at the Annual Meeting of the Entomology Society of America, Nov 2017.

Expected outcomes: Preliminary economic, environmental, and gender analyses conducted.

Activity 2: Assess gender impacts of IPM practices, packages, and policies and means for improving gender-sensitivity in IPM diffusion (scaling up activities).

PIs: Christie, Norton, Kim Hian, Sah and Mian

Site/Location: Cambodia, Bangladesh, Nepal

Status: Continuing

Description: Gender impacts of IPM activities and policies will be assessed. Survey data from baseline surveys in Nepal and Cambodia and from qualitative analysis in Nepal will analyzed with respect to gender constraints and opportunities for adoption. Gender analysis will examine: 1) beliefs and perceptions about pest management practices, 2) household decision making on pest management practices, 3) access to extension services and information, 4) knowledge of crops, pests, and traditional pest management practices, 5) attitudes toward health consequences of pesticide use, and 6) who benefits from and controls income from plots where IPM is used, among other topics. The IPM diffusion process in each country will be examined (analyzed) from a gender perspective and recommendations made to facilitate IPM scaling strategies that include a gender perspective.

Expected outcomes: Preliminary gender analyses conducted for Nepal, and recommendations made for gender-sensitive IPM scaling strategies.

Objective 5: Identify policies and regulations that affect the viability and spread of IPM in the target countries and inform officials of policy changes that would be socially, economically, and environmentally beneficial.

Activity 1: Finish review of existing and potential policies and regulations that affect the viability and spread of IPM in each of the target countries and of the factors that may influence those policies and regulations

PIs: Norton, O'Rourke, Christie, Mian, Sah, Kim Hian

Site/Location: Cambodia, Bangladesh, Nepal

Status: Continuing

Description: Finish review and analysis of existing and potential policies and regulations that affect the viability and spread of IPM in the target countries and of the factors that may influence those policies and regulations. Previous analyses of polices and regulations will finish being reviewed for each country and identification made of key constraints and groups that might be involved in promoting policy changes where warranted. (Co-PIs: M. Sayed Issa in U.S; Y. Mian in Bangladesh; L. Sah in Nepal; S. Kim Hian in Cambodia)

Expected outcomes: Policies affecting IPM summarized and policy recommendations made.

Graduate Students and Post-Doctoral Research Associates:

1. Name: Farhanaz Sharmin
Sex: Female
Nationality: Bangladesh
Discipline: Agricultural Economics
Site/Country: Bangladesh
Degree: Ph.D.
Start date: October 1, 2015
Completion date: December 2017.
IPM IL funds: 0% (Started program in 2014 on Bangladesh Associate award and now has used up her allocated funds on the IPM IL. She will finish on her own resources by December)
Advisor/PI: George Norton
Thesis topic: Effects of IPM Training on Knowledge Building, Adoption, and Pesticide Use in Bangladesh
University: Virginia Tech

2. Name: Alexis Villacis-Aveiga
Sex: Male
Nationality: U.S.
Discipline: Agricultural Economics
Site/Country: Cambodia
Degree: PhD
Start date: August 16, 2017
Completion date: September 2020.
IPM IL funds: 100% (Started program as a teaching assistant in August 2016 and switched to IPM IL funds for research in August 2017)
Advisor/PI: George Norton
Thesis topic: Economic impacts of vegetable IPM in Cambodia
University: Virginia Tech

3. Name: Arjun Kanel (Sandwich student)
Sex: Male
Nationality: Nepal
Discipline: Agricultural Economics
Site/Country: Nepal
Degree: PhD
Start date: October 1, 2015
Completion date: December 2017.
IPM IL funds: 100% (Started program in previous phase of IPM IL and has now used up allocated funds. He will finish on his own funds by December 2017)
Advisor/PI: George Norton
Thesis topic: Economic impacts of vegetable IPM in Nepal
University: Tribhuvan University (Sandwich program with Virginia Tech)

4. Name: Sulav Paudel
Sex: Male
Nationality: Nepal

Discipline: Entomology
Site/Country: Nepal
Degree: PhD
Start date: August 2016, 2016
Completion date: October, 2019.
IPM IL funds: 100%
Advisor: Ed Rajotte and Cristina Rosa
Thesis topic: TBD
University: Penn State

5. Name: Kaitlyn Spangler
Sex: Female
Nationality: U.S.
Discipline: Gender Studies through Geography Department
Site/Country: Nepal
Degree: MS
Start date: August, 2016
Completion date: July 2018.
IPM IL funds: 100%
Advisor: Maria Elisa Christie
Thesis topic: Implications for IPM of the feminization of agriculture in Nepal
University: Virginia Tech

6. Name: Ram Bahadur Khadka
Sex: Male
Nationality: Nepal
Discipline: Plant Pathology
Site/Country: Nepal
Degree: PhD
Start date: August, 2016
Completion date: October 2019.
IPM IL funds: 100% except for the tuition, which is paid for by Ohio State
Advisor: Sally Miller
Thesis topic: Application of Nepalese *Trichoderma* spp. with Anaerobic Soil Disinfestation (ASD) to Control Soil-borne Diseases and Effect of ASD on Weeds
University: Ohio State University

7. Name: Majd Sayed Issa
Sex: Male
Degree: Post Doc in U.S.
Discipline: Agricultural Economics
Start Date: February 16, 2017
End Date: August 2019
IPM IL funds: 25%
Advisor/PI: George Norton
Topic: Objective 5 to review policies and regulations that affect viability and spread of IPM in the target countries and assess policy changes that would be socially, economically, and environmentally beneficial
University: Virginia Tech

8. If funding permits, we will add a sandwich program Master's student from RUA to Ohio State for plant pathology.

Short-Term Training planned

- Annual meetings in Cambodia, Nepal, and Bangladesh
- Disease diagnostic workshops in Cambodia
- Virus diagnostic training in Cambodia and Nepal

Publications planned:

- Theses: 2
- Research articles: 2
- Books and book chapters: 2
- Posters: 1
- Conference abstracts: 2
- Extension articles: 2

Biological Control of the Invasive Weed *Parthenium hysterophorus* in East Africa

PI: Wondi Mersie, Virginia State University (VSU), Petersburg, VA

CO PIs: Sintu Alemayehu (VSU-Ethiopia), Samuel Assefa (GTZ, Ethiopia), Maria Elisa Christie (Virginia Tech), Samora Macrice (Sokoine University – Tanzania), Ramadhan Kilewa (Tropical Pesticides Research Institute (TPRI) – Tanzania), Richard Molo (National Agricultural Research Organization – Uganda), Mulugeta Negeri (Ambo University (AU) – Ethiopia), Tesfay Amare (AU) - Ethiopia), Lisanework Nigatu (Haramaya University (HU) – Ethiopia), Lorraine Strathie (Agricultural Research Council – Plant Protection Research Institute (ARC-PPRI) South Africa), Arne Witt (CABI-Kenya), Birru Yitaferu (Amhara Regional Agricultural Research Institute (ARARI) – Ethiopia), Kassahun Zewdie (Ethiopian Institute of Agricultural Research (EIAR)).

Collaborating Institutions:

- Virginia Tech
- Ethiopia
    - Ambo University (AU)
    - Amhara Regional Agricultural Research Institute (ARARI)
    - Ethiopian Institute of Agricultural Research (EIAR)
    - Haramaya University (HU)
- South Africa – ARC-PPRC
- Tanzania

    - Sokoine University of Agriculture (SUA)
    - Tropical Pesticides Research Institute (TPRI)
- Uganda – National Agricultural Research Organization (NARO)

Objective 1: Scale-up the rearing and release of the two approved bio-control agents, the leaf-feeding beetle *Zygogramma bicolorata* and the stem-boring weevil *Listronotus setosipennis* in parthenium infested areas of Ethiopia

Activity 1: Maintain and expand biocontrol agent rearing facilities in Ethiopia

PIs: Wondi Mersie, Sintu Alemayehu, Tesfay Amare, Mulugeta Negari, Lisanework Nigatu
Site/Location: Wollenchiti, Guder (Ambo University), and Haramaya

Status: Continuing

Description: Three major rearing facilities were established to cover the central, western and eastern Ethiopia. The primary site will continue to be in central Ethiopia at Wollenchiti, which has been operational since 2013; the other two will be in western Ethiopia at Guder (Ambo University –AU) and eastern Ethiopia at Haramaya University (HU). The Guder rearing facility will supply the leaf-feeding beetle *Zygogramma bicolorata* and the stem-boring weevil *Listronotus setosipennis* to western Ethiopia. The rearing facility at HU will supply both biocontrol agents to the eastern region of Ethiopia including to the parthenium infested rangelands of the Somalia Region. The Wollenchiti site will provide biocontrol agents to central and northern Ethiopia. Each rearing site will have at least three rearing cages (5 m x 7 m). Two of the cages will be used for each bioagent and the third will serve as a nursery. Parthenium in pots will be grown at each site for rearing the bioagents. Adults will be collected periodically and released in parthenium infested fields. The sites will also be used to demonstrate the specificity of the bioagents to parthenium to farmers and the community as a whole.

Expected outcomes: Mass rearing facilities are maintained and expanded; *Zygogramma* and *Listronotus* are mass-reared and released in parthenium infested areas of Ethiopia; Personnel are trained on how to mass rear bioagents.

Objective 2- To evaluate the establishment and impact of the released agents on parthenium, crops, and biodiversity

Activity 1: Collect baseline and performance data on the establishment and spread of biocontrol agents

Site/Location: Guder and Haramaya

Status: Continuing

Description: This evaluation will have three parts: 1) collect baseline data on the seed bank and above-ground parts before the release of the bioagents at selected sites; 2) measure the establishment, prevalence, abundance, and spread of the released biological agents over space and time after release; 3) determine the impact of the bioagents on weed, crop yield, and diversity of the seed bank, as well as on above-ground vegetation. These activities will be conducted at Guder and Haramaya. Parthenium before and after release and agent presence after release will be measured. **Abundance of parthenium:** Number of plants; height; above-ground, below-ground and total biomass; number of flowers per plant;

parthenium seed bank. **Abundance of bioagent:** Number of adults, larvae, eggs per plant or pupae in a specified soil sample. **Extent of damage:** Number of defoliating plants; extent of defoliation on visual score of 0-5 (0=no defoliation; 5=complete defoliation); percent leaf area damage.

Expected outcomes: Data on the abundance and level of damage by each agent at each locality is available. Data on biodiversity is collected. Data on the establishment, abundance and spread of each bioagent becomes available.

Objective 3: To evaluate new parthenium bio-control agents for their safety to non-target plant species under quarantine and, if safe, to seek permits from the Ethiopian government and USAID for their release.

Activity 1: Host-range evaluation of the seed-feeding weevil, *Smicronyx lutulentus*

PI: Teshale Daba

Site/Location: Ambo

Status: Suspended

Description: A permit to introduce the cultures of the seed-feeding weevil, *Smicronyx lutulentus* and the day-flying, clear-wing moth *Carmenta sp* nr. *Ithacae* was received in 2015. Pursuant to receiving the permit, a culture of Smicronyx was brought from South Africa and introduced to the quarantine facility at Ambo, Ethiopia at the Ethiopian Institute of Agricultural Research (EIAR) facility. Adults were placed on newly emerged flower buds and the emerging larvae of Smicronyx were transferred to pupation boxes filled with soil and watered regularly. However, EIAR staff reported that no emergence of adults from these pupation boxes has been observed. The monitoring continued in 2017 and no adult emergence was observed. So, implementation of this objective will be suspended in 2018 until the cause for the lack of emergence is determined.

Objective 4: To scale-up the release and monitoring of *Zygogramma bicolorata* in Tanzania, and to obtain the necessary permits for field release of Zygogramma in Uganda; and to release Listronotus and other natural enemies (evaluated in Ethiopia) in Tanzania, and Uganda

Activity 1: Undertake surveys to determine if previous releases of *Z. bicolorata* in Tanzania have resulted in establishment

Co-PI: Samora Macrice

Site: In and around Arusha, Tanzania

Status: Establishment was not confirmed – surveys will continue

Description: Two surveys were undertaken at all of the previous release sites – no establishment was confirmed. No larvae or adults were seen and there was no feeding damage. Will continue to undertake surveys in 2018.

Expected outcomes: Advancement of ecologically-based biocontrol technologies for managing parthenium in East Africa

Activity 2: Import, mass rear and release *Z. bicolorata* in Tanzania

Co-PI: Samora Macrice at Sokoine University (SU) and Ramadhan Kilewa at Tropical Pesticides Research Institute (TPRI)

Site: Mass rearing will take place at the Tropical Pesticides Research Institute (TPRI) in Arusha and releases will be made in and around Arusha, Tanzania

Status: Mass rearing site has been identified at TPRI, tunnels have been acquired and set-up and additional equipment purchased to undertake rearing of the biocontrol agent.

Description: An agreement for TPRI to work with Sokoine University has been drawn up. Tunnels have been acquired and move to the identified site at TPRI. Pots, potting soil and other material required to grow parthenium plants and rearing of the beetle have been purchased. The site and the rearing facility will be further expanded in 2018 to increase the number of Z. bicolorata produced at this facility. Staff from SU and TPRI will be trained in Ethiopia on the rearing of approved bioagents for parthenium control.

Expected outcomes: Field establishment of Zygogramma in Tanzania.

Activity 3: Apply for permission to import, mass rear and release *Z. bicolorata* in Uganda

Co-PIs: Richard Molo (Uganda)

Site: If importation is approved the bioagent agent will be shipped to Entebbe, Uganda. Mass rearing will take place in Entebbe.

Status: A Risk Assessment (RA) has been completed for the proposed importation of *Z. bicolorata* into Uganda.

Description: NARO has managed to acquire additional funds which will allow then to undertake additional host-range (HR) testing if required to do so. If permission for release is granted the beetle will be imported from South Africa, mass reared and released in Uganda in 2018.

Expected outcomes: Advancement of ecologically-based biocontrol technologies for managing parthenium in East Africa

Activity 4: Undertake trials/research to determine the impacts of parthenium weed on crop and pasture production

Co-PIs: Samora Macrice and Richard Molo

Site: In all project countries - Tanzania and Uganda

Status: Students that will undertake most of this research and set-up the demonstration trials have been identified in Tanzania – they have also registered for their degrees.

Description: Students in each of the two countries will undertake research to determine the impacts of parthenium weed on crop and pasture production. These trials will be set-up in such a way so as to fulfill another function that of demonstration trials, to raise awareness of the impacts of parthenium weed. It is envisaged that these trials will continue in 2018.
Expected outcomes: Improved knowledge sharing, awareness and education on biocontrol of parthenium, through increased capacity of stakeholders in Uganda and Tanzania

Graduate and undergraduate students sponsored by the project

- Leticia J. Musese, MSc – Sokoine University of Agriculture, Tanzania - Impact of parthenium weed on rangelands.
- Joyce Christopher, MSc - Sokoine University of Agriculture, Tanzania - Monitoring of establishment, efficacy and host specificity of *Z. bicolorata* in the field.
- Hamis Wambura, MSc – Sokoine University of Agriculture, Tanzania - Impact of parthenium weed on crop production.

Short term training planned: A training session in Ethiopia will be held on mass-rearing of the leaf-feeding beetle *Zygogramma bicolorata* and the stem-boring weevil *Listronotus setosipennis*; location: Guder, Ethiopia; date; December 2017; type: hands-on demonstration of rearing techniques; number: 20; 12 males and 8 females.

Publications planned:
Thesis: If any of the above students complete their thesis research and write on time there will be a publication.

Article: Host-range evaluation of the stem-boring weevil *Listronotus setosipennis* in Ethiopia
Book chapter: none

Poster: Challenges in rearing the leaf-feeding beetle *Zygogramma bicolorata* for mass-rearing.
Posters and other awareness material will be developed and disseminated in late 2018
Conference Abstracts: Challenges in rearing the leaf-feeding beetle *Zygogramma bicolorata* for mass-rearing

Technical bulletin: None
Extension bulletin: Relationship between weed density and agent population
Other

A High-resolution Interaction Based Approach to Modeling the Spread of Agricultural Invasive Species

PI
Abhijin Adiga

CO PIs
Nicolas Desneux, Thierry Brévault, J. B. van Kretschmar, Godshen Robert Pallipparambil, Madhav Marathe, Stephen Eubank, Achla Marathe

Collaborating Institutions
Virginia Tech, Biocomplexity Institute, Blacksburg, VA 24061, USA
CIRAD (French agricultural research and international cooperation organization) and BIOPASS Lab (Biology of Sahelo-Sudanian animal populations), Senegal
French National Institute for Agricultural Research (INRA), France
North Carolina State University (NCSU) Center for Integrated Pest Management (CIPM)
Indian Institute of Horticultural Research (IIHR), India
University of Catania, Via Santa Sofia 100, Catania, Italy
Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA), Centro Ricerche Casaccia, Via Anguillarese 301, 00123, Roma, Italy
Center for the Analysis of Sustainable Agricultural Systems Global (CASAS Global), Kensington, CA, 94707-1035, USA

Objective 1: The spread of *T. absoluta* and its impact in Nepal

Activity 1: Model enhancements

PIs: Abhijin Adiga, Srinivasan Venkatramanan, Achla Marathe

Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA

Status: Continuing

Description: We investigate the spread of *T. absoluta*, long-term establishment and its economic impact in Nepal. A version of this work was submitted and has been reviewed. Currently, we are working on making improvements based on suggestions by the reviewers. Specific improvements include (i) incorporating spatial spread of the pest (ii) incorporating phenological data.

Expected outcomes: Draft will be submitted for possible publication.

Objective 2: Assessment of threat of *T. absoluta* to North America

Activity 1: Analysis of USDA APHIS Pest Interception Database (PestID)

PIs: Abhijin Adiga, Youngyun Chungbaek, Srinivasan Venkatramanan

Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA

Status: New

Description: The PestID is comprised of records of pests intercepted by APHIS personnel during inspections of travelers' baggage, cargo, conveyances and related items arriving at U.S. ports of entry and border crossings. To assess the threat of *T. absoluta* to US, it is critical to analyze this data source. Currently we are in the process of developing an MoU between Virginia Tech and USDA APHIS to gain access to the data. Analysis will focus on (i) identifying countries/regions which pose the highest risk for US, (ii) mode/pathways of invasion: trade/travel, (iii) variations in annual trade/travel patterns.

Expected outcomes: MoU will be submitted. Datasets will be analyzed and documented.

Activity 2: Analysis of production data sources

PIs: Abhijin Adiga, Youngyun Chungbaek, Srinivasan Venkatramanan

Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA

Status: Continuing

Description: In the previous phase, we identified several high-resolution datasets on tomato production which contain (i) county-level area, yield and volume data (ERS), (ii) information on greenhouse production and outdoor production (NASS), (iii) company names and operations (GFSi certification schemes) and (iv) survey data (Vegesumm and Agcensus from NASS). We will continue the analysis of these data sources.

Expected outcomes: High-resolution distribution of tomato production for the US will be constructed by integrating these datasets. This will include production distribution by volume, type of cultivation as well as operations (fields, storage houses, distribution centers, etc.). This analysis will identify areas that will be impacted by possible *T. absoluta* invasion. Analysis will be documented.

Activity 3: Analysis of international and domestic trade

PIs: Abhijin Adiga, Youngyun Chungbaek, Srinivasan Venkatramanan

Site/Location NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA

Status: New

Description: We have identified potential data sources to model imports/exports (FAOstat, USATrade) and domestic commodity flows in North America (FAF). These datasets will be analyzed.

Expected outcomes: This analysis will identify possible points of entry for pests and hubs for vegetable (and in particular tomato) trade. Analysis will be documented.

Objective 3: Assessment of threat of *T. absoluta* to South-east Asia

Activity 1: Data exploration: Climate, production and trade

PIs: Abhijin Adiga, Srinivasan Venkatramanan

Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA

Status: Continuing

Description: This work will focus on South-east Asian countries. It will include Bangladesh and China in the study to assess the risk of *T. absoluta* to these countries. It will seek to collaborate with AVRDC (BMZ/GIZ funded project). Data on trade (markets, trade routes, imports and exports), production, consumption indicators (population, GDP), climatic factors will be collected for these countries.

Expected outcomes: Collected datasets will be curated and standardized.
Datasets will be analyzed using approaches of Objective 1. Data gaps will be identified.
This work will provide light on vulnerable regions, important hubs and possible entry points of the pest for the focus countries.

Activity 2: Model development

PIs: Abhijin Adiga, Srinivasan Venkatramanan

Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA

Status: New

Description: The modeling framework developed for Objective 1 will be adapted for this purpose. This work will study various counterfactual scenarios to assess the threat of *T. absoluta* to this region.

Expected outcomes: This work will provide possible routes taken by *T. absoluta* should it be introduced into this region. Analysis will be documented.

Objective 4: Assistance in *T. absoluta* website development

Activity 1: Help with infographics and visualization

PI: Abhijin Adiga

Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA

Status: New

Description: NDSSL will work with IPM-IL in developing visualizations of data pertaining to *T. absoluta*.
Expected outcomes: A javascript implementation on *T. absoluta* spread across the globe will be implemented. Data on historical reports of *T. absoluta* will be visualized.

Objective 5: Biological and ecological determinants of *T. absoluta* invasion in sub-Saharan Africa

Activity 1: Routes of introduction

PI: Thierry Brévault

Site/Location: Biopass, Senegal

Status: Continuing

Description: In collaboration with another research project on *T. absoluta* (JEAI IBAO), we are currently analyzing the genetic variability of *T. absoluta* samples collected in North and West African countries, using microsatellite markers and COI gene sequencing (see Guillemaud et al., 2015).

Expected outcomes: Routes of introduction of the invasive pest and possible genetic structuring in West Africa. Improved regulatory framework for quarantine pest monitoring and phytosanitary import requirements.

Activity 2: Demographic parameters

PI: Anaïs Chailleux

Site/Location: Senegal

Status: Continuing

Description: Classical bioassays in temperature-controlled chambers are carried out to evaluate the impact of high temperatures on *T. absoluta* and its major natural enemy in Senegal, *Nesidiocoris tenuis*. The objectives are to (i) establish life tables of Senegalese strains of *T. absoluta*, and to (ii) assess predation capacity of *N. tenuis*, e.g. under high temperatures and low relative humidity as experienced in Senegal during dry season.

Expected outcomes: Data on population growth of *T. absoluta*, particularly under hot temperatures as encountered in savanna biomes in West Africa. Improved practices for integrated pest management.

Activity 3: Distribution and carrying capacity of host plants

PI: Serigne Sylla

Site/Location: Senegal

Status: Completed

Description: Greenhouse experiments (mesocosm) with tomato plants and other host plants identified in Senegal (including wild host plants) were carried out to evaluate the effect of host plants on the population parameters of *T. absoluta*. We tested the oviposition preference (choice and no choice situations) of adults and the ability of larvae to develop on different host plants (carrying capacity).

Another field study was conducted during the rainy season to explain observed decrease of populations at that time. The objective of the study was to identify factors that can explain the reduction of its population during the rainy season.

Expected outcomes: Improved pest management practices (better knowledge of other cultivated solanaceous crops acting as source or reservoir of *Tuta absoluta* populations).

Activity 4: Impact of crop management and landscape context

PI: Thierry Brévault

Site/Location: Senegal

Status: Completed

Description: Monitoring of a network of 25 focal tomato fields in a highly-infested area (Niayes) on 3 crop cycles (2015-2017 seasons) to assess the effect of crop management (particularly insecticide use) and landscape context on *T. absoluta* abundance and natural pest control. Two academic publications in preparation.

Expected outcomes: Improved pest management practices including recommendations on crop management and features of pest-suppressive landscapes.

Activity 5: Impact of natural enemies

PI : Anaïs Chailleux

Site/Location: Senegal

Status: Continuing

Description: Parasitoids of *Tuta absoluta* collected in Activity 4 have been conserved for further morphological and molecular identification at UMR CBGP (Montpellier, France). Other observations from Activity 4 highlighted the potential of an indigenous predator, *Nesidiocoris tenuis*, for biocontrol. We are currently evaluating the local and landscape determinants of its efficacy in tomato fields, and searching for alternative plants in the surrounding landscape.

Expected outcomes: Improved practices for conservation biological control and detection of new biological control agents.

Activity 6: Commercial trade of fresh tomato in Senegal

PI : Thierry Brévault

Site/Location: Senegal

Status: Continuing

Description: A study has been launched to map commercial flows of tomato in Senegal, and examine their potential role in the rapid expansion of *Tuta absoluta*. This activity will provide a data set that can be used to accurately model international and domestic commodity flow (similar to Objectives 1 and 3).

Expected outcomes: Identify patterns of commodity flows and assess the vulnerability of countries to biological invasion.

Objective 6: Physiologically-based Demographic Models for *T. absoluta*

Activity 1: Temperature and photoperiod diapause induction

PI: Mateus Ribeiro de Campos

Site/Location: INRA

Status: continuing

Description: We are characterizing key ecological parameters in order to design a PBDM (Physiologically-based Demographic Model) model for *T. absoluta*. In a first step, we are studying the effects on *T. absoluta* diapause induction of temperature and photoperiod at different exposure durations. For this, 3rd and 4th instar *T. absoluta* larvae are being exposed to different temperatures (2, 5 and 10 °C) at different photoperiods (10:14 vs 14:10, 15:09 vs 09:15, 18:06 vs 06:18 of Light and dark) and at different time intervals, 7, 14, 28 and 42 days. After exposure larvae and/or developed pupae are evaluated for survival and reproduction. The data in the temperature at 2 °C and photoperiods 10:14 vs 14:10, 15:09 vs 09:15 and different intervals times 7, 14, 28 and 42 days have been already developed. We are collecting data in the temperature at 2 °C in the photoperiods 15:09 vs 09:15 in different intervals times 7, 14, 28 and 42 days. We will collect data of temperature at 5 and 10° C in different photoperiods and time interval, as described above.

Expected outcomes: The obtained results will help understanding for the first time the potential diapause induction by acute environmental factors, new insights on overwintering attitude of *T. absoluta* will be gained. Altogether, these results will be essential for developing a most accurate PBDM for predicting *T. absoluta* demographical dynamics and survival in those non-tropical areas where such environmental conditions can happen.

Activity 2: Suitability and overwintering potential of the European black nightshade (*Solanum nigrum*) as alternative host plant for *Tuta absoluta*

PIs Antonio Biondi and Mateus Ribeiro de Campos

Site/Location University of Catania and INRA

Status: continuing

Description: We are studying the oviposition preference and the biological performances of *T. absoluta* between the common crop host plant (tomato) and an alternative host plant, among the favorite weed hosts, the widespread European black nightshade (*Solanum nigrum*). Indeed, although *T. absoluta* prefers tomato, it can also feed, develop and reproduce on other cultivated Solanaceae as well as on

non-cultivated Solanaceae such as *S. nigrum*. Alternative host plant has been neglected until the moment and there is a few information on the *T. absoluta* biology in alternative host plant. In this way, biology and behavior of *T. absoluta* in *S. nigrum* is important information for the PBDM development. The objectives are (i) to provide data on immature developmental times and survival, pupal weight, age specific fecundity, net reproductive rate, intrinsic rate of increase, and mean generation time on tomato (*Solanum lycopersicum*) and on *S. nigrum* in the temperature at 25 °C, (ii) verify the per capita fecundity profile on female age in the temperature at 25 °C on *S. lycopersicum* and *S. nigrum*, and (iii) provide information on survival of pupae exposed in low temperature at 4°C for in different time intervals (7, 14 and 21 days).

Expected outcomes: Developed data will be useful for understanding how this important alternative wild plant can support *T. absoluta* generations during winter in those areas where the main crop is absent on that season. Data will also be incorporated into the PBDM model.

Activity 3: *Tuta absoluta* juvenile development and reproduction at high and low temperatures

PI: Mateus Ribeiro de Campos

Site/Location: INRA

Status: continuing

Description: Bioassays at temperature-controlled conditions have been and are being carried out to evaluate the impact the low and high temperatures on *T. absoluta* biology. The objective is (i) to provide data on oviposition, age-specific fertility and survival of females developed (eggs to adults) at temperatures of 6, 10, 15 and 20 °C, (ii) verify on young instars development duration and survival at temperatures of 30, 33 and 36°C.

Expected outcomes: The obtained data will be useful to fill the knowledge gaps on the biology of *T. absoluta* at low and high temperatures. These data are essential for developing an accurate PBDM.

Objective 7: East Africa Invasive Groundnut Leafminer DNA Sequencing Project: Collection of Groundnut leafminer larvae from groundnut and soybean fields in E. Africa

Activity 1: Collection of larvae from Uganda

PIs: J. B. van Kretschmar, Godshen Robert Pallipparambil, Dr. Moses Biruma (Program leader, oilcrops) and Mr. Dennis Gayi (entomologist), NaSARRI (Nationa Semi Arid Resources Research Institute), P.O. Box 56, Soroti, Uganda

Site/Location: Identification of groundnut and soybean sites pending.

Status: New

Description: Late instars will be collected from host plants and shipped to NCSU CIPM for sequence analysis.

Expected outcome: Species will be confirmed on the basis of sequence alignment with sequences generated for reference specimens (*Aproaerema modicella* and *A. simplexella*).

Activity 2: Collection of larvae from Malawi

PIs: J. B. van Kretschmar, Godshen Robert Pallipparambil, Dr. Donald Kachigamba (entomologist) and Mrs. Trust Donga (entomologist), LUANAR (Lilongwe University of Agriculture & Natural Resources), Bunda College Campus, P.O. Box 219, Lilongwe, Malawi

Site/Location: Identification of groundnut and soybean sites pending.

Status: New

Description: Late instars will be collected from host plants and shipped to NCSU CIPM for sequence analysis.

Expected outcome: Species will be confirmed on the basis of sequence alignment with sequences generated for reference specimens (*Aproaerema modicella* and *A. simplexella*).

Activity 3: Collection of larvae from South Africa

PIs: J. B. van Kretschmar, Godshen Robert Pallipparambil, Dr. Hannalene du Plessis (Associate Professor), Unit for Environmental Sciences and Management, North-West University, Potchefstroom, South Africa

Site/Location: Identification of groundnut and soybean sites pending.

Status: New

Description: Late instars will be collected from host plants and shipped to NCSU CIPM for sequence analysis.

Expected outcome: Species will be confirmed on the basis of sequence alignment with sequences generated for reference specimens (*Aproaerema modicella* and *A. simplexella*).

Activity 4: Collection of *Aproaerema modicella* larvae from groundnut fields in Asia

PIs: J. B. van Kretschmar, Godshen Robert Pallipparambil, Others: Finalization pending

Site/Location: Identification of groundnut sites in Asia pending.

Status: New

Description: Late instars will be collected from host plants and shipped to NCSU CIPM for sequence analysis.

Expected outcome: These *A. modicella* sequences will function as reference-standards for alignment of sequences from larvae collected in East Africa.

Activity 5: Collection of *Aproaerema simplexella* larvae from soybean fields in Australia.

PIs: J. B. van Kretschmar, Godshen Robert Pallipparambil, Others: Finalization pending

Site/Location: Identification of groundnut sites in Asia pending.

Status: New

Description: Late instars will be collected from host plants and shipped to NCSU CIPM for sequence analysis.

Expected outcome: These *A. simplexella* sequences will function as reference-standards for alignment of sequences from larvae collected in East Africa.

Objective 8: DNA sequence analysis of Gelichiidae larvae collected from groundnuts and soybeans in E. Africa, Asia, and Australia

Activity 1: Isolation and amplification of mitochondrial CO1 and nuclear ITS2 DNA

PIs: J. B. van Kretschmar, Ph.D, and Godshen Robert Pallipparambil, Ph.D.

Site/Location: NCSU

Status: New

Description: Total DNA will be isolated from 10 individual larvae from each collection site. Primers appropriate to the targeted CO1 and ITS2 will be used during amplification to provide DNA for sequence analysis.

Expected outcome: Purified target-sequence DNA will be of sufficient quantity for sequencing.

Activity 2: Sequencing of larval mitochondrial CO1 and nuclear ITS2 DNA

PIs: J. B. van Kretschmar, Ph.D, and Godshen Robert Pallipparambil, Ph.D.

Site/Location: NCSU Genomic Sciences Laboratory (GSL)

Status: New

Description: Sanger sequencing of larval DNA will be performed by an ABI 3730 DNA Analyzer, followed by editing and trimming to produce consensus sequences

Expected outcome: Sequence (FASTA) files for alignment analysis.

Activity 3: Alignment analysis

PIs: J. B. van Kretschmar, Ph.D, and Godshen Robert Pallipparambil, Ph.D.

Site/Location: NCSU

Status: New

Description: Sequences for the larvae collected in E. Africa will be aligned with *A. modicella* and A. *simplexella* sequences

Expected outcome: Confirmation of the species and potential identity of the national origin of the Groundnut leafminer that was first detected in E. Africa (Uganda) in 1997.

Activity 4: Provide *A. modicella* and *A. simplexella* CO1 and ITS2 reference sequences for publicly accessible research databases

PIs: J. B. van Kretschmar, Ph.D, and Godshen Robert Pallipparambil, Ph.D.

Site/Location: NCSU

Status: New

Description: The sequences for reference larvae will be submitted to databases for use by other researchers.

Expected outcome: Increased confidence in the data and actionable information generated by future studies with these and similar crop-pest leaf-mining Gelichiidae.

Graduate and undergraduate students sponsored by the project

- Joseph McNitt, USA, Master student, Department of Mathematics, Virginia Tech, 08/15/17 to 07/31/18, 100% funding, advisor(s) Abhijin Adiga, Assessing threat of *T. absoluta* in South-east Asia.
- Awal Issa, M, Niger, Master student, Statistics and Econometrics, Biopass/Senegal, 03/01/17 to 08/31/17, 100% funding, advisor(s) T. Brévault and A. Chailleux, Mapping of tomato trade flows: Reconstitution of value chains, modeling of flows and role In the spread of the tomato leaf miner *Tuta absoluta*, ENSAE (Ecole Natiobnale de la Statistique et de l'analyse économique), Dakar, Senegal.
- Ndjiliw Saliou, M, Senegal, Master student, Entomology, Biopass/Senegal, 05/01/17 to 10/30/17, 100% funding, advisor(s) A. Chailleux and T. Brévault, Field monitoring for the development of conservation biological control of *Tuta absoluta*, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, Dakar, Senegal.
- Bousso Mame Diarra, F, Senegal, Master student, Entomology, Biopass/Senegal, 06/01/16 to 07/31/17, 75% funding, advisor(s) A. Chailleux and T. Brévault, Influence of temperature on the efficacy of biological control of *Tuta absoluta*, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, Dakar, Senegal.
- Sylla Serigne, M, Senegal, PhD student, Entomology, Biopass/Senegal, 02/01/14 to 12/31/17, 50% funding, advisor T. Brévault,) Invasion of the tomato leaf miner, *Tuta absoluta* (Lepidoptera, Gelechiidae), in Senegal: spatial dynamics, ecological niche, and potential for

biological control, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, Dakar, Senegal.

- Ndiaye Arame, F, Senegal, Postdoc, Population genetics, Biopass/Senegal, 07/01/17 to 06/30/18, 50% funding, advisor(s) T. Brévault and A. Chailleux, Population structure and routes of introduction of *Tuta absoluta* in Senegal.

Short term training planned:

Publications planned:

Thesis

- Sylla S (2017) Invasion of the tomato leaf miner, *Tuta absoluta* (Lepidoptera, Gelechiidae), in Senegal: spatial dynamics, ecological niche, and potential for biological control. Faculté des Sciences et Techniques, Université Cheikh Anta Diop (Ucad), Senegal (*Thesis defense scheduled on October 2017*).

Article

- Venkatramanan S et al. Modeling Commodity Flow in the Context of Invasive Species Spread: Study of *Tuta absoluta* in Nepal (in prep)
- Diatte M, Brévault T, Sylla S, Tendeng E, Sall-Sy D, Diarra K (2017) Arthropod pest complex and associated damage in field-grown tomato in Senegal. International Journal of Tropical Insect Science (*In press*).
- Sylla S, Brévault T, Bal AB, Chailleux A, Diatte M, Desneux N, Diarra K (2017) Rapid spread of the tomato leafminer, *Tuta absoluta* (Lepidoptera, Gelechiidae), an invasive pest in sub-Saharan Africa. Entomologia Generalis (*In press*).
- Sylla S, Brévault T, Monticelli L, Diarra L, Desneux N (2017) Geographic variation of host preference by the invasive tomato leafminer *Tuta absoluta*: implications for host range expansion *(Submitted to Biological Invasions).*
- Sylla S, Diarra L, Seydi O, Brévault T (2017) Factors affecting seasonal population dynamics of the tomato leafminer, *Tuta absoluta*, in Senegal *(In prep.)*.
- East Africa Invasive Groundnut Leafminer DNA Sequencing Project: The work will be summarized in a manuscript prepared by the PIs and cooperators that will be submitted to a scientific journal for publication.
- Do low temperature effect the development time and oviposition preference of *Tuta absoluta* on Solanaceae? Antonio Biondi, Mateus Ribeiro de Campos, Marianne Araújo Soares, Philippe Bearez, Edwiges Amiens-Desneux, Nicolas Desneux

- Thermal and photoperiodic effects in diapause induction on invasive tomato pinworm *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Antonio Biondi, Mateus Ribeiro de Campos, Marianne Araújo Soares, Philippe Bearez, Edwiges Amiens-Desneux, Nicolas Desneux

- Development time and thermal requirement of tomato pinworm *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Antonio Biondi, Mateus Ribeiro de Campos, Marianne Araújo Soares, Philippe Bearez, Edwiges Amiens-Desneux, Nicolas Desneux

Participatory biodiversity and climate change assessment for integrated pest management in the Chitwan-Annapurna Landscape, Nepal

PI
Pramod K Jha, Tribhuvan University, Nepal (to be confirmed)

Co-PIs
Anjana Devkota (TU, Nepal); Bharat Shrestha (TU, Nepal); Naba Devkota (AFU, Nepal); Mohan Sharma (AFU, Nepal); R. Muniappan, Amer Fayad and E.A. Heinrichs (VT)

Collaborating Institutions
Central Department of Botany, Tribhuvan University (TU); Agriculture and Forestry University (AFU).
Objective 1: Biodiversity-climate-IPM scholarship and research capacity development through fieldwork, data analysis, and interaction with Nepal and regional scholarly communities

Activity 1: Student training and mentorship
PIs PK Jha (TU coordination), N Devkota (AFU coordination)
Site/Location Nepal (TU in the Kathmandu area, AFU in Rampur, various locations in ChAL); Virginia Tech

Status Continuing
Description
Advise and assist students in conducting research towards their theses topics.
Expected outcomes
Mentoring of students on research processes and methods; strengthen ecology, agronomy, climate research communities in Nepal.

Graduate and undergraduate students sponsored by the project

Name	M/F	Nationality	Discipline	Site	Degree	Start	End	%	Advisor	Title	Univ.
Dol Raj Luitel	M	Nepal	Botany	Nepal	PhD	2016	2019	100	Siwakoti, E.A. Heinrichs	Impact of climate change on finger millet across altitudinal gradients	TU
Seerjana Maharjan	F	Nepal	Botany	Nepal	PhD	2016	2019	100	A. Devkota, R. Muniappan	Ecology and management of *Parthenium hysterophorus* through biological methods	TU
Anju Sharma	F	Nepal	Botany	Nepal	PhD	2016	2019	100	BB Shrestha, R. Muniappan	Management of the invasive species *Ageratina adenophora* through restoration of native vegetation	TU
Pristi Dangol	F	Nepal	Botany	Nepal	MSc	2016	2018	100	BB Shrestha, R. Muniappan	Life history traits of invasive weed *Lantana camara* along the elevation gradient	TU
Sanjeeb Bhandari	M	Nepal	Botany	Nepal	MSc	2016	2018	100	Siwakoti, E.A. Heinrichs	Fodder diversity and production along a hillside, with income and environmental aspects	TU
Bidya Maya Shrestha	F	Nepal	Biodiversity & Environmental Management	Nepal	MSc	2016	2018	100	PK Jha, Amer Fayad	Impact of climate change on biodiversity utilization by smallholder farmers and gender issues	TU
Yashoda Panthy	F	Nepal	Environmental Science	Nepal	MSc	2016	2018	100	BB Shrestha, R. Muniappan	Impact of invasive plant species on ecosystem services	TU
Bivekananda Mahat	M	Nepal	Entomology	Nepal	MSc	2016	2018	100	RB Thapa, E.A. Heinrichs	Assessing hygienic behavior of native honey bee species across elevations for healthy colony production	AFU

Name	M/F	Nationality	Discipline	Site	Degree	Start	End	%	Advisor	Title	Univ.
Madhu Sudhan Ghimire	M	Nepal	Plant Pathology	Nepal	MSc	2016	2018	100	SM Shrestha, Amer Fayad	Integrated management of *Stemphylium* blight in lentil	AFU
Ramesh Upreti	M	Nepal	Horticulture	Nepal	MSc	2016	2018	100	AK Shrestha, E.A. Heinrichs	Fruit thinning and defoliation effect on the quality and yield of papaya var. Red Lady	AFU
Hom Nath Giri	M	Nepal	Horticulture	Nepal	PhD	2016	2019	100	MD Sharma, Amer Fayad	Adaptation of late season cauliflower under different agronomical and IPM practices	AFU
Ghanashyam Bhandari	M	Nepal	Entomology	Nepal	PhD	2016	2019	100	RB Thapa, R. Muniappan	Climate change effect on maize insect diversity, and developing eco-friendly management practice for maize stem borer *Chilo partellus*	AFU
Sarita Sapkota	F	Nepal	Entomology	Nepal	MSc	2016	2018	100	RB Thapa, R. Muniappan	Biodiversity and ecological role of dung beetles	AFU
Pratiksha Sharma	F	Nepal	Agricultural Economics	Nepal	MSc	2016	2018	100	Dhakal, Amer Fayad	Perception of and adaptation to climate change in agriculture sector among Chepang community in Chitwan, Dhading and Gorkha districts	AFU

Publications planned
Thesis
10 (AFU and TU MSc students).
Articles
10

Strengthening production and export of Vietnamese fruit crops through innovative and market-oriented IPM

PI: Nguyen Van Hoa, PhD.; Southern Horticultural Research Institute (SOFRI)

CO PIs: Dr. Le Quoc Dien (SOFRI); Dr. Le Xuan Vi (PPRI), Dr. Nguyen Duy Hung (FARVI); Dr. Ngo Thi Thanh Truc (CTU); Dr. Quyen Dinh Ha (VNUA); Mr. Le Van Thiet(PPD), Mr. Mai Van Tri (SOFRI).

Collaborating Institutions: Southern Horticultural Research Institute (SOFRI); Plant Protection Research Institute (PPRI); Fruit and Vegetable Research Institute (FAVRI); Plant Protection Department (PPD); Can Tho University (CTU); Nong Lam University (NLU); Vietnam National University of Agriculture (VNUA); Virginia Tech (VT); Washington State University (WSU).

Objective 1: Component 3: Research and development of new, bio-rational IPM technologies in the face of disrupted/changing agro-ecosystems, resource availability, climatic conditions and market requirements.

Activity 1: Identify new biopesticides for control of fruit crops pests
PIs: Dr. Le Quoc Dien (supported by Mr. Mai Van Tri, Dr. Tran Thi My Hanh, Ms. Dang Thi Kim Uyen, Mr. Huynh Thanh Loc, Mr. Nguyen Huy Cuong, Ms. Dang Thuy Linh, Ms. Nguyen Ngoc Anh Thu, Mr. Do Hong Tuan (SOFRI) and others from PPRI.

Site/Location: SOFRI, TienGiang, Vinh Long, Dong Nai, Dong Thap, Long An, BinhThuan,BaRia-Vung Tau, Hung Yen, BacGiang and Hai Duong provinces

Time: Whole year, Jan.-Dec., 2018

Status: Continuing

Description: New biopesticides such as entomopathogenic nematodes for controlling fruit fly pupae on dragon fruit and mango, and *Beauveria* sp. for control of stink bug on longan and stem end borer on lychee will be tested. These beneficial organisms will be isolated and introduced, tested, reared, mass produced and released under field conditions. Plant extracts will be tested for control of fungal diseases on DF and mango and controlling mites on longan and scale on mango (by SOFRI, PPRI, FAVRI) (one PhD. scholar, one MSc. Scholar).

Expected outcomes: One entomopathogenic nematode, one parasitoid, one entomopathogenic fungus and a plant extract, effective for controlling fungus diseases on mango and dragon fruit, will be developed.

Objective 2: Component 4: Technology transfer (RIU)

PIs: Dr. Nguyen Van Hoa (supported by Mr. Mai Van Tri, Ms. Dang Thi Kim Uyen, Dr. Tran Thi My Hanh, Mr. Huynh ThanhLoc, Mr. Nguyen HuyCuong, Ms. Nguyen Ngoc Anh Thu, Mr. Do Hong Tuan (South) and Dr. Le Xuan Vi, Dr. Nguyen Duy Hung (North)
Site/Location: TienGiang, Vinh Long, Dong Nai, Dong Thap, Long An, BinhThuan, Ba Ria-Vung Tau (South), Hung Yen, BacGiang and Hai Duong provinces (North)

Time: Whole year, Jan.-Dec., 2018

Status: Continuing

Description: With the results from Component 2 and 3, the new bio-rational IPM technologies developed will be used to build new IPM packages for each crop which is suitable for each of different agro-ecosystems. These will be applied to farmer group/cooperative in each zone by incorporating the VietGAP standards. The input of these models will be supplied by select pesticide companies.

Disease/pest incidence, pest damages, pesticide residues on fruits, populations of biocontrol agents, productivity and quality of fruits will be recorded every 3 to 6 months depending on the parameters measured (by SOFRI,PPRI, FAVRI, PPD, in consultation with WSU).

Scale:9 models (15 ha/model x 1 model/province)

Site/Location: SOFRI responsible for enlarge IPM application DF models in TienGiang, Long An and Binh Thuan, longan models in TienGiang and Vinh Long, mango models in Dong Thap, PPRI responsible for enlarge IPM application longan modelsin Hung Yen and BacGiang and lychee model in Hai Duong province.

Expected outcomes: Increasing the number of farmers and farms who work according to the new IPM model

Objective 3: Component 5: Technology transfer and extension using innovative frameworks (plant clinics, fact sheets, pest management decision guides), mobile technology-driven agro-advisory services and mass media/entertainment education

PIs: Dr. Le Quoc Dien (supported by Dr. Tran Thi My Hanh, Ms. Dang Thi Kim Uyen, Mr. Do Hong Tuan, Mr. Huynh Thanh Loc, and Mr. Le Cao Luong in the South, and Dr. Le Xuan Vi (in the North)

Time: Whole year, Jan.-Dec., 2018

Status: Continuing

Description: The Southern Horticultural Research Institute has partnered with government (national and local governments' extension systems, universities and other institutions) and non-governmental organizations (CABI-Plantwise project) in efforts to leverage resources and reach much larger audiences. Earlier with JICA-SOFRI project on citrus, many extension model farms have been built as well as the latest technologies have been transferred to local agricultural officers and farmers. In addition, in the Plantwise project with CABI, we develop a system of plant doctors in three provinces in the South and

two provinces in the North of Vietnam, who can help farmers every fortnight with the fact sheets and pest management guidelines. This project will closely work with the implementers for scaling up the technology transfer and practices. This will include working with local entrepreneurs and agro-vets. The project will identify and support local entrepreneurs with potential for developing biopesticides and IPM product supply chains. Institutions/Universities will be trained in the production of bio-pesticides and new techniques. Information will be disseminated through extension system and by NGOs conducting farmer meetings, field trips, training sessions and using mass media. Successful IPM demonstration sites where new technologies are used will be used as a tool for transferring technology and educationg farmers.

Scale: 20 courses (2 course/province, 40-50 person/course consisting of farmers, local extension staffs of IPM sites, etc.).

Site/Location: **NLU/SOFRI** will carry out training courses in TienGiang, Vinh Long, Dong Thap, Long An, BinhThuan, Ba Ria-Vung Tau and **PPRI** will carry out training courses in Hung Yen, BacGiang and Hai Duong province.

Content of training: Dragon fruit protocol; Mango IPM protocol; Longan IPM protocol; Lychee IPM protocol

Expected outcomes:*Increasing awareness and* knowledge of farmers in fruit crops *IPM*

Objective 4: Component 6: Monitoring & Evaluation including economic, environmental and gender impact evaluations (The PMSPs for each crop can serve as the baseline starting point).

PIs: Dr. Doan HuuTien (supported by Dr. Ngo ThiThanhTruc, Dr. Tran Thi My Hanh, Ms. Dang Thi Kim Uyen, Mr. Do Hong Tuan, Mr. Huynh ThanhLoc, and Mr. Le Cao Luong in the South, and Dr. Le Xuan Vi (in the North)

Time: Whole year, Jan.-Dec., 2018

Status: New

Description: The monitoring and evaluating systems will be developed to manage the adaptation of farmers and local agricultural staffs in the knowledge and participatory learning on IPM approaches. In addition, the pesticide usage and residues will be analyzed and evaluated based on the data collected from Component 2 and 4 (pesticide tests) and expected to satisfy the U.S. market and other market requirements. Furthermore, the population of soil beneficial organisms will be recorded on VietGAP/IPM model farms in comparison to traditional farms.
Gender impacts will be assessed both before and after implementation of IPM technologies using surveys and Focus Group Discussions looking at knowledge, belief, perception and other related women empowerment indicators. Gender will be integrated in the final survey in the following ways: collecting sex-disaggregated data (i.e. noting if the respondent is male or female); interviewing both men and women (separately) in the household; interviewing women in the value chains; including questions related to women's empowerment (access to information, status, decision-making, income, etc.) in the survey; and finally, analyzing the data from a gender perspective to see what it tells us about gender-based constraints and opportunities as well as impacts of the project.

The plan will include the following: (1) the results to be achieved by the program; (2) the indicators to be used to measure achievement of the results; (3) the method of data collection to be used to obtain the indicator data; and (4) targets for each indicator by year; and benchmarks for the development of organizational sustainability for the implementing partners. The recipient may consult with the donor in the development of the Performance Monitoring Plan.
A set of tables that identifies: (a) the discrete, measurable indicators to be used to measure achievement of the results; (b) the method of data collection and data source to be used to obtain the data for each indicator; (c) the schedule for data collection for each indicator; (d) baseline datafor each indicator; (e) targets for each indicator by year; and (f) a description of any known data limitations. Data presented in the M&E plan tables will be disaggregated by gender and target groups, to the extent feasible.

Expected outcomes: A 20-30% increase in the number of farmers adopting new IPM technologies, gender equality participating in all activities and reduction in pesticide residue (if there is any) under the U.S. market requirements/regulations.

Other activities

Long term training

- PhD. scholar: Name: Ms. Dang Thi Kim Uyen, Nationality: Vietnamese, Discipline: Plant Pathology, Country: Viet Nam, Degree: PhD. Plant Protection, Start date: 2016, Completion date: 2020, Advisor(s): Assoc. Prof. Tran Vu Phen at Can Tho University and Dr. Nguyen Van Hoa (continuing).
- PhD. scholar: Name: Mr. Do Hong Tuan, Nationality: Vietnamese, Discipline: Entomology, Country: Viet Nam, Degree: PhD. Plant Protection, Start date: February, 2017, Completion date: February, 2021, at Can Tho University.
- MSc. scholar: Name: Ms. LuongThiDuyen, Nationality: Vietnamese, Discipline: Entomology, Country: Viet Nam, Degree: MSc. Plant Protection, Start date: 2017, Completion date: 2019, at Can Tho University (continuing).
- MSc. scholar: Name: Ms. Nguyen ThiHanh, Nationality: Vietnamese, Discipline: Entomology, Country: Viet Nam, Degree: MSc. Plant Protection, Start date: 2017, Completion date: 2019, at Nong Lam University (continuing).
- MSc. scholar: Name: Ms. Le Ngo NhuTuyen, Nationality: Vietnamese, Discipline: value chain, Country: Viet Nam, Degree: MSc. Agicultural Economy, Start date: 2017, Completion date: 2019, at Can Tho University (continuing).

Short term training planned

Title: Development of Integrated Pest Management (IPM) systems; Location: USA; Date: June, 2018 (7 days); Type: Training; Number: 1 person; Gender: Male

Title: New technology on detection and identification of new plant viral, Phytoplasma disease and insect identification; Location: USA; Date: July, 2018 (7 days); Type: Training; Number: 1 person; Gender: Female

Title: IPM symposium; Location: India; Date: 2018; Type: Workshop; Number: 2 person; Gender: Female

Publications
Expected technical bulletin
- Manual for identification of arthropod pests on mango crop
- Manual for identification of arthropod pests on lychee crop

Meetings

Project management meetings will be organized at SOFRI and field sites in 4th quarter (by VT, SOFRI, PPRI, FAVRI, CTU, PPD)
Project annual review and planning will be done in 4th quarter
Reports: PPRI, FAVRI and NLU will responsible to submit their activity report to SOFRI every 3 months. SOFRI will combine data from PPRI, FAVRI and itself to write the annual report to submit to USAID-VT.

IPM for Rice, Maize and Chickpea in East Africa

PI – Tadele Tefera (International Center of Insect Physiology & Ecology, *icipe*)

Co-PI -Menale Kassie (International Center of Insect Physiology & Ecology, *icipe*)

Local/international partners: Girma Demissie (EIAR, Bako), Asrat Zewdie (EIAR, DZ); Paddy Likayo (KALRO); Charles Chuwa (Dakawa Research Center); Nsami Elibaraki (National Biological Research Center); William Hutchinson (University of Minnesota)

Objective 1: Identify key partners, develop IPM technologies and define implementation strategies in maize, rice and chickpea production systems

Activity 1.1 and 1.2: completed

Activity 1.3. Design and establish adaptive on-station/on-farm IPM participatory trials
Task-1: Identify available IPM technologies in target countries in collaboration with local partners
Task-2: Establish IPM technologies on-farm or on-station trials with participating farmers or research centers including the EIAR (Ethiopia), KARLO (Kenya) and Tanzania (Dakawa and Kibaha centers)
Task-3: Train extension agents and farmers on push pull for maize stem borers; maize termite IPM; chickpea pod borer and wilt IPM; rice diseases and insect pests.

Countries: Ethiopia (Hawassa and Bako for maize, Debrezeit for chickpea), Kenya (Nakuru, Naivasha and Bomet for maize) and Tanzania (Morogoro for rice and maize)

Status: on-going

Scientists involved: icipe (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Asrat Zewdie, Girma Demissie)

Description: Already recommended/released IPM technologies were sought in each country for rice, maize and chickpea in collaboration with local partners. These technologies were partly assembled and carried out on-farm in participatory IPM process with farmers and researchers. Trainings were given to farmers and extension agents on selected IPM technologies.

Progress to date: Proven technologies such as push-pull has been identified and being demonstrated against stem borers in Kenya in Naivasha and Nakuru and in Ethiopia in Hawassa in 2017 crop season. New IPM components are being tested in Bako against termites in maize.

Expected outputs: Available IPM technologies identified, demo trials established and trainings given to beneficiaries and extension agents.

1.4. Evaluation and assessment of IPM packages and implementation strategies

Task-1: Identify and engage relevant stakeholders in evaluation of the IPM package (push pull for stem maize borers; maize termite IPM; chickpea pod borer and wilt IPM; rice pests IPM) and implementation approaches
Task-2: Train extension agents and farmers on selected IPM technologies including (push pull for stem maize borers; maize termite IPM; chickpea pod borer and rot/wilt IPM; rice blast and stem borers IPM).

Countries: Ethiopia (Hawassa and Bako for maize, Debrezeit for chickpea), Kenya (Nakuru, Naivasha and Bomet for maize) and Tanzania (Morogoro for rice and maize)

Status: ongoing

Scientists involved: icipe (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likhayo, Asrat Zewdie, Girma Demissie).

Description: Participatory evaluation of the IPM technologies would be carried out which includes farmers, extension agents, researchers, local authorities and other relevant stakeholders.

Progress to date: IPM technologies were demonstrated in the three countries with several farmers; trainings were given to farmers, researchers and extension service providers.

Expected outputs: maize IPM and chickpea IPM presently being implemented will be evaluated with stakeholders, lessons would be drawn and trainings would be given to beneficiaries and extension agents

1.5. Scaling up proven IPM technologies

Task-1: Disseminate proven IPM technologies (such as maize stem borers push-pull) through organizing field days
Task-2: Demonstrate and evaluate IPM technologies (integrated wilt/ root rot and pod borer management in chickpea; integrating botanicals, soil fertility and intercropping for termite control in maize; rice diseases tolerant varieties) to farmers and extension agents in multiple sites

Countries: Ethiopia (Hawassa and Bako for maize, Debrezeit for chickpea), Kenya (Nakuru, Naivasha and Bomet for maize) and Tanzania (Morogoro for rice and maize).

Status: ongoing
Scientists involved: icipe (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Asrat Zewdie, Girma Demissie)

Description: Demo plots in Nakuru and Naivasha (Kenya) and Hawassa, Bako and East Shoa (Ethiopia), and Morogoro (Tanzania) were visited by farmers, extension agents and relevant stakeholders

Progress to date: about 120 farmers are presently demonstrating push pull technology in Ethiopia, 40 farmers in Kenya and 11 farmers in Tanzania; about 11 farmers demonstrated rice IPM in Tanzania and about 50 farmers demonstrated chickpea IPM in Ethiopia.

Expected outputs: knowledge would be gained by farmers. Farmers and extension workers will learn IPM technologies in managing maize, rice and chickpea pests. The IPM technologies are: integrated wilt/ root rot and pod borer management in chickpea; integrating botanicals, soil fertility and intercropping for termite control in maize; rice diseases tolerant varieties; and push pull for stem borer management.

Objective 2: Develop pragmatic pest diagnostic capacity

Activity 2.1: Identifying local diagnostics and national pest and diseases priority

Task 1: Assess local partners' pest diagnostic capacity through onsite observation and onsite stakeholders' consultation with stakeholders in the three countries

Countries: Ethiopia, Kenya and Tanzania

Status: completed

Scientists involved: icipe (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Asrat Zewdie, Girma Demissie)

Description: Pest diagnostic is a gateway to IPM implementation. Timely and accurate diagnosis of new and established pests that pose a significant risk to East African agriculture is very important. Accurate and timely diagnosis of plant health problems is an essential component of integrated pest management which supports the competitiveness of East African agricultural industries. Diagnostic capability is also a critical foundation supporting surveillance and regulatory mandates.

Progress to date: assessed local pest diagnostic capacity in the three countries; identified the required capacity developing components.

Expected outputs: Local pest diagnostic capacity assessed and necessary capacity building proposed.

Activity 2.2. Developing and testing diagnostic kits

Task 1: visit to the project countries by Prof William Hutchinson; planning with local partners and icipe team

Countries: Ethiopia, Kenya and Tanzania

Status: ongoing

Scientists involved: William Hutchinson from University of Minnesota; icipe (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Asrat Zewdie, Girma Demissie)

Description: Pest diagnostic is a gateway to IPM implementation. Timely and accurate diagnosis of new and established pests that pose a significant risk to East African agriculture is very important. Accurate and timely diagnosis of plant health problems is an essential component of integrated pest management which supports the competitiveness of East African agricultural industries. Diagnostic capability is also a critical foundation supporting surveillance and regulatory mandates.

Progress to date: assessed extension service providers use of smart phones to aid in mobile app for pest diagnostics; developed one animations on push pull technology for teaching extension workers and lead farmers.

Expected outputs: Mobile phone application and animations designed and developed for pest diagnosis

Activity 2.3. Capacity building through training on insect pest and disease diagnosis

Task 1: Organize training on methods in insect pest diagnostics at icipe Kenya or Ethiopia.
Countries: Ethiopia, Kenya and Tanzania

Status: new

Scientists involved: Project team icipe (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Tebkew Damitie, Asrat Zewdie, Girma Demissie)

Description: Pest diagnostic is a gateway to IPM implementation. Timely and accurate diagnosis of new and established pests that pose a significant risk to East African agriculture is very important. Accurate and timely diagnosis of plant health problems is an essential component of integrated pest management which supports the competitiveness of East African agricultural industries. Diagnostic capability is also a critical foundation supporting surveillance and regulatory mandates.

Progress to date: New

Expected outputs: Local partners would be equipped with recent advances in pest identification using different methods

Activity 2.4: postponed to next year

Objective 3: improving IPM communication and education

Activity 3.1. Develop tailor made communication plan for IPM to address different stakeholders

Task-1: Identify the purpose of the project *communication, i*dentify the audience, p*lan* and design messages.

Countries: Ethiopia, Kenya and Tanzania

Status: New

Experts involved: Desalegn Tadesse; local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Asrat Zewdie, Girma Demissie)

Description: Awareness creation is very important for uptake of the IPM technology; thus, information on maize, rice and chickpea IPM would be compiled and presented to the stakeholders during the annual planning workshop.

Progress to date: New.

Expected outputs: improved awareness of the project and common understanding of stakeholders on IPM and major biotic factors in the three countries

Activity 3.2: Create awareness and disseminate information on IPM to enhance stakeholders' knowledge and responsiveness.

Task-1: Organize annual planning of activities separately for rice, maize and chickpea by inviting relevant partners in the three countries; share IPM activities presentations from the three countries

Countries: Ethiopia, Kenya and Tanzania

Status: On-going

Scientists involved: Desalegn Tadese, local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Asrat Zewdie, Girma Demissie)

Description: Awareness creation is very important for uptake of the IPM technology; thus, information on maize, rice and chickpea IPM would be compiled and presented to the stakeholders during the annual planning workshop.

Progress to date: Stakeholders from the three countries were invited to the project launching and planning workshop, presentations were made by selected local partners on maize, rice and chickpea insect pests and diseases and their control tactics. Besides, field days and trainings were held in the three countries and information regarding the project was shared among stakeholders.

Expected outputs: improved awareness of the project and common understanding of stakeholders on IPM and major biotic factors in the three countries

Activity 3.3. Develop promotional materials targeted to different stakeholders to enhance up-take of the IPM technologies

Task-1: Develop and disseminate project summary brochures/flyers explaining the project objectives, implementing countries and local partners
Task-2: Develop and disseminate the project's current IPM practices (integrated wilt/ root rot and pod borer management in chickpea; integrating botanicals, soil fertility and intercropping for termite control in maize; rice diseases tolerant varieties; push pull for stem borer control) in appropriate language with implementing countries and local partners

Countries: Ethiopia, Kenya and Tanzania

Status: Ongoing

Scientists involved: Desalegn Tadese; local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Tebkew Damitie, Asrat Zewdie, Girma Demissie)

Description: Awareness creation is very important for uptake of the IPM technology; the information on rice, maize and chickpea IPM would be compiled and promotional materials would be developed and disseminated.

Progress to date: Promotional materials were developed and disseminated to partners in Tanzania, Ethiopia and Kenya.

Expected outputs: Awareness created and information on the project and IPM disseminated

Activity 3.4. Establish network of key stakeholders in IPM through a web-based interface that allows stakeholders to continually access emerging policy messages from the project

Task-1: Create microsites for the project and links the project with IPMIL websites and parodically update information

Countries: Ethiopia, Kenya and Tanzania

Status: New

Expert/Scientists involved: Desalegn Tadesse

Description: Awareness creation is very important for uptake of the IPM technology; the information on rice, maize and chickpea IPM would be compiled and shared with stakeholders.

Progress to date: New

Expected outputs: information on the project progress and achievements shared with stakeholders

Activity 3.5. Conduct training needs assessment in the target countries

Task-1: Gather data from stakeholders and determine what training needs to be developed to help farmers, researchers and extension agents accomplish the project goals and objectives.

Countries: Ethiopia, Kenya and Tanzania

Status: Completed

Scientists involved: Menale Kassie and Josphat Korir
Description: asses local partners and farmers knowledges, skills, and abilities, and identify any gaps or areas of IPM training need.

Progress to date: Survey was carried out to assess the training needs of extension staff, agricultural researchers and other stakeholders who participated in the implementation of the project.

Expected outputs: knowledge gaps identified and relevant training proposed.

Objective 4: Provide information and capacity building to reform and strengthen policies that influence integrated pest management

Activity 4.1. Identification of incentives and disincentives, policy gaps and institutional arrangements for adoption of IPM

Task-1: Review all the agriculture policies relevant to IPM or crop protection that are currently in effect, either as proper policy documents or in the form of notifications, speeches, or in any other form;
Task-2: Identify gaps in the existing policies, with respect to their relevance to IPM or crop protection; importation and use of biopesticides; make recommendations on how to address the gaps

Countries: Ethiopia, Kenya and Tanzania

Status: ongoing

Scientists involved: Menale Kassie, Korir Jospaht (PhD tudent) and consultants to be identified

Description: Adoption of IPM practices depends on national polices and market forces; existing national policies and institutional arrangements would be assessed through document reviews and interview of key informants

Progress to date: Consultants identified

Expected outputs: Policy gaps and institutional arrangements identified

Activity 4.2. Conduct a cost benefit analysis for IPM options for maize, rice and chickpea

Task-1: measuring willingness to pay and economic benefits of the IPM options for maize, rice and chickpea

Countries: Ethiopia, Kenya and Tanzania

Status: ongoing

Scientists involved: Menale Kassie and Korir Jospaht (PhD student)

Description: CBA will be undertaken to compare the costs and benefits of IPM options especially to the smallholder farmers in the target countries. CBA will be used to design policy recommendations that inform the policy decision on whether governments in the target countries should adopt IPM as a pest management policy to be mainstreamed in the national development agenda
Progress to date: willingness to pay assessed among farmers in Kenya and Ethiopia

Expected outputs: economic benefits of the IPM options for maize, rice and chickpea identified
Activity 4.3: pushed to next year

Students:
Recruited: 5 PhD and 4 MSc students

Short-Term Training planned

- Annual planning meeting for partners in the three countries (1)
- Training farmers Kenya (1)
- Training farmers Ethiopia (1)
- Training farmers Tanzania (1)
- Training for researchers (1)
- Training for extension agents Kenya (1)
- Training for extension agents Ethiopia (1)
- Training for extension agents Tanzania (1)

Publications planned:

- Project brochures-3
- Baseline summary report -1
- Study reports (2)

Performance Indicators for Monitoring and Evaluation:

ID	Description	Completion Date	Responsible
Outcome 1	Identify key partners, develop IPM technologies and define implementation strategies		
Activity 1.3	Design and establish adaptive on-station/on-farm IPM participatory trials	30-09-2018	Tadele Tefera, Menale Kassie, Students and local partners
Task-1	Identify available IPM technologies in target countries in collaboration with local partners	30-12-2017	Tadele Tefera, Menale Kassie, Students and local partners
Task 2	Establish IPM technologies on-farm or on-station trials with participating farmers or research centers	30-09-2018	Tadele Tefera, Menale Kassie, Students and local partners

Task 3	Train researchers, extension agents and farmers on selected IPM technology(ies)	30-09-2018	Tadele Tefera, Menale Kassie, Students and local partners
Activity 1.4.	Evaluation and assessment of IPM packages and implementation strategies	30-9-2018	Menale Kassie, Korir Josphat, Tadele Tefera, Local partners
Task-1	Engage relevant stakeholders in evaluation and draw lessons of the IPM package and implementation approaches	30-7-2018	Menale Kassie, Korir Josphat, Tadele Tefera, Local partners
Task -2	Train extension agents and farmers on selected IPM technology (ies)	30-8-2018	Menale Kassie, Korir Josphat, Tadele Tefera, Local partners
Activity 1.5	Scaling up proven IPM technologies	30-9-2018	Tadele Tefera, Menale Kassie, Students and local partners
Task-1	Disseminate proven IPM technologies through organizing field days	30-9-2018	Tadele Tefera, Menale Kassie, Students and local partners
Task-2	Demonstrate proven IPM technologies to farmers and extension agents in multiple sites	30-9-2018	Tadele Tefera, Menale Kassie, Students and local partners
Outcome 2	Develop pragmatic pest diagnostic capacity		
Activity 2.1	Identifying local diagnostics capacities and national pest and diseases priority	Completed	Tadele Tefera, local partners
Task 1	Assess local partners/institutions pest diagnostic capacity through onsite observation and onsite stakeholders' consultation	Completed	Tadele Tefera, local partners
Activity 2.3.	Capacity building in training on pest and disease diagnosis	30-5-2018	Tadele Tefera, local partners
Task-1	Short-term training for scientists from participating countries in insect pest and disease diagnosis	30-5-2018	Tadele Tefera, local partners
Outcome 3	improving IPM communication and education	30-09-2018	

Activity 3.2	Create awareness and disseminate information on IPM to enhance responsiveness of the stakeholders.	30-12-2018	Tadele Tefera, local partners
Task-1	Organize annual planning of activities by inviting partners from the three countries; share IPM activities presentations from the three countries	30-9-2018	Tadele Tefera, local partners
Activity 3.3	Develop promotional materials targeted to different stakeholders to enhance up-take of the IPM technologies	30-11-2018	Tadele Tefera, local partners
Task-1	Develop and disseminate project summary brochures/flyers explaining the project objectives, implementing countries and local partners	30-11-2018	Tadele Tefera, local partners
Task-2	Develop and disseminate the project's current IPM practices in maize, rice and chickpea in appropriate language with implementing countries and local partners	30-2-2017	Tadele Tefera, local partners
Activity 3.5	Conduct training needs assessment in the target countries	completed	Menale Kassie, Korir, local partners, Tadele Tefera
Task-1	Gather data from stakeholders and determine what training needs to be developed to help farmers, researchers and extension agents to accomplish the project goals and objectives	Completed	Menale Kassie, Korir, local partners, Tadele Tefera
Outcome 4	Provide information and capacity building to reform and strengthen policies that influence integrated pest management	30-9-2018	Menale Kassie, Korir, local partners
Activity 4.1.	Identification of incentives and disincentives, policy gaps and institutional arrangements for adoption of IPM	30-12-2017	Menale Kassie, Korir, local partners
Task-1	Review all the agriculture policies relevant to IPM or crop protection that are currently in effect, either as proper policy	30-12-2018	Menale Kassie, Korir, local partners

	documents or in the form of notifications, speeches, or in any other form		
Task-2	Identify gaps in the existing policies, with respect to their relevance to IPM or crop protection; make recommendations on how to address the gaps	30-12-2018	Menale Kassie, Korir, local partners

Development of Ecologically based Participatory Integrated Pest Management (IPM) Package for Rice in Cambodia (EPIC)

PI: Buyung Hadi

CO PIs: Virender Kumar, Il-Ryong Choi, Ricardo Oliva, Alexander Stuart, Nancy Castilla, Rica Joy Flor
Collaborating Institutions
GIZ ASEAN SAS, Nagoya University, Virginia Tech, GDA, CARDI, CEDAC

Objective 1: Advance the knowledge on rice IPM technologies appropriately designed for Cambodian rice production systems

Activity 1: Adaptive research platform

PI: Virender Kumar, Il-Ryong Choi, Ricardo Oliva, Alexander Stuart, Nancy Castilla

Site/Location: Cambodia

Status: Continuing

Description: This is a continuation of 2016-2017 activities. The type of experiment and the location is given in table 1.

Table 1. Locations and treatments of adaptive research platform DS 2017-2018

Province	Village	Target biotic stress	Planned on-station and on-farm research	Main Cambodian Partner
Battambang	GDA station	Diseases	Trichoderma x Fungicide	GDA/PDA
	Ota Gnean	Weeds	Integrated weed management	GDA/PDA
	Boeung Pring	Weeds	Integrated weed management	GDA/PDA
Kampong Thom	PDA station	Diseases	Trichoderma x Fungicide	GDA/PDA

	Pahnachi	Insects	Biocontrol agents	GDA/PDA
	O Kunthor Tbong	Weed	Integrated weed management	GDA/PDA
Prey Veang	PDA Station	Diseases	Trichoderma x Resistant varieties	GDA/PDA
	Sdao	Insects	Biocontrol agents	GDA/PDA
	Thom	Weeds	Integrated weed management	GDA/PDA
Takeo	Kan Daul	Rodents	Community action	CARDI/PDA
	Ror Veang	Rodents	Community action, CTBS	CARDI/PDA
Phnom Penh	CARDI station	Diseases/Insects	Trichoderma x Resistant varieties / Ecological Engineering	CARDI

Expected outcomes: Validation data on a number of potential IPM components against different pests, weeds and diseases: biological control agents, Trichoderma, resistant varieties, trap barrier system, no early spray, drum seeder and mechanical weeder, ecological engineering.

Activity 2: Innovative research platform (MSc and PhD students)

PIs: Buyung Hadi, Ricardo Oliva, Virender Kumar, Nancy Castilla, partners from Royal University of Agriculture (RUA), Royal University of Phnom Penh (RUPP) and Nagoya University.

Site/Location: Experimental stations at the four provinces above, CARDI, Battambang.

Status: Continuing

Description: We will have a new Cambodian PhD student and continue another Cambodian PhD student at Nagoya University. We will also continue one MSc student at Battambang University working on integrated weed management. At least one new MSc student will start at RUA working on innovation system index and lock-in mechanisms for IPM technology adoption in Cambodia. The continuing PhD student at Nagoya University is working on the effects of trichoderma and resistant varieties on rice blast disease in Cambodia. The new PhD student at Nagoya University work on characterizing pathogen strains (BLB, blast) in Cambodia and conduct assessment on the effects of Trichoderma application on soil microbial diversity. If funding permits, we will recruit another MSc student at RUA (cost split with George Norton) to work on end-line survey and impact assessment of select IPM technologies in Cambodia. This student will spend four months in 2019 at Virginia Tech.

Expected outcomes: At least 5 graduate students (2 PhD and 3 Master) will start/continue their study programs.

Objective 2: Develop an effective communication system involving all stakeholders in rice production to support the participatory development and scaling out of successful IPM technologies

Activity 1: Provincial learning alliance
PIs: Rica Joy Flor, partners from GDA, CARDI and CEDAC.

Site/Location: Central location across chosen district at each province (above).

Status: Continuing

Description: Provincial learning alliances act as platforms for broad consultancy with value chain actors on various topics in rice IPM needs and implementation. Through the provincial learning alliances in 2017-2018, we expect to learn about the gender specific pathways for IPM technology to have a broad scale impact in farming communities. We will also focus on identifying ways to scale out the validated IPM package. We plan to conduct at least one provincial learning alliance meeting per province for a total of four meetings across the country.

Expected outcomes: Documented gender specific impact pathways for IPM technologies
Documented ways to scale out validated IPM package

Activity 2: Knowledge sharing activities

PIs: Buyung Hadi, CARDI, GDA, RUA, Battambang University

Site/Location: Phnom Penh

Status: New

Description: We plan to produce an image bank for key weeds, pests and diseases in Cambodia to be use by RUA, Battambang University, CARDI and GDA for lesson and extension presentation creation.

Expected outcomes: Image bank on key weeds, pests and diseases in Cambodia.

Objective 3: Empower Cambodian rice value chain actors (e.g., agricultural input suppliers and distributors, producers, etc.) together with public extension and research institutions to conduct effective rice IPM research and extension programming

Activity 1: Training opportunities on key skills in IPM validation and implementation

PIs: Buyung Hadi, Virender Kumar, Alex Stuart, Nancy Castilla, Ricardo Oliva, Harvey Reissig, Rica Joy Flor, partners from GDA, CARDI and CEDAC.

Site/Location: Phnom Penh, adaptive research platform sites (at four target provinces), IRRI.

Status: Continuing

Description: We will provide a number of short-term trainings for various rice value chain actors in Cambodia. The training may take place as a workshop in Phnom Penh, field visits at the adaptive research platform sites or a training course at IRRI. A list of planned short-term training for this workplan period is provided under a separate heading below.
The long term training opportunities are described above under objective 1, activity 2.

Expected outcomes: At least 100 Cambodian rice value chain actors trained across different fields listed under the short term training opportunities. As a result of the training, the GDA, PDA, CARDI and RUA staff are expected to learn essential skills on gender-sensitive extension programming, Rice weed, pest and disease diagnostics, usage of biological control in rice IPM; farmers, farmer groups and NGO staff are expected to adopt the IPM technologies being tested in the project and also to take an active part in disseminating these technologies either through words of mouth or through the development of grassroot IPM business provider.

Objective 4: Provide information and capacity building for policy reform that will support rice IPM practice

Activity 1: Biological control forum

PIs: GIZ, Rica J. Flor, Virender Kumar, Buyung Hadi, partners from CEDAC and GDA.

Site/Location: Phnom Penh

Status: Continuing

Description: We will conduct the third National biocontrol forum. The forum encompasses presentation, demonstration and policy discussion to move the registration of biological control product forward in Cambodia.

Expected outcomes: At least 50 stakeholders exposed to the idea of biological control product's efficacy and safety. Draft of registration policy for biocontrol product.

Objective 5: Implement strategies that ensure efficient monitoring, impact assessment, and gender equity of the project

Activity 1: Annual planning meeting – November/December 2017

PIs: all PIs and partners.

Site/Location: Phnom Penh/one of the project sites

Status: Continuing

Description: Annual planning meeting will be conducted in November/December 2017. Progress in year 2 will be reviewed and activities for year 3 will be thoroughly discussed. Input from Management entity, USAID mission and other stakeholders will be solicited.

Expected outcomes: Progress review and concrete plan for 2017/2018.

Activity 2: Prepare papers from baseline surveys and from baseline survey.

PIs: Buyung Hadi, Rica J. Flor, George Norton, partners from GDA and CEDAC.

Site/Location: Phnom Penh
Status: Continuing

Description: The baseline surveys identified priority pests, pest management practices, knowledge of IPM, extent of current vegetable IPM adoption, and nature of adopters (farm size, wealth level, male or female, etc.). A MS thesis at Virginia Tech in FY 17 analyzed who adopts IPM and factors affecting IPM adoption and pesticide use for rice in Cambodia. In FY18: (a) a journal article manuscript out of the MS thesis will be prepared and submitted to a journal, (b) a policy brief will be prepared that highlights results from the surveys and journal article paper.

Expected outcomes: Journal article and a policy brief to help guide the IPM program efforts with respect to priorities and targeting of factors to influence audience. The journal article also spreads information from the project to broad scientific audience.

Graduate and undergraduate students sponsored by the project

Name	Gender	Nationality	Discipline	Work site	Degree	Start date	Completion date	Portion funding	Advisor	Thesis topic	University
Chou Cheythirith	M	Cambodia	Plant pathology	Cambodia	PhD	September 1 2016	August 31 2019	Research costs	Sotaro Chiba, Buyung Hadi	Rice IPM components against rice blast, a dominant rice disease in Cambodia	Nagoya University
Ong Socheath	F	Cambodia	Plant Pathology	Cambodia	PhD	September 1 2017	August 2020	Research cost	Nagoya University professor, Ricardo Oliva	Characterization of BLB and blast in Cambodia	Nagoya University
Chhun Sokunroth	M	Cambodia	Weed Management	Cambodia	MSc	September 2016	August 2018	Research cost	Srean Pao, Virender Kumar	Integrated weed management	Battambang University
TBD	?	Cambodia	Social Science	Cambodia	MSc	September 2017	August 2019	Research cost	TBD, Rica Flor	Innovation system index and lock in mechanism for IPM adoption	RUA
TBD	?	Cambodia	Economics	Cambodia	MSc	September 2017	August 2019	Research cost	TBD, George Norton	End-line survey, impact assessment	RUA (in funding permits) – 4 months at Virginia Tech
Corey Grant	M	USA	Entomology	Cambodia	MSc	September 2016	August 2019	100% (Through Virginia Tech's portion of the funds)	Doug Pfeiffer	Ecological engineering	Virginia Tech

Short term training planned

Short-term training	Target audience	Potential numbers to be trained	Length of training	Planned sites
Field visits of adaptive research platforms	Lead farmers and early adopters	40 farmers and early adopters	2 times a season	Adaptive research sites
Farmer's field days	Farming community at large	100 farmers	1 time a season (at harvest)	Adaptive research sites
Field and Laboratory techniques in insect, weed and disease ID	GDA, CARDI, RUA, private sector	15 research and extension staff	3 days	CARDI
Ecologically-based rice pest management	GDA, CARDI, PDA	4 staff	2 week workshop	IRRI
Rice IPM curriculum (trainers' training)	GDA, CARDI, PDA, RUA, Battambang U	20	1 week	GDA/CARDI

Publications planned:
Conference Abstracts

- "Vegetable-based ecological engineering: Participatory development of a conservation biological control method for Asian rice landscape " - Entomology 2017, ESA's 65thAnnual Meeting, November 2017

Extension bulletin

- Rice IPM cards – in Khmer

Article

- Special issue on pest management in the tropics at Crop Protection

East Africa Vegetable IPM Work Plan

IPM Innovation Lab Project – Tanzania, Kenya, and Ethiopia
Work Plan for Year 3 (Oct. 2017 - Sept. 2018)

Project Title
East Africa IPM Innovation Lab: Research and Technology Transfer for Vegetable Crops

Project PI: John Cardina, Department of Horticulture & Crop Science, Ohio State University

CO PIs
Ferdu Azerefegne, School of Plant and Horticultural Sciences, University of Hawassa, Ethiopia;
Luis Cañas, Department of Entomology, OSU;
Danny Coyne, Soil Health Scientist, IITA, Kasarani, Nairobi, Kenya;

J. Mark Erbaugh, Director of the Office of International Programs in Agriculture, OSU;
Robert Gilbertson, Department of Plant Pathology, University of California – Davis;
Matthew Kleinhenz, Department of Horticulture and Crop Science, OSU;
Amon P. Maerere, Department of Crop Science and Horticulture, Sokoine University ofAgriculture, Tanzania;
Jesca Mbaka, Kandara/Deputy Director Horticulture Research Institute, Kenya Agricultural andLivestock Research Organization (KALRO), Kenya;
Sally A. Miller, Department of Plant Pathology, OSU;
George W. Norton, Department of Agricultural and Applied Economics, Virginia Tech;
Cathy Rakowski, School of Environment and Natural Resources, OSU;
Peter Sseruwagi, Mikocheni Agriculture Research Institute, Tanzania;

In-country teams:
SUA Team, Tanzania
Dr. Amon Maerere – Leader, Horticulturalist, and co-PI
Dr. Delphina Mamiro – Plant Pathologist
Dr. Gration M. Rwegasira - Entomologist
Dr. Hossea Mtui – Horticulture Research Station Manager

KALRO/Kandara Team, Kenya
Dr. Jesca Mbaka – Leader, Plant Pathologist, and co-PI
Caeser Kambo - Entomologist
Dr Beth Ndungu - Gender expert
Sylvia Kuria - Plant Pathologist
Mr S.J.N. Muriuki - Entomologist
Cecilia Ngugi - entomologist
Mr Simon Wepukhulu, biometrician
Farmer groups (Kilele, Kimbo, Thambo and Mt Kenya Technologies) in Tharaka Nithi County

Hawassa University Team, Ethiopia
Dr. Ferdu Azerefegne, Leader, Entomologist, and co-PI
Dr. Yibrah Beyene, Entomologist
Dr. Alemayehu Chala, Plant Pathologist

Collaborating Institutions
School of Plant and Horticultural Sciences, University of Hawassa, Ethiopia;
IITA, Kasarani, Nairobi, Kenya;
Department of Plant Pathology, University of California – Davis;
Department of Crop Science and Horticulture, Sokoine University of Agriculture, Tanzania;
Horticulture Research Institute, Kenya Agricultural andLivestock Research Organization (KALRO), Kenya;
Department of Agricultural and Applied Economics, Virginia Tech;
Mikocheni Agriculture Research Institute, Tanzania;

Objective 1

Conduct participatory needs assessments to identify priority pests, current pest management practices, availability of alternative IPM technologies, and constraints to IPM adoption by farmers, including policy and regulatory constraints;

Activity 1
Title: Prepare papers from baseline surveys and from completed Master's thesis.
PIs: Norton, Rakowski
Cooperators: Menale Kassie, Beth Ndungu, Simon Wepukhulu, Amon Maerere, Mark Erbaugh

Activity 2
Title: Survey the nurseries of vegetables in the rift valley area and assess the practices for seedling production.
PIs: Drs. Ferdu Azerefegne, Yibrah Beyene, and Alemayehu Chala
Description: The survey will include farmers raising seedlings for own use as well as commercial nurseries. Collect data on seed source, types of beds and media, common pests, pest management, seedling health, and quality. Include physical observation by the investigators/ researchers / students. Use results to prepare an analysis of gaps in good nursery practice.

Activity 3
Evaluate project impact.
PIs: Mbaka, Ndungu, Wepukhulu, Erbaugh, Rakowski
Site/Locations: Kenya
Status: New
Description: Design a tool to conduct and test the tool to conduct a survey to collect data for evaluating project impact. Organize a stakeholders' workshop to share findings.

Expected outcomes: Farm-level and county-level economic, environmental, and gender impacts evaluated for specific IPM practices for specific crops in the target countries.

Objective 2: Conduct long- and short-term training and capacity-building in i) IPM systems and ii) pest diagnostics, with an emphasis on adoption of modern communication tools when and where appropriate.

Activity 1
Title: Long-term training of graduate students
PI: Norton, Canas, Kleinhenz, Rakowski, Mbaka, Maerere, Mamiro, Rwegasira, Azerfegne, Beyene, Chala
Site/Location Virginia Tech, Ohio State, Kenya, Tanzania, Ethiopia
Status: Two students at OSU; new MS student at VT, ongoing students at SUA and Hawassa.
Description:
1. Ms. Hellen Elias Kanyagha**,** Ph.D. student; started March 15, 2017. Proposed dissertation title: Characterization and Potential IPM Strategies in Managing *Ralstonia solanacearum* in Tomato. General objective: To develop techniques for managing devastating *Ralstonia solanacearum* infestations in Tomato production.

2. An MS student at Virginia Tech will be selected who will begin work in May 2018 on impact assessment for selected IPM practices (See Objective 4 below) of the East Africa Vegetable IPM project.

3. A new MS student will start at OSU in the Department of Entomology to work with Dr. Luis Canas on *Tuta absoluta*.

4. Continue supporting Ms Cecilia Ngugi on her PhD project on use of entomopathogenic nematodes for management of *Tuta absoluta* in tomato. (Kenya)

5. Continue supporting SUA and Hawassa undergraduate and graduate students in undertaking end of study and dissertations research under the project. A summary of students is given below. (Tanzania, Ethiopia)

Name	Gender	Degree program	Discipline	University	Academic Year
Ester Rehema Matendo	Female	MSc.	Plant Protection	SUA	2016/2017
Peter A. Maerere	Male	MSc.	Plant Protection	SUA	2016/2017
Tumsifu Samwel	Male	MSc.	Plant Protection	SUA	2016/2017
Happiness Christopher	Female	MSc.	Plant Protection	SUA	2017/2018
Hellen Kanyagha	Female	PhD	Plant Protection	OSU	2017 - 2020
Kumsa Dida	Male	MSc.	Plant Protection	Hawassa	2017 - 2019
Feysisa Bekele	Male	MSc.	Plant Protection	Hawassa	2017 – 2019
Yosef Berihun	Male	MSc.	Plant Pathology	Hawassa	2017 - 2019

Expected outcomes: Graduate study leading to theses and published papers in peer-reviewed journals.

Activity 2
Title: Short-term training of farmers and trainers.
PI: Maerere, Mtui, Mamiro, Rwegasira (SUA); Sseruwagi (MARI); Mbaka, Kambo, Ndungu, Kuria, Muriuki, Ngugi (KALRO); Coyne (IITA); Azerefegne, Beyene, Chala (Hawassa)
Status: on-going

Tanzania
Audience: Morogoro, Mvomero, Iringa and Kilolo districts – 2 farmer groups in each district.
Description: Conduct short term hands-on in-field and on station training to farmers and agricultural extension agents from the project sites (Morogoro, Mvomero, Iringa and Kilolo districts) on:
1. improved vegetable nursery techniques for enhanced health seedling production and supply,
2. Good Agricultural practices,
3. use of bio-control and proper pesticide rotations,
4. vegetable grafting and microclimate management using mulch and protective structures such as screen houses and tunnels

Audience: Farmers and stakeholders (extension, crop inspectors) throughout Tanzania.
Description: Conduct training at MARI in field identification, monitoring and IPM of vegetable virus diseases, including use of WhatsApp to inquire, share and communicate pest and disease problems.

Kenya

Audience: Three farmer groups in Chuka County (Mbuiru-Mwanjati, Mbogoni and Nthambo)
Description: Conduct training on:
a) IPM systems and technologies (use of pathogen free seeds; establishment of seedlings in sterile media, coco peat and peat moss in germination trays; exclusion of pests in the nursery by use of insect proof netting);
b) Compost making using Trichoderma at farm level;
c) Methods for training others in pest and disease diagnostic and use of WhatsApp for pest and disease diagnostics.

Audience: Over 200 farmers representing three groups in Chuka County.
Location: One farm at Mbuiru-Mwanjati, two farms at Mbogoni and one farm at Nthambo
Activity: Establish on-farm demonstration sites to educate farmers on the best bet IPM technologies with participation of regulatory agencies such as the Kenya Plant Health Inspectorate Services (KEPHIS), The Pest Control Products Board (PCPB) to raise awareness of IPM and the opportunities other non-pesticide approaches can offer.

Audience: participants from ministries, universities, and leaders of farmer groups.
Location: Kandara and Chuka County
Activity: Conduct a 2-day workshop for extension and other trainers on pest and disease diagnostics, pest scouting and monitoring to inform decision making in pest management. Instructors will be drawn from KALRO as well as project participants from other countries.

Ethiopia
Audience: Trainers, including extension personnel, ministry personnel, plant health clinic workers, crop protection workers, graduate students, and junior researchers. 20 participants expected.
Activity: Conduct training of trainers focusing on raising healthy seedlings, diagnosis of major pests of vegetables, methods of scouting, current practices and gaps on pest management, options for pest management. Location will be Hawassa and Ziway and will include field visits to nurseries and research sites with good practices.

Audience: Select vegetable farmers with different capacities, including about 40 farmers from Alaba, Butajira, Meki, Ziway, and Hawassa.
Activity: Train farmers on seedling production, including seed treatment, soil sterilization with burning and solarization, rotation, screen covering, protecting from pathogens and pests with pesticides, good nursery practices (seed rate, watering, shading, mulching, sanitation, rogueing symptomatic plants). We will identify producers of healthy seedlings, visit nurseries with good practices, and raise seedlings with good practices for demonstration to farmers.

Audience: Technical staff from plant health clinics in Hawassa, Ziway, and Meki, graduate students, extension staff.
Activity: Conduct training for technical staff on nematology methods for resource limited situations-basic techniques for plant parasitic nematodes linked to industry and agro-input dealers.

Activity 3:
Title: IPM Communication for diagnosis and management recommendations
PI: Mathenge (Real IPM); Maerere, Mtui, Mamiro, Rwegasira (SUA); Sseruwagi (MARI); Mbaka, Kambo, Ndungu, Kuria, Muriuki, Ngugi (KALRO); Coyne (IITA); Azerefegne, Beyene, Chala (Hawassa)
Site/Location: Tanzania, Kenya, Ethiopia

Status: on-going

Description:

1. Expand the WhatsApp IPM Diagnosis and Management Network to at least 2 villages or farmer groups.

Within-village/group networks will be linked to PI organizations through village or group leaders. Link plant health clinics, farmer groups, value chain partners, and others involved in this project to WhatsApp group. Training will be provided on how to capture images, access information, and link to wider network.

2. Continue progress on the web site associated with the network.

The goal is to improve the web site so that users can access it easily to get information on pest identification, biology, control etc. Real IPM will structure the network and develop an associated web site for support materials and images.

Objective 3: Evaluate prototype IPM technologies in on-station and on-farm trials

TANZANIA:

Activities at SUA:

1. Continue with trials to evaluate effects of tomato grafting on Solanaceae and cucurbits on Cucurbitaceae rootstocks with resistance to nematodes, bacterial and fusarium wilts.

Tomato grafting was not conducted in Tanzania during the previous phases of the project. It has been introduced during this phase to evaluate the solanaceous rootstocks previously tested in Kenya and Uganda as well as those introduced in Tanzania by seed companies. For the Cucurbitaceae, four local species of the family (*Luffa aegyptica, cucumis ficifolius, C. metuliferus and Lagenaria vulgaris*) will be evaluated for use as rootstocks. The cucurbitaceous crops to be addressed are watermelon and cucumber.

(Maerere, Mamiro, Mtui)

Treatments:

1. Control: Tomato variety Cal-J and Cucumber Variety Ashley not treated with any of the bio-pesticides
2. Trichoderma applied at transplanting
3. Neem cake applied in soil at transplanting
4. Bio-slurry drenched in the trench two days before planting/transplanting
5. Intercropping with Marigold (*Tagetes* spp.)

Methods: Forty-eight hours old R. solanacearum inoculum will be inoculated to the test plants through scalpel injured roots and observed for wilting symptoms for a t least 4 weeks. Basic plant pathology scoring for infection, phenotypic responses, growth reduction, visual evaluation of root health; also standard plant pathology techniques for isolation and identification of pathogens.

2. Development and evaluation recipes for bio-slurry and microbe/bio-pesticides (*Trichoderma, Bacillus,* etc.) to get consistent products/recipes for control of root diseases as transplant treatment for tomato, cucurbits, onion, and brassicas. Bio-slurry and its mixture with microbial pesticides will be used. Vegetable diseases to be evaluated are as follows:

Tomato and Cucurbits: Nematodes, Fusarium wilt, Bacterial wilt
Onion: White grub
Brassicas: club-root

Methods: Experiments will use manure, molasses, wheat and rice bran using soils collected from infected areas. We will test efficiency, timing, temperature and dosage of each or combined treatment. Data will be collected to allow analysis of presence/absence and quantity of bacteria every two weeks. (Mamiro)

3. Conduct on-farm trials on onion variety selection for pest resistance, yield, quality and other characteristics.
(Maerere, Mtui)

Location: one farm each in Morogoro and Iringa.
1. Control: Variety "Red Bombay" the currently most popular and cultivated variety.
2. Three open pollinated varieties
3. Three hybrid F1 varieties

Methods: A randomized block design with four replications will be conducted for an on-going effort to select onions with desirable traits. Fields will be plowed and worked using standard techniques. Plots will include a single test row bordered by two border rows each 4-m long. Onions will be planted using standard methods and weeds removed as needed by hand pulling and hoeing. We will measure pest resistance by visual scoring, visual identification of pests, and examination of plant tops at 2-week intervals. At harvest onions will be scored visually for damage and divided into size classes, each of which will be weighed fresh. A caliper will be used to measure bulb diameter and a standard firmness test will be used. Data will be analyzed by analysis of variance.

4. Conduct on farm evaluation of bio-pesticides: *Trichoderma, Metarhizium*, and *Beauveria* products from Real IPM, for their effectiveness in controlling nematodes in tomato, cucurbits and the white grubs in onion. *Trichoderma, Metarhizium,* and *Beauveria* are expected to have effect on nematodes in tomato and cucurbits, particularly when it is applied pre-planting on healthy seedlings. It is however known that the type of soil may have an influence on their effectiveness. (Maerere, Mamiro, Mtui)

Treatments:
1. Control
2. *Trichoderma*
3. *Metarhizium*
4. *Beauveria*

Location: One farm in each of Morogoro, Mvomero, Iringa and Kilolo districts.
Methods: Randomized block demonstration experiments will be conducted with four replications and four treatments. Plots will range from 4 to 6 m wide and 4 to 8 m long depending on location and available space. The controls will be whatever standard practices the farmer uses. Biopesticides will be applied according to label instructions. Nematode response will be assessed

by visual analysis of roots for knots and other malformations. White grubs will be assessed by visual damage and counting insects.

5. On farm evaluation of the effect of overhead irrigation to interrupt mating of the diamondback moth attacking brassicas.

It is has been shown that sprinkler irrigation and other types of overhead irrigation will interfere with the mating of the moth. What would be important in this study is to determine the effective mating time of the day. Application of overhead irrigation to dislodge the moth at the effective mating time, i.e., when the moths are most active, will disturb the process. This would thus lead to reduced mating, reproduction, insect population and hence crop damage. This is a good IPM practice because it would not involve pesticides or harm the environment in any way, and it does not require additional purchased inputs. Another interesting feature of this work is that they are paying attention to plant disease along with moth survival. (Rwegasira, Mamiro)

Location: One farm in Iringa district.

Treatments:

1. Control 1: no mulch, surface irrigation
2. Control 2: mulched, surface irrigation
3. No mulch; Timing of overhead irrigation: 1500-1700 hr continuous
4. Mulched; Timing of overhead irrigation: 1500-1700 hr continuous
5. No mulch; Timing of overhead irrigation: 2000-2200 hr continuous
6. Mulched; Timing of overhead irrigation: 2000-2200 hr continuous
7. No mulch; Timing of overhead irrigation: 2000 – 2300 intermittently
8. Mulched; Timing of overhead irrigation: 2000 – 2300 intermittently

Methods: Plots will be established on a farm where overhead irrigation has been used on part of the farm. A locally adapted variety of cabbage will be used. The study will follow methods similar to those of Foster and students at Purdue University (McHugh Jr, John J., and Rick E. Foster. "Reduction of diamondback moth (Lepidoptera: Plutellidae) infestation in head cabbage by overhead irrigation." Journal of Economic Entomology 88.1 (1995): 162-168.. Overhead irrigation will be applied at three timings. Plots will be split with and without mulch. Diamondback moth infestations will be assessed by visual inspection as per published methods James, W. Clive. "Assessment of plant diseases and losses." Annual review of Phytopathology 12.1 (1974): 27-48.). Plant disease will be evaluated by visual inspection of leaves; at harvest heads will be cut open for detection of moth and disease damage.

6. Conduct on farm demonstrations on IPM technology packages for tomato (mulching, pesticide use only when needed, use of adapted varieties, harvesting at appropriate ripening stages, postharvest treatment with Sodium hypochlorite and proper packaging) as strategies to increase tomato yield, quality, and lengthen shelf life. Only two varieties are commonly grown throughout the country. These are varieties Red Bombay and Red Creole (OPVs). Red Bombay is the most popular. New (recently introduced) varieties; include Russet, Jambar, (F1 Hybrids), Tajirika, Meru Super and Lumuma (OPVs).

Use of healthy seedlings, appropriate seedbed preparation, mulching, appropriate use of pesticides and fertilizer application, use of resistant varieties, right stage and time of harvesting, postharvest treatment; including use of sodium hypochlorite, handling (packaging, storage and transportation practices) are the range of pre- and post-harvest technologies.

With respect to the use of sodium hypochlorite, the work done in the previous phase was mainly on evaluation and dissemination in the then project sites in two districts. No evaluation trials will be conducted in this phase. The aim will be to further out-scale the practices to the new project sites, which include a total of five districts with 15 villages. (Maerere, Mamiro, Mtui, Rwegasira).

Locations: Demonstrations on one farm each in Iringa, Mvomero and Kilolo Districts.

Methods: On-farm experiment/demonstrations will compare three approaches:

1. Control: untreated (no pest management practice applied)

2. : Standard pesticides as per manufacturer's recommendations

3. Integrated Pest Management (IPM) treatments as needed will consisting of: m trapping of Tuta using pheromone traps + sulphur + Azadirachtin + *Bacillus thuringensis* (Bt) + sanitation (removal of infested plants) and Spinosad. If necessary, Dudumida (Imidaclroprid) from will be applied.

Randomized blocks with four replications will be used. Plots will range from 4 to 6 m wide and 4 to 8 m long depending on location and available space. The controls will be an untreated plot where no pesticides are applied, and a standard practice control based on farmer practice. All treatments will be applied according to label instructions. Tomatoes will be staked and irrigated with a drip irrigation system. Weeds will be removed by hand hoeing and pulling. Tomatoes will be harvested and separated by size and maturity classes. Fruits were harvested, with assistance of farmers, early in the morning and stored on the farm according to local practice. Farmers will take a sample of 30 tomatoes from each treatment and class, retain them in storage, and monitor them weekly for 6 wk. In addition, 50 fruits without visible damage will be randomly selected and taken to the laboratory for evaluation and storage. These will be placed in a plastic basin according to respective quality class. Fruit quality will be assessed weekly for six weeks discarding those fruits found with unacceptable market quality (shriveled, fungal growth, water soaked). Final data will be shelf life as indicated by proportion of fruit remaining in acceptable market quality condition over time.

Activities at MARI:

1. On-farm evaluation of IPM strategies for vegetable virus diseases (Sseruwagi, Ndunguru)

Location: Two farms in Bagamoyo district. Target group for this activity will be 20 vegetable producers, who will be given tours of the demonstrations.

Crops: Tomato, cabbage and cucurbits; Priority pests: Viruses, whiteflies, aphids

Methods: There will be a comparison of farmer practice vs improved IPM practices. These will be set up as randomized blocks with at least four replications. IPM practices will include: healthy seedling production in an insect proof screen house, isolation, roguing, mulching, pesticide use only when needed, use of adapted varieties, biological control and other IPM technologies as needed. For example, the following IPM components will be used depending on the site, pest history, and status of the crop: Pre-season: Crop rotation, Resistant varieties, Seed selection, Host-free period; pre-plant: Tillage, Soil bed preparation; At seeding: Seed treatment, Planting media (in plug trays); Seedling carrier: Treatment of planting media with biocontrols, Seedling protection (netting), Grafting, Roguing; Crop establishment: Staking, Mulching, Sticky and pheromone traps, Pruning, Microbial controls, Botanical pesticides, Conservation biocontrol, Drip irrigation; Post-harvest: Fruit treatment, Sanitation. . . Farmers will evaluate crop health, yield, and quality. Outputs expected include better procedures for healthy seedling production and experiential information to include in IPM packages.

2. On-farm validation of combinations of IPM strategies for tomatoes with 6 farmers.
Location: 3 farms each near Zinga and Kingingoni.
Methods: These will be comparison plots with the standard practice used on the farm compared with IPM strategies. Specific treatments will depend on pest problems, cropping situation (irrigated vs non-irrigated etc), and farmer interest. Treatments will include: healthy seedlings, grafted seedlings, resistant varieties, mulching, staking, pruning, drip irrigation and other best practices. According to farmer interest, plots will include use of *Trichoderma*, BT, *Metarhizium,* and *Beauveria* products from Real IPM applied according to label instructions. Researchers and farmers will jointly assess results in terms of crop yield and quality.

KENYA

Activities at KALRO

1. On-farm validation of *Trichoderma* and evaluation of a biofertilizer, "Plantmate," for their efficacy in management of bacterial wilt of tomato. (Mbaka, Kuria, Wepukhulu)

Experimental site: Chuka Sub-County, Tharaka Nithi County, Kenya
Audience: 40+ member Farmer Group: Mbogoni Horticultural Growers' Self Help Group
Treatments:

1. *Trichoderma harzianum* (Triunum)
2. *Trichoderma asperellum* (Real Trichoderma)
3. *T. harzianum* + *T. asperellum* (Triunum + Real Trichoderma)
4. Plantmate (Biofertilizer)
5. Control (drenching with water only)

Methods: The experiments will be laid out in a completely randomized design replicated three times and repeated twice. Disease incidence (percent bacterial wilt) will be observed by counting the number of wilted plants in each plot at weekly intervals. Data on inhibition and pest incidence will be recorded and subjected to analysis of variance (ANOVA) using the procedure GLM of SAS.

2. On-farm validation of selected biopesticides for management of *Tuta absoluta*, tomato leaf miner (*Liriomyza trifolii*) and other arthropod pests of tomato. (Kambo, Wepukhulu)

Location: Chuka Sub-County, Tharaka Nithi County, Kenya
Audience: Farmer Groups: Mbogoni Horticultural Growers' Self Help Group, Mbuiru-Mwanjati Horticultural Growers' Self Help Group
Treatments:

1. Pyrethrin+Garlic extract (Pyegar)
2. *Bacillus thuringiensis* (Halt 5 WP)
3. Refined base oil (98.8%) (DC-TRON)
4. Azdirachtin (Nimbecidine EC)
5. Control (water spray)

Methods: Farmers will plant tomatoes as per standard practice in well prepared field soil. Plants will be drip irrigated, staked, and pruned to keep leaves off of the soil surface. Healthy tomato seedlings will be produced using good horticultural practices, and transplanted uniformly. Treatments will be applied and repeated according to product label. Pheromone traps will be placed in the fields for detection of first appearance of Tuta. The plants will be watered every other day. Damage will be estimated weekly on overall percent injury and on previously marked leaflets and the difference between the initial and final values established. Data will be analyzed with repeated measures ANOVA using a mixed model approach in SAS.

3. On-farm validation of the efficacy of T*richoderma* and *Bacillus* strains for management of black rot and soft rot of cabbage. (Mbaka, Muriuki, Kihara)

Experimental site: Chuka Sub-County, Tharaka Nithi County, Kenya
Farmer Group: Nthambo Horticultural Growers' Self Help Group
Treatments:

1. *Trichoderma harzianum* (Triunum)
2. *Bacillus Thuringiensis* (Halt 5 WP)
3. *Trichoderma asperellum* (Real Trichoderma)
4. *Bacillus subtilis* (Real Bacillus)
5. Control (spray or drench with Water only)

Methods: Farmers will plant cabbage as per standard practice in well prepared field soil. Plants will be drip irrigated. Healthy seedlings will be produced using good horticultural practices, and transplanted uniformly. Treatments will be applied and repeated according to product label. Damage will be estimated by assessing external and internal rot symptoms, 70 days after transplanting. Scoring will use the external black rot index (EBRindex). Leaves not part of the head will be classed with injury as none, >0–10%, 11–20%, 21–30% and >30% of the surface
of a leaf showing black rot symptoms. For internal symptoms, heads will be cut into quarters and classed as: no discoloration or symptoms on the heart leaves; vein discoloration <half of the stem, no symptoms on the heart leaves; vein discoloration >half the stem, no symptoms on the heart leaves; vein discoloration of stem and up to 3 of the heart leaves; vein discoloration of stem and on more than 3 heart leaves. Data will be analyzed with ANOVA using a mixed model approach in SAS.

4. On-farm validation of four biopesticides and a trap crop in the management of the cabbage moth (*Crocidolomia pavonana*) and aphids in brassicas. (Kambo, Muriuki)

Location: 2 farms each in Chuka Sub-County, Tharaka Nithi County, Kenya
Audience: Farmer Groups Nthambo Horticultural Growers' Self Help Group
Treatments

1. *Beauveria bassiana* (Biopower 1.15 EC)

2. Azandrachtin (Neemraj Super 3000)
3. *Bacillus thuringiensis* (Dipel DF)
4. Tomato as trap crop
5. Control (Spray with only water)

Methods: Farmers will plant cabbage as per standard practice in well prepared field soil. Plants will be drip irrigated. Healthy seedlings will be produced using good horticultural practices, and transplanted uniformly. Applications of products will be made every 4-7 days throughout the crop cycle. Label rates of registered products and equivalent rates applied. Plants randomly selected from each plot will be destructively sampled weekly and complete larval counts made. Yield will be evaluated at harvest.

5. On-farm validation of selected bio pesticides for their efficacy on management of arthropod pests of French beans. (Kambo, Ngugi, Wepukhulu)

Location: One farm each in Chuka Sub-County, Tharaka Nithi County, Kenya
Audience: Farmer Groups Mbogoni Horticultural Growers' Self Help Group, Mbuiru-Mwanjati Horticultural Growers' Self Help Group
Treatments:

1. Pyrethrin+Garlic extract (Pyegar)
2. *Bacillus thuringiensis* (Halt 5 WP)
3. Refined base oil (98.8%) (DC-TRON)
4. Azdirachtin (Nimbecidine EC)
5. Control (water spray)

Methods: Pod borer (*Maruca vitrata*) is becoming a major pest along with false codling moth (*Cydia pomonella*). Farmers will plant beans as per standard practice on their farms. Plots consisting of 6 rows 4 m long will be replicated 4 times in a randomized block design. Treatments will be applied as per label. Results will be assessed by weekly observations of plots for damage. Tagged plants will be visited for specific insect and damage quantification through harvest. The yield and quality will be evaluated and data analyzed using SAS.

6. On-farm validation of three biopesticides for their efficacy in the management of foliar diseases and nematodes in French beans. (Mbaka, Kuria)

Location: Experimental sites in Chuka Sub-County, Tharaka Nithi County, Kenya
Audience: Farmer Groups Mbogoni Horticultural Growers' Self Help Group, Mbuiru-Mwanjati Horticultural Growers' Self Help Group
Treatments:

1. *Trichoderma asperellum* (Real Trichoderma)
2. Azdirachtin (Nimbecidine EC)
3. *Paecilomyces lilacinus* (Bionematone)
4. Control (Foliar spray with water only)

Farmers will grow French beans as per standard practice on their farms. Plots consisting of 4 rows 3 m long will be replicated 6 times in a randomized block design. Treatments will be applied as per label. Results will be assessed by weekly observations of plots for damage. Tagged leaves will be evaluated for damage. Samples of suspect diseases will be taken to the lab for identification. Five randomly selected plants will be dug up monthly for evaluation of nematode damage. Crop yield will be measured at harvest and data analyzed using SAS.

7. On-farm Demonstrations for field days (to be established in October 2017) (Mbaka, Kuria, Kambo, Ngugi, Wepukhulu)

1. IPM Package for tomato-Mbogoni Group
2. Integrated management of French bean Nematodes-Mbuiru Mwanjati Group
3. Integrated management of Brassica pests and diseases-Ntahmbo Group

Technologies used in the on-farm demonstrations will be based on the history of pest problems at the site, the resources available locally, the crop rotation, availability of irrigation, and farmer choice of management practices, including high tunnels and grafting. In all cases we will start with healthy seedlings, grafted plants as needed, adapted resistant varieties, mulching, staking, pruning, drip irrigation and other best practices. According to farmer interest, plots will include use of botanicals, biological controls, and reduced pesticide use. Periodic assessment of plant health will be made in association with participating farmers. Crop yield will be measured at harvest.

High tunnels used to grow tomatoes during the rainy season reduce rain splash and hence soil-borne disease. Moreover, high tunnels are especially conducive to the integration with other IPM technologies including biocontrols and so are an IPM tool. HTs are used to create microenvironments that interfere with development of disease and/or insect pest populations. In extreme cases they provide exclusion opportunities. There is a wealth of literature and practical experience verifying this.

ETHIOPIA

Activities at Hawassa

1. Integration of pest management practices for onions in the Rift Valley. (Azerfenge, Yibrah, Alemayehu)

Location: Farms near Hawassa and Ziway.

Audience: Area farmers and farming groups.

Main pest target: Thrips.

Treatments: Monitor thrips and rotate insecticides. A rotation of Abamectin, dimethotae, profenofos and imidachloprid, each of will be applied for two consecutive weeks based on number of thrips. The threshold for Abamectin will be 2-3 thrips/plant; for others the threshold is 5-10 thrips per plant.

Methods: Onions will be planted in two farms with two treatments. Half of the plots will receive our selected treatments and the other the current farmer practice, which is continuous spray with profenofos every 5-7 days. All the plots will be protected from fungal diseases with the indicated fungicides. Plots will be evaluated for crop injury on a weekly basis and harvest yield.

2. Efficacy and economic evaluation of weed control methods on onion. (Azergenge)

Location: Two farms each in Hawassa and Ziway.

Treatments:

1. Weedy check
2. Weed-free (hand-weeded) check
3. Pendimethalin followed by 1 weeding.
4. Pendimethalin followed by 2 weedings.
5. Pendimethalin followed by 3 weedings.
6. Pendimethalin followed by 4 weedings.

Methods: We will compare with farmers practice in Ziway and Meki at four farms. All the plots will be protected from Thrips with rotation of insecticides. Data will be collected on onion growth

and yield, number of person-hours for weeding, economic analysis, and include a farmer evaluation of weed control and onion growth.

3. Performance of *Trichoderma* on pepper and tomato seedlings. (Azerfegne, Alemayehu)

Locations: On two farms each around Hawassa and Ziway where there are problems of soil borne diseases.

Hawassa has two confirmed sources of *Trichoderma*: Koppert and Real IPM. They are allowed to bring *Trichoderma* from any source for experimental purposes. If there is another source they will be include. Ethiopian collections will also be included for comparison purposes. Besides, this is the interest of the ministry of Agriculture and the research system. The study will be both in greenhouse and field. They are allowed to conduct the field experiments.

Audience: Four influential farmers each associated with 6 – 8 farmers in surrounding growing areas.

Treatments:

1. untreated control
2. Trichoderma from Real IPM applied as per directions.
3. Trichoderma from Koppert applied as per directions.
4. Trichoderma from Ambo Research Center applied as per directions.

Methods: There will be two phases of this experiment. First is a preliminary graduate student greenhouse pot experiment to evaluate different formulations of *Trichoderma*. Second is on-farm experiments with similar treatments of *Trichoderma*. Treatments will include seedlings treated with *Trichoderma* from various sources compared with untreated seedlings. The on-farm plots will be laid out in a completely randomized design replicated three times. Disease incidence (percent bacterial wilt) will be observed by counting the number of wilted plants in each plot at 7 to 10-day intervals. Data on pest incidence will be recorded and subjected to analysis of variance (ANOVA).

4. Evaluate netting to exclude pests for pepper virus management. Pepper viruses of interest include thrips –transmitted Tospo viruses e.g. Tomato spotted wilt, and white-fly transmitted gemini viruses. Of particular interest is the Ethiopian pepper mottle virus. (Azerfenge, Yibrah, Alemayehu)

Location: Hawassa vegetable farm.

Treatments:

1. untreated control
2. Pepper covered with net for 20 days
3. Pepper covered with net for 40 days
4. Pepper covered with net for 60 days
5. Pepper covered until flowering

Methods: We will start with healthy seedlings treated with *Trichoderma*. Treatments will be different durations of netting and protection against vectors, plus a no-net barrier control. Pepper will be covered with net for 20, 40, 60 days and until flowering, followed by repeated spraying with dimethoate 40% EC. After net removal, peppers will be sprayed with dimethoate 40% EC as needed. The netting is expected to provide protection against vectors. The data will be assessments of the disease prevalence and severity, and population of vectors, pepper performance.

5. Tomato IPM package evaluation. (Azerfenge, Yibrah, Alemayehu)

Location: On-farm experiment at four farms near Nazareth.

Audience: Participating farmers and up to 20 local farmers per site during field days.
Treatments:
1. Standard farmer practices.
2. IPM Packages.
Methods: The IPM packages will be designed in cooperation with participating farmers based on site conditions and resources available locally. The options include the following: healthy seedlings, *Trichoderma*, border plants, removal of solanceous weeds in and around the field, rogueing symptomatic plants, monitoring and early detection of vectors, pests and diseases, pesticides applied based on monitoring. For Tuta we will introduce traps to monitor attractants and evaluate their efficiency. The experimental design will be a randomized complete block with three to four replications. Informal field days will be conducted to bring neighboring farmers to the sites at times when clear differences are apparent for tomato health and yield. Farmers will assist in evaluation of crop vigor, disease and pest incidence, yield, and crop quality.

Activities conducted in Ethiopia through IITA

1. Impact of source and application rate of Biochar on population of *M. incognita* and yield of Chilies. (Coyne)

Treatments:
1: Control (2:1 sterilized soil and sand)
2: Coffee husk (0.5 g per pot)
4: Bonn mill (0.5 g per pot)
4: Saw dust (0.5 g per pot)
5: Animal manure (0.5 g per pot)
6: poultry litter (0.5 g per pot)
7: Coffee husk (0.25 g per pot)
7 Bonne meal (0.25 g per pot)
8: Woodchips (0.25 g per pot)
9: Saw dust (0.25 g per pot)
10: Animal manure (0.25 g per pot)
11: poultry litter (0.25 g per pot)
Methods: The experimental design will be a randomized complete block with 8 replications. This is a preliminary pot experiment to test the concept of Biochar impacts on nematodes. Chilies will be propagated in the lab to the two-leaf stage. Uniform seedlings will be transplanted individually into pots where the soil has been prepared with the designated amendment and a standard uniform population of *M. incognita*. Half of the pots will be sacrificed at flowering wherein plants will be removed from pots for examination of roots following washing. The other half of the pots will be retained until harvest, at which time fruits will be harvested and weighed, and roots removed from pots, washed, and examined for assessment of nematode infection.

2. Screening of the host-pathogen relationships of available tomato varieties in Ethiopia to *M. hapla*. (Coyne)

Treatments: Fifteen tomato varieties selected from available adapted and acceptable types.
Methods: The experimental design will be a completely randomized design with 20 replications. The experiment will be conducted in a screen house using plants growing in pots. Seedlings will be produced from clean seeds germinated in petri dishes. Cotyledon-stage seedlings will be planted in soil infected with the root-knot nematode *M. hapla*. Data will be collected by removing flowering-stage plants from pots, washing roots, and examining for *M. hapla* infection. After 6 weeks, resistance or susceptibility will be evaluated by examining the roots for appearance of

galls. Plants will be scored "resistant" when 0–3 galls are visible on the roots and "susceptible" when more than 10 galls are found. This experiment will be repeated, using additional varieties that come available, to determine if any sources of resistance exist in available varieties.

3. Screening microbial antagonists against root-knot nematodes in tomato. (Coyne)

Treatments:

1. Control (Un-inoculated plants)
2. Root-not nematode alone
3. bacterial antagonists alone
4. fungal antagonists alone
4. Root-not nematodes + bacterial antagonists
5. Root-not nematodes + fungal antagonists

Methods: Four varieties of locally adapted tomato varieties will be used. This gives 4 varieties x 5 treatments, replicated 12 times. Seedlings will be grown from clean seeds and grown in sterilized potting media to the 3-leaf stage. Tomato seeds planted in a screen house in soil infected with the root-knot nematodes *M. incognita, M. javanica*, *M. arenaria,* and *M. hapla*. For each microbial treatment, 10–24 seedlings will be assayed after 6 weeks of growth. Treatment response will be determined by examining the roots for appearance of galls. Plants will be scored 'clean' when 0–3 galls are visible on the roots and "damaged" when more than 10 galls are formed. The numbers of clean and damaged plants for each variety will be analyzed using analysis of variance.

Objective 4: Evaluate outcomes and impacts (economic, environmental, gender) of the IPM program

Activity 1

Evaluate impacts (yield, economic, environmental, gender) of specific IPM practices on tomatoes, cabbage, and French beans such as seedling trays, sanitizing seed treatment, rogueing, and nursery nets.
PIs: Norton, Erbaugh, Maerere, Norton, Rakowski, Mbaka, Ndungu, Wepukhulu, Azerefegne, Beyene
Site/Locations: Tanzania, Kenya, Ethiopia
Status: New
Description: Use results of the baseline survey data, field trial data, targeted new farm-level survey followed by regression analysis, and village-level focus groups to evaluate economic, environmental (pesticide-related), and gender impacts of specific IPM practices on tomatoes, cabbage, and beans (Kenya) or onion (Tanzania and Ethiopia). We will explore the impacts of IPM on farm households and at a county level.

Activity 2

Stakeholder workshop for project assessment
PIs: Maerere Mtui, Mamiro, Rwegasira (SUA); Sseruwagi (MARI);
Site/Locations: Tanzania
Status: New
Description:
1. Organize stakeholder workshop to provide feedback on baseline survey results and share results from on-farm trials to evaluation prototype IPM technologies
2. Initiate activities for development and testing tools for project impact assessment.

Activity 3

Knowledge sharing and transfer/scaling out
PIs: Sseruwagi, Maerere

Site/Locations: Tanzania – MARI, SUA
Status: On-going
Description: Share knowledge about the efficient IPM technologies/strategies in a stakeholders' workshop organized together with other partners in Tanzania – September 2018.

Objective 5: Draw on project findings and impacts to inform national and regional policies that support IPM implementation to benefit the health of people
Activity 1:
Policy development
PIs: Maerere, Sseruwagi, Mbaka, Azerfegne
Site/Locations: Tanzania, Kenya, Ethiopia
Status: New
Description: Prepare Policy briefs on safe use and disposal of pesticides in vegetable production. Use data from baseline survey and the IPM trials to suggest policy alternatives. Identify county and national policies that support or hinder IPM adoption.

Graduate Students:
1.
Name: TBD
Gender:
Nationality: TBD
Discipline: Agricultural Economics
Site/Country: Kenya, Ethiopia, Kenya
Degree: M.S.
Start date: May 2018
Completion date: July 2019.
IPM IL funds: 100% after May 2018 (Ag Econ Department will pay for period of August 2017 to May 2018 prior to his starting on this IPM IL project)
Advisor/PI: George Norton
Thesis topic: Impacts of IPM for vegetables in Kenya
University: Virginia Tech

2.
Name: Hellen Elias Kanyagha
Gender: female
Nationality: Tanzania
Discipline: Plant Pathology
Site/Country: Tanzania, USA
Degree: Ph.D.
Start date: 15 March 2017
Completion date: July 2019.
IPM IL funds: 100%. (Plant Pathology Department will pay if extension needed)
Advisor/PI: Sally Miller
Thesis topic: Characterization and Potential IPM Strategies in Managing *Ralstonia solanacearum* in Tomato.
University: Ohio State University

3.
Name: Denis Nyamu
Gender: male
Nationality: Kenya
Discipline: Entomology
Site/Country: Kenya, USA
Degree: M.S.
Start date: 15 August 2017
Completion date: July 2019.
IPM IL funds: 100%. (Entomology Department will pay if extension needed)
Advisor/PI: Luis Canas
Thesis topic: *Tuta absoluta* biology and management.
University: Ohio State University

4.
Name: Cecilia Ngugi
Gender: female
Nationality: Kenya
Discipline: Plant Pathology
Site/Country: Kenya
Degree: Ph.D.
Start date: 2016
Completion date: July 2019.
IPM IL funds: 20%
Advisor/PI: Jesca Mbaka
Thesis topic: Use of entomopathogenic nematodes for management of *Tuta absoluta* in tomato.
University: Chuka University

Publications planned

Thesis: Four theses in preparation from project research.
Articles: One article per year expected from each graduate student;
Book**:** Sikora, Coyne, Hallman, Timper 2018. Plant parasitic nematodes in subtropical and tropical agriculture. CAB International, UK.
Book chapter: Coyne, et al. 2018. Plant-Parasitic Nematodes and Food Security in Sub-Saharan Africa. Annual review of Phytopathology
Posters: Three posters at ESA and IPM Symposium meetings.
Conference Abstracts: Three
Technical bulletin: SOPs - One
Extension bulletin: Vegetable Crops Production Manuals/Leaflets to support pest diagnosis and management. Develop vegetable pest management brochures in two languages, which will eventually develop into IPM manuals at the completion of the project.

Other: IPM Communications Network: Web sites at OSU and Real IPM will be completed to provide a resource for users of the WhatsApp IPM Diagnosis and Management Network for use by extension personnel and farmer groups in all three countries.