The *Feed the Future Innovation Lab* for

Integrated Pest Management

Technical Workplan

Fiscal Year 2019

IPM IL | Integrated Pest Management
Innovation Lab

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Contents

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.
b) Crop/pest monitoring for other existing and potential pests 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.

Expected outcomes: (1) Increased knowledge of *Tuta absoluta* spread 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 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 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 to the collection of plants with viral symptoms and disease data. Data collected will be summarized.

Expected outcomes: Data will be summarized with information on major pests by vegetable crops, 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

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 tomato pith necrosis IPM practices under polyculture that include removing infected pith and painting wound 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 are involved.
b) Trapping of fruit flies with protein bait and cuelure will be tested on farm for cucumbers and bitter gourd. Special attention will be given to assessing the economic benefits of the protein bait. NARC entomology scientists will be involved in the trial sites.
c) A chili package will be tested on a farm that includes raised beds, compost amended with *Trichoderma* and *Pseudomonas*, and resistant varieties. NARC plant pathology scientists will be involved.
d) 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*. There will also be varietal screening of OP and hybrid tomato varieties against the pest. These trials and screening will occur in an area where *Tuta* is a major problem. NARC entomology scientists will be involved.

e) 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, and Kathmandu, Banke and Surkhet). NARC entomology scientists will be involved in the trials.
f) On-station testing of anaerobic soil disinfestation.
g) Test virus management strategies for tomato production under greenhouse conditions. NARC plant pathology scientists will be involved.
h) Test management practices for bacterial/fungal wilt on tomatoes and chili. Treatments include lime, silver hydrogen peroxide, *Pseudomonas fluorescens* (seed treatment, dipping and drenching), solarization with white plastic, and control. Trial will be conducted in Surkhet and Banke, and it will be conducted in two seasons.

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 tomato, eggplant, chili, cucumber, and bitter gourd will have been 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
Co-PIs: Bangladesh scientists as listed below

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 work will be undertaken to test 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 an IPM package for managing *Tuta absoluta* on tomato (Panchagorh, Jessore, Comilla, Sylhet and Gazipur) while disseminating best known current IPM practices through field days and other training as described below under Objective 2 (Co-PIs M.S. Hossain, A. Roy, and M.Y. Mian)
b) Test IPM management package for white mold (*Sclerotinia sclerotorium*) on country bean in Bogra using an on-farm trial with randomized and replicated treatments. Some bio-control agents such as fungal antagonistic viz. *Trichoderma harzianum* and *T. viride* and bacterial antagonistic viz. *Bacillus subtilis* BVC38 and *Pseudomonas* sp. were found to be effective to control the pathogen. However, these bio-control agents need to be tested against the pathogen in field conditions. Impact of treatments on yield and yield contributing factors will be assessed (BARI Co-PIs: M. S. Nahar, M. Afroz, L. Yasmin, M. N. Naher, M. J. Hossain, M. J. Alam).
c) 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.R. Ali, M. Afroz, G.M.A. Halim, M.S. Hossain, M.Y. Mian).

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 tomatoes and country bean will have been 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.

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 and CE SAIN Technology Park) 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 for rainy season 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 tomato IPM package for dry and rainy seasons on farm in Siem Reap with cooperative farmers, CE SAIN technology park and RUA. The package includes: selection of resistant variety of *Ralstonia solani, Trichoderma* seed/seedling/soil treatment, nursery nets, Pheromone traps – for *Spodoptera* and *Helicovepa;* sticky taps and using biological control agents including Bacillus subtilis, *Beauveria bassiana* and *Bacillus thuringiensis*.
c) Tomato rootstock evaluation for *Ralstonia* resistance at RUA
d) Monitoring tomatoes for *Tuta absoluta* using pheromone traps at various locations
e) Monitor vegetables (cucumbers, tomatoes, chili peppers, eggplant and long beans) for viruses in all project sites and identify prevalent viruses.
f) 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 have been 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. For example, 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. In Bangladesh, the project will disseminate information on the biopesticide *Beauveria bassiana* for mango hoppers (Co-PIs: M.S. Hossain, B.C. Barker, M. Hossain, and M.Y. Mian)
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, providing information to them 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. In Bangladesh, the project will coordinate with BARI and DAE to disseminate the *Bt* eggplant IPM package in Gazipur, Jessore, and Bogura (BARI Co-PIs: M.S Hossaain, AKM Qamruzzaman, A. Roy, and Y. Mian). Dissemination will also occur for mango bagging with double layer brown paper bag for controlling mango fruit fly *Bactrocera dorsalis* in high rainfall and hilly areas) Moulvibazar, Sylhet and Khagrachari) of Bangladesh (Co-PIs: M.S. Hossain, A. Hossain, M.R. Ahmad, and J.C. Sarker). In Nepal, representatives from local governing bodies will also be brought for visits to the research sites so they understand the IPM practices and are able to help with dissemination over time.

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, (4) Local governments disseminate IPM practices and incorporate them in their annual plans.

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 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, and Miller, Kim Hian, Sah and Mian

Site/Location: Cambodia, Bangladesh, Nepal

Status: Continuing

Description: a) Use a 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 impact surveys in Nepal and assess factors affecting IPM adoption, pesticide use, and economic impacts of *Tuta absoluta* management on tomato. Assess economic impacts from field trial data in each country.

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 data from Nepal along with data from the various on-farm trials will be used. Farm-household and market-level benefits of *Tuta* management in Nepal will be calculated. Theses will be completed as part of these impact assessments and papers will be submitted to journals out of the theses.

Expected outcomes: Economic and environmental analyses conducted and published.

***Activity 2*:** Assess gender impacts of IPM and policies and means for improving gender-sensitivity in IPM diffusion.

PIs: Christie, Norton, Sah

Site/Location: Nepal, Bangladesh, Nepal

Status: Continuing

Description: Gender impacts of IPM activities and policies will be described in a journal article and in presentations based on MS thesis completed in 2018 for Nepal. Gender constraints to and opportunities for adoption will be presented. The IPM diffusion process in each country will be examined from a gender perspective and recommendations made to facilitate IPM scaling strategies that include a gender perspective.

Expected outcomes: 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*:** Prepare paper that summarizes IPM policy issues in each of the three countries. These policies include 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: Write up of analyses 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.

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

Graduate Students, Undergraduate 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: May 2019.
IPM IL funds: 0% (Started program in 2014 on Bangladesh Associate award, used up her allocated funds on the IPM IL and went off funding. After taking a leave from her graduate studies, she was able to obtain a scholarship from the Graduate School at Virginia Tech and will finish by May 2019)
Advisor/PI: George Norton
Thesis topic: Effects of IPM Training on Knowledge Building, Adoption, and Pesticide Use in Bangladesh
University: Virginia Tech

2. Name: Lauren Knaresboro
Sex: Female
Nationality: U.S.
Discipline: Agricultural Economics
Site/Country: Nepal
Degree: MS
Start date: January, 2018
Completion date: June 2019.
IPM IL funds: 100% (Started program in August 2017 on own funds and began on IPM IL funds in January 2018)
Advisor/PI: George Norton
Thesis topic: Economic impacts of IPM program for *Tuta absoluta* on tomato in Nepal.
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: May 2019.
IPM IL funds: 100% (Started program in previous phase of IPM IL and *has now used up allocated funds.* He has a job in Nepal and intends to finish in July 2019, but will not receive new funds)
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: September, 2019.

IPM IL funds: 100%
Advisor: Ed Rajotte and Cristina Rosa
Thesis topic: TBD
University: Penn State

5. 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 by Ohio State
Advisor: Sally Miller
Thesis topic: TBD
University: Ohio State University

6. 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: 20%
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

7. Undergraduates in Cambodia at RUA:

No	Name	Gender	Discipline	Degree	Start date	Completion date/ Status	Advisors	Thesis tittle
1.	Lim Kevmonirath	F	Agronomy/ Plant Pathology	BS	1/18	6/19	Ong Socheath	Evaluation the efficacy of *Bacillus subtilis* and *Trichoderma spp.* for controlling bacterial wilt on tomato
2.	Heng PengHorng	M	Agronomy/ Plant Pathology	BS	1/18	6/19	Ong Socheath	The efficacy of plant extracts and *Trichoderma harzianum* for *Alternaria solani*
3.	Nheum Dara	M	Agronomy/ Plant Pathology	BS	1/18	6/19	Ong Socheath	IPM package on tomato

4.	Suarng Sokonthearaet	F	Agronomy/ Plant Pathology	BS	1/18	6/19	Ong Socheath	IPM package on tomato
5.	Voeurn Sokunthea	F	Agronomy/ Plant Pathology	BS	1/18	6/19	Ong Socheath	Biological control of Chili Anthracnose
6.	Seang Oun	M	Agronomy/ Plant Pathology	BS	1/18	6/19	Ong Socheath	Efficacy of *Bt* on Diamond Back Moth in Chinese Kale

Short-Term Training planned

Annual meetings in Cambodia, Nepal, and Bangladesh

Publications planned:

Theses: 5
Research articles: 4
Books and book chapters: 2
Posters: 1
Conference abstracts: 2
Extension articles: 2

Travel Matrix

Trip No.	Number of Individuals	Destination Country(ies)	Duration*	Function (Site planning, workshop, symposium etc)
1	**8**	**Bangladesh, Nepal Cambodia**	**4 days to 9 days in each country**	**Participating in site planning and review and short term training workshops**
2	**1**	**Cambodia**	**2 weeks**	**Participating in mid-year planning and review**
3	**1**	**Bangladesh, Nepal**	**1 week**	**Participating in site planning, reviewing progress**
4	**2**	**Nepal, Bangladesh, Cambodia**	**1-2 weeks each**	**Workshops on various topics**

*Proposed duration may change depending on changing circumstances

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

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

CO PIs: Lidya Alemayehu (VSU-Ethiopia), Samuel Assefa (GTZ, Ethiopia), Maria Elisa Christie (Virginia Tech), Muo Kasina, Kenya Agricultural and Livestock Research Organization (KALRO), 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), 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)
Kenya - Kenya Agricultural and Livestock Research Organization (KALRO)
South Africa – ARC-PPRC
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, Lidya Alemayehu, Tesfay Amare, Mulugeta Negari, Lisanework Nigatu

Site/Location: Wollenchiti, Guder (Ambo University), and Haramaya

Status: Continuing

Description: The three rearing facilities in Ethiopia will continue to operate during the FY19. The primary site will continue to be in central Ethiopia at Wollenchiti, which has been operational since 2013; the other two are 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 primarily supply *Z. bicolorata* 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 has 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 is grown at each site for rearing the bioagents. Adults are collected periodically and are being released in *Parthenium* infested fields. The sites are also 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; *Z. bicolorata* and *L. setosipennis* are mass-reared and released in *Parthenium* infested areas of Ethiopia; Personnel are trained on how to mass rear these biocontrol agents.

Objective 2: To evaluate the establishment and impact of the released agents on *Parthenium*, crops, and biodiversity

Activity 1

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

Site/Location: All release sites including Agemiti, Arba Minch, Finote Selam, Gerbi, Melkassa, Mojo and Wollenchiti.

Status: Continuing

Description: This evaluation will have two parts: 1) measure the establishment, prevalence, and abundance, of the released biological agents over space and time after release; 2) 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 the 2018 release sites that include Agemiti, Arba Minch, Finote Selam, Gerbi, Melkassa, Mojo and Wollenchiti. *Parthenium* before and after release and agent presence after release is being measured. **Abundance of *Parthenium*:** Number of plants; height; above-ground, below-ground and total biomass; number of flowers per plant; **Abundance of bioagent:** Number of adults, larvae, eggs per plant or pupae **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 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 continue to be suspended in 2019 until the cause for the lack of emergence is determined.

Objective 4: To scale-up the release and monitoring of *Zygogramma bicolorata* and *Listronotus setosipennis* in Uganda, and to obtain the necessary permits for field release of *Z. bicolorata* in Kenya.

Activity 1: Secure permit from the Ugandan Government to introduce *Zygogramma bicolorata* and *Listronotus setosipennis* in Uganda

Co-PI: Richard Molo

Site: Entebbe, Uganda

Status: Permit was granted based on host-range data generated in Ethiopia

Description: In April 2017, NARO through its Biological Control Unit filed an application to the quarantine department at the Ugandan Ministry of Agriculture. The objective was to conduct studies on two *Parthenium* biocontrol agents, *Z. bicolorata* and *L. setosipennis* under Uganda conditions. In June 2017, approval was given for importation of the two biocontrol agents that will be sourced and introduced concurrently in Uganda.

Expected outcomes: Biocontrol agents that are deployed against *Parthenium* in other countries will be tested for their suitability in Uganda.

Activity 2: Rear and release *Z. bicolorata* and *L. setosipennis*.

Co-PI: Richard Molo – National Agricultural Research Organization (NARO)

Site: Mass rearing is taking place at NARO's research facility in Entebbe, Uganda

Status: Mass rearing of the above biocontrol agents is proceeding.
Description: *Z. bicolorata* and *L. setosipennis* were imported in January 2018 to control the weed and cultures were established in the screen house for mass rearing. Mass rearing of the biological control agents has been successful in the screen house with average percentage emergence of adults from soil ranging from 45-67%. A total of 200 insects of each species have so far been released at a pilot site in Mbiko, Central Uganda, Jinja district.

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

Co-PIs: Muo Kasina, Kenya Agricultural and Livestock Research Organization (KALRO)

Site: KALRO National Sericulture Research Centre, Thika.

Status: A list of plant species for host-range testing in being compiled.

Description: Applications to introduce and rear the biocontrol agents, *Z. bicolorata* and *L. setosipennis* in Kenya is being prepared. In addition, discussion has been held with relevant partners in Kenya about the steps that need to be undertaken once the permit is approved.

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: Wollenchiti, Ethiopia; date; May 2019; type: hands-on demonstration of rearing techniques; number: 20; 12 males and 8 females.

Publications planned

Article: Establishment and dispersal of the stem-boring weevil *Listronotus setosipennis* in Ethiopia
Survival and spread of the leaf-feeding beetle *Zygogramma bicolorata* one year after release at three different regions of Ethiopia

2019 Travel Matrix

Trip No.	Number of Individuals	Destination Country(ies)	Duration	Function (Site planning, workshop, symposium etc)
2	1	Ethiopia, Kenya and Uganda	15 days each	Mersie will travel four times to Ethiopia and once to the other eastern African countries for planning, monitoring and project meetings.

3	3	Ethiopia	7 days each	Partners from Kenya and Uganda will travel to Ethiopia in May 2019 to participate in training/workshop on mass rearing of bioagents.
3	3	South Africa	7 days each	Ethiopian staff will travel to Agricultural Research Council – Plant Protection Research Institute (ARC-PPRI) South Africa to receive training on rearing new natural enemies and monitoring of released biocontrol agents

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: Submission to Crop Protection

PIs: Abhijin Adiga, Srinivasan Venkatramanan, Achla Marathe

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

Status: Continuing
Description: the work was updated based on current data and manuscript has been submitted for editorial review. Based on changes suggested, it will be modified and submitted for review.

Expected outcomes: Draft will be submitted to Journal of Crop Protection.

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: This is same as previous year's Objective 2 (Activity 1). The MoU between Virginia Tech and USDA APHIS to gain access to the data was signed in July 2018. 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. 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: 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: *Submission to Nature Comm.*

PIs Abhijin Adiga

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

Status Continuing

Description

This work focuses on South-east Asian countries. Multipathway models have been developed to study the current spread in Bangladesh and Myanmar and predict the possible spread in other countries.

Expected outcomes

- This work is in the final phase. Manuscript has been prepared and will be submitted in August 2018 for possible publication.

Objective 4: Integrating Physiologically-based Demographic models with multipathway models: case study of Senegal and India

Activity 1: Model implementation

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

Status: New

Description: The work will extend the current multipathway model developed in Objective 3 by incorporating phenology models for *T. absoluta*.

Expected outcomes: It will provide a retrospective analysis of spread in both India and Senegal helping the countries better prepare for future invasions. This work is aimed at possible publication in *Journal of Pest Science*.

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

Activity 1: Routes of introduction

PIs: (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

PIs (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: Biological control

Pis : (Anaïs Chailleux)

Site/Location: (Senegal)

Status: Continuing

Description: Studies highlighted the potential of an indigenous predator, *Nesidiocoris tenuis*, for biocontrol. We are currently evaluating the local determinants of its efficacy in tomato fields, e.g. the abundance of wild relay host plants in the surrounding landscape, but also insecticide applications. We will also study the life history traits of the predator on potential African companion plants (lab experiments) and develop agroecological pest control programs (field experiments).

Expected outcomes: Development of new biological control practices for conservation biological control.

Activity 4: Spread and Impact of *Tuta absoluta* accounting for ecological and anthropogenic drivers

PIs: (Abhijin Adiga, 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 commodity flow (see Objective 1, Abhijin Adiga).

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

PIs: Mateus Ribeiro de Campos

Site/Location: INRA/France
Status: Continuing

Description: The effect of temperatures and photoperiods at different exposure durations have been studied to verify whether *T. absoluta* may be inducted to diapause. For this, 3rd and 4th instars of *T. absoluta* larvae have been exposed to different temperatures (2, 5, 10 and 15 °C) at different photoperiods (10:14 vs 14:10, 15:09 vs 09:15, 18:06 vs 08:16 of Light and dark) and at different time intervals 7, 14, 28 and 42 days. Development time are evaluated to *T. absoluta* pupae and after adult's emergence are evaluated the survival and reproduction. We are characterizing key ecological parameters in order to design a Physiologically-based Demographic Model (PBDM) for *T. absoluta*.

Expected outcomes: All the photoperiods in different exposition time are ready to temperature at 2 and 5°C. The study is suggesting that *T. absoluta* could be induced to diapause in low temperature. The missing 20% of study will be completed soon. All the data collect for diapause induction in *T. absoluta* will be used to develop PBDM cover all gaps identified previously. 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. The obtained results will help to understand for the first time the potential diapause induction by acute environmental factors, new insights on overwintering attitude of *T. absoluta* will be gained.

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/Italy and INRA/France

Status: Continuing

Description: We are studying demographic parameters and behavior of *T. absoluta* between the host plant (*Solanum lycopersicum*) and a wild host plant European black nightshade (*Solanum nigrum*). Demographic parameters 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 (ii) and on *S. nigrum* in the temperature at 25 °C, (iii) verify the per capita fecundity profile on female age in the temperature at 25 °C on *S. lycopersicum* and *S. nigrum*, and (iv) 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: The results will provide insight about *T. absoluta* biology in wild host plant. The study was completed at 90% and some missing replicates will be performed to proceed with the statistical analysis. Furthermore, insight about the biology of *T. absoluta* in wild host plant has been neglected over years and this data can be used to develop PBDM becoming it more precise prediction of *T. absoluta* in specific area. 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.

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

PIs: Mateus Ribeiro de Campos

Site/Location: INRA/France

Status: Continuing

Description: The direct influence of temperature on insect development can be measured by determining the thermal threshold and thermal constant. These parameters will help to determine the development rate of *T. absoluta* in different interval exposure time. Besides, data on oviposition, age-specific fertility and survival of females developed (eggs to adults) at temperatures of 6, 10, 15, 20, 25, 30, 33 and 36 °C will be provided to PBDM development

Expected outcomes: The experiments at low temperatures such as 6, 10, 15, 20 and 25°C had a long duration different high temperature 30, 33 and 36°C with a short duration. The thermal requirement has shown that *T. absoluta* can survive and develop in low temperature. All the temperature was performed except in the temperature at 6°C, which is in the final stages. These data are essential for developing an accurate PBDM. The thermal requirement will provide data to calculate the development of *T. absoluta* in the experiment of diapause induction that will be used to develop 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: Continuing

Description Late instars were collected from host plants and shipped to NCSU CIPM for sequence analysis (pending).

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: Continuing

Description: No groundnut leafminer infestation evident during 2017-2018 growing season. Survey will resume during 2018-2019 growing season.

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; Dr. Godfery E. Zharare (Head of Department of Agriculture), University of Zululand, KwaDlangezwa, South Africa

Site/Location: Groundnut and soybean sites in north-central South Africa; groundnut sites in northeast South Africa.

Status: Continuing

Description: No groundnut leafminers were found during 2017-2018 survey season in north-central South Africa. Survey of sites in NE South Africa will be added during 2018-2019 growing season.

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 India

PIs: J. B. van Kretschmar, Godshen Robert Pallipparambil, Dr. Jagdish Jaba (entomologist), International Crops Research Institute for the Semi-arid Tropics (ICRISAT), Patancheru, India

Site/Location: Identification of groundnut sites in India pending shipment of collected specimens.

Status: Continuing

Description: Shipment of specimens collected from host plants to NCSU pending approval of export application.

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, Dr. Andreas Zwick (entomologist), Australian National Insect Collection, Commonwealth Scientific and Industrial Research Organization (CSIRO), Acton, ACT

Site/Location: Identification of groundnut sites in Australia pending collection.

Status: Pending

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.

Activity 6: Collection of *Aproaerema simplexella* larvae from groundnuts in Ethiopia.

PIs: J. B. van Kretschmar, Godshen Robert Pallipparambil, Dr. Muluken Goftishu Muleta, Assistant Professor of Entomology, College of Agriculture and Environmental Sciences, Haramaya University

Site/Location: Identification of groundnut sites in Ethiopia pending collection.

Status: New

Description: Late instars will be collected from host plants and shipped to NCSU CIPM for sequence analysis; survey will begin August 2018.

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

Activity 7: Collection of *Aproaerema simplexella* larvae from groundnuts in Kenya.

PIs: J. B. van Kretschmar, Godshen Robert Pallipparambil, Dr. Muo Kasina, Director, National Sericulture Research Centre, Industrial Crops Research Institute, KALRO (Kenya Agricultural & Livestock Research Organization)

Site/Location: Identification of groundnut sites in Kenya pending collection.

Status: New

Description: Late instars will be collected from host plants and shipped to NCSU CIPM for sequence analysis; survey will begin in 2018.

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

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: Pending

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: Pending

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: Pending

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: Pending

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 08/30/18, 100% funding, advisor(s) Abhijin Adiga, Assessing threat of *T. absoluta* in South-east Asia.
- Correa Philippe, M, Senegal, Master student, Entomology, Biopass/Senegal, 100% funding, advisor(s) A. Chailleux, Field experiments for the development of conservation biological control of *Tuta absoluta*, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, Dakar, Senegal.
- Mbodj Amy, F, Senegal, PostMaster student, Entomology, Biopass/Senegal, 100% funding, advisor(s) T. Brévault, Field experiments for the development of conservation biological control of *Tuta absoluta*, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, Dakar, Senegal.
- Sylla Serigne, M, Senegal, Postdoc, Entomology, Biopass, 50% 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.

- 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

T. absoluta workshop in Vietnam.

Publications planned

Article

- A multi-pathway model to assess the threat of *Tuta absoluta* in Southeast Asia. Joseph McNitt, Young Yun Chungbaek, Henning Mortveit, Madhav Marathe, Mateus Ribeiro de Campos, Nicolas Desneux, Thierry Brévault, Rangaswamy Muniappan, and Abhijin Adiga.
- Climate warming effects on *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in the Eastern Palearctic. Luigi Ponti, Andrew Gutierrez, Mateus Ribeiro de Campos, Antonio Biondi, Nicolas Desneux
- Development time and thermal requirement of tomato pinworm *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in wild host plant. Mateus Ribeiro de Campos, Antonio Biondi, Philippe Bearez, Edwiges Amiens-Desneux, Nicolas Desneux
- Mansour et al. (2018) Current knowledge of biology, fortuitous natural enemies and management of the South American tomato pinworm in Africa and future priorities for its sustainable control *(In prep.).*
- Adiga et al. (2018) Spread and Impact of *Tuta absoluta* accounting for ecological and anthropogenic drivers *(In prep.).*
- Sylla S, Brévault T, Monticelli L, Diarra L, Desneux N (2019) Geographic variation of host preference by the invasive tomato leafminer *Tuta absoluta*: implications for host range expansion *(Submitted to Journal of Pest Science).*
- Sylla S, Brévault T, et al. (2019) Landscape and crop management affect biological control of the invasive tomato leafminer, *Tuta absoluta (In prep.).*
- Desneux et al. (2019) Current practical implementations of Integrated Pest Management (IPM) on the South America pinworm *Tuta absoluta (In prep.).*
- Chailleux A. et al. (2019) Temperature impact on the biological control of *Tuta absoluta* by *Nesidiocoris tenuis*. In prep. for Biological Invasion.
- Chailleux A. et al. (2018) Potential of wild bordering plants for the conservation biological control of *Tuta aboluta* in Senegal. In prep. For Biological control.

Book chapter

None

Poster
1

Conference Abstracts

Technical bulletin
None

Extension bulletin
None

Other
None

Assessment of Invasive Alien Species Distribution in the Chitwan Annapurna Landscape (CHAL) Region, Nepal with the Application of Satellite Imageries.

PI: Pramod Kumar Jha, Tribhuvan University, Nepal

CO PIs: Madhav Marathe, Biocomplexity Institute, Virginia Tech, USA.

Collaborating Institutions: Tribhuvan University, and Biocomplexity Institute, Virginia Tech, USA.

Objective 1: To map the habitat distribution of the major IAS over the time between 1990 and 2017.

Activity 1: Delineation of areas of interest and identification through remote sensing imageries.

PIs: Pramod Kumar Jha and Krishna Paudel

Site/Location: Chitwan Annapurna Landscape in Central Nepal

Status

- Field sites identified

- New-started in May 2018

Description: Five invasive alien species (IAS), namely *Parthenium hysterophorus, Ageratina adenophora, Chromolena odorata, Lantana camara* and *Mikenia micrantha*) have been selected for present study. Pure patches of these species in the field have been identified for comparison with satellite imageries. A quadrate of 10 km sq will be constructed at five different altitudes up to 300, 300-600, 600-1000, 1000-1500 and 1500-2500 m for delineation of quadrate or area of interest. Since objects (individual IAS) have their unique spectral features (reflectance or emission regions), they will be identified from remote sensing imageries according to their unique spectral characteristics.

Expected outcomes: Maps of distribution and increasing trend of expansion of invasive species in the CHAL area.

Objective 2: To identify the high potential spatial location for most common IAS through Geo Information based multi-criteria analysis.

PIs & Experts: Pramod Kumar Jha, Krishna Paudel and Madhav Marathe

Site/Location: CHAL area in Central Nepal.

Status

- Work in progress
- New

Description: A specific set of remotely sensed data and techniques will be utilized to study each type of invasion characteristic. Considering the increasing trend of expansion of invasive species in the CHAL area and field based study, imageries with temporal, spectral and spatial resolution and algorithm of classification will be applied to determine high potential spatial location of IAS.

Expected outcomes: High potential spatial location of selected IAS.

Objective 3: To draw a trend of distribution of IAS over time and develop the linkage of IAS distribution and climate change as a proxy indicator.

Computational methods that combine ideas in GIS and machine learning to assess biodiversity and its change in Nepal will be developed. These methods will combine detailed GIS data with satellite imagery to infer how biodiversity is affected due to climate change and human settlements.

Objective 4: Graduate and undergraduate students sponsored by the project.

Short-term training planned

List of PhD Students in Tribhuvan University (1, 2 & 3) and Agriculture and Forestry University (4, 5)

SN	Student Name	Gender	Level	Topic	Registration Date	Advisory detail
1	Mr. Dol Raj LUITEL	M	PhD	Impact of Climate Change on Finger millet in and altitudinal gradients of Chitwan-Annapurna transient landscape in central Nepal	20 May 2016 (submission minimum 3 yrs from registration)	Supervisor: Prof. Dr. Mohan Siwakoti, CDB, TU Co-supervisors: Prof. Dr. P.K. Jha, CDB, TU.
2	Ms Seerjana MAHARJAN	F	PhD	Ecology and management of *Parthenium hysterophorus* through biological methods in central Nepal	20 May 2016 (submission minimum 3 yrs from registration)	Supervisor: Dr. Anjana Devkota, Co-supervisors: Prof. Dr. Pramod Kumar Jha.
3	Ms Anju Sharma POUDEL	F	PhD	Management of an invasive species *Ageratinaadenophora* through restoration of native vegetation in Chitwan and Annapurna Landscape, Nepal	15 June, 2016 (submission minimum 3 yrs from registration)	Supervisor: Dr. Bharat Babu Shrestha, Co-supervisors: Prof. Dr. Pramod Kumar Jha
4	Mr. HomNath GIRI	M	PhD	Performance of late season cauliflower under different agronomical and IPM practices in Chitwan to Annapurna landscape areas	February 2016 (submission minimum 3 yrs from registration)	Supervisor: Prof. Dr. Moha Dutta Sharma Co-supervisor: Prof. RB Thapa.
5	Mr. Ghanashyam BHANDARI	M	PhD	Climate change effect assessment on insect diversity and development of IPM technologies for maize based farming in Nepal	February 2016 (submission minimum 3 yrs from registration)	Supervisor: Prof. Resham Bahadur Thapa Co-supervisor: Dr. Hirakaji Manandhar & Dr. Yagya Prasad Giri

The process of selection of four students of MSc level has begun, and will be finalized in the first week of August 2018. Names will be sent immediately after selection.

Publications planned

PhD Thesis: 5 by September 2019.
MSc Dissertations: 4 by September 2019.
Article: At least 10 articles by September 2019.
Book chapter
Planning to edit a book on IAS in Nepal.
Poster: 2
International Conference on Biocontrol, Bengaluru, India, September 27-29, 2018.
Technical bulletin
Extension bulletin
Other

Project title: Strengthening production and export of Vietnamese fruit crops through innovative and market-orientated IPM

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

CO PIs: Mr. Mai Van Tri, 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. Le Cao Luong (NLU).

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: Develop the new bio-agents for controlling of fruit crop pests

PIs: Dr. Nguyen Van Hoa (supported by Mr. Mai Van Tri, Mr. Nguyen Thanh Hieu, Dr. Tran Thi My Hanh, Ms. Dang Thi Kim Uyen, Dr. Nguyen Thi Kim Thoa, Mr. Huynh Thanh Loc, Mr. Nguyen Huy Cuong, Ms. Dang Thuy Linh, Ms. Nguyen Ngoc Anh Thu from SOFRI and Dr. Le Xuan Vi from PPRI).

Site/Location: SOFRI, Tien Giang, Vinh Long, Dong Nai, Dong Thap, Long An, Binh Thuan, Hung Yen, Bac Giang and Hai Duong province.

Time: Oct. 2018-Sep. 2019

Status: Continuing

Description: Identifying new bio-agents such as entomopathogenic fungi and entomopathogenic nematodes to control thrips (pupae in the soil) on dragon fruit and mango. Rearing of ladybird beetle *Menochilus sexmaculatus* and lacewing *Chrysoperla* sp. on artificial diets to control mealybugs on dragon fruit and longan. Rearing of *Amblyseius longispinosus* to control *Aceria* (*Eriophyes*) *dimocarpi* on longan. Multiplication of *Beauveria* sp. to control stink bug on longan and shoot borer on lychee. These bio-agents will be tested, mass multiplied and field released. Plant extracts will be tested to control anthracnose and canker on dragon fruit and mango (by SOFRI, PPRI) (one PhD. scholar, one MSc. Scholar).

Expected outcomes: One entomopathogenic nematode, one entomopathogenic fungi will be identified. One plant extract will be identified and developed to control anthracnose and canker disease on dragon fruit and mango.

Activity 2: The local registration, market requirements (i.e. market analysis or assessment) and SPS for dragon fruit, longan, mango and lychee for export to US and other markets

PIs: Dr. Doan Huu Tien (supported by, Mr. Le Van Thiet (PPD), Dr. Nguyen Van Hoa, Mr. Nguyen Thanh Hieu, Dr. Le Quoc Dien, Dr. Tran Thi My Hanh, Ms. Dang Thi Kim Uyen, Mr. Huynh Thanh Loc and Dr. Le Xuan Vi)

Site/Location: Tien Giang, Long An, Binh Thuan, Vinh Long, Dong Nai, Dong Thap, Hung Yen, Bac Giang and Hai Duong province

Time: Oct. 2018-Sep., 2019

Status: Continuing

Description The local registration, market requirements (i.e. market analysis or assessment) and SPS for four target crops exported to US and other countries will be conducted (PPD, SOFRI and PPRI).

Expected outcomes: Information on local registration, market requirements and SPS for four target crops to export to US and other countries will be identified.

Objective 2: Component 4: Putting research into use

PIs: Dr. Nguyen Van Hoa (supported by Mr. Nguyen Thanh Hieu, Dr. Le Quoc Dien, Dr. Tran Thi My Hanh, Ms. Dang Thi Kim Uyen, Dr. Doan Huu Tien, Dr. Nguyen Thi Kim Thoa, Mr. Huynh Thanh Loc, Mr. Nguyen Huy Cuong, Ms. Nguyen Ngoc Anh Thu, Mr. Luong Thi Duyen in the South and Dr. Le Xuan Vi, Dr. Nguyen Duy Hung in the North).

Site/Location: Tien Giang (2 models), Long An, Binh Thuan, Vinh Long, Dong Nai, Dong Thap province in the South, Hung Yen, Bac Giang and Hai Duong province in the North.

Time: Oct. 2018-Sep. 2019

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 that are suitable for the agro-ecosystems and will be released to farmer groups/cooperatives in each zone to incorporate with VietGAP standard. Disease/pest incidence, damage, pesticide residue on fruits, beneficial organism population, productivity and quality of fruits will be recorded every 3 to 6 months (SOFRI, PPRI, PPD).

Scale: 10 trials (15 ha/trial x 1 trial/province)

Site/Location: Tien Giang, Long An, Binh Thuan, Vinh Long, Dong Thap, Dong Nai, Hung Yen, Bac Giang and Hai Duong province.

- Dragon fruit (45 ha): SOFRI is responsible for implementation of dragon fruit IPM trials in Tien Giang, Long An and Binh Thuan. We will be working with Hoang Hau Ltd. Co., or/and Hoang Phat Ltd. Co., or/and My Tinh An Co-operative.
- Longan (50 ha): SOFRI and PPRI are responsible for implementation of longan IPM trials in Tien Giang, Vinh Long and Hung Yen provinces. We will be working with Chanh Thu Ltd. Co., Cat Tuong Ltd., Co., and Green Agricultural Ltd. Co.
- Mango (45 ha): SOFRI is responsible for implementing mango IPM trials in Dong Thap and Dong Nai provinces. We will be working with Long Uyen Ltd. Co.

- Lychee (30 ha): PPRI is responsible for implementing lychee IPM trials in Hai Duong province. It will be working with Green Agricultural Ltd. Co. and Red Dragon Co. Ltd.

Expected results: Increase in export of volume of fruits in compliance with market requirements.

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

PIs: Dr. Le Quoc Dien (supported by Mr. Nguyen Thanh Hieu, Dr. Tran Thi My Hanh, Ms. Dang Thi Kim Uyen, Mr. Le Cao Luong, Dr. Nguyen Thi Kim Thoa, Mr. Huynh Thanh Loc, and Ms. Nguyen Ngoc Anh Thu (in the South), and Dr. Le Xuan Vi (in the North).

Time: Oct. 2018-Sep. 2019

Status: Continuing

Description The Southern Horticultural Research Institute has partnered with the government (national and local government extension systems, universities and other institutions) in efforts to leverage resources and reach much larger audiences. 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 bio-agents and IPM product supply chains. Institutions/Universities will be trained in the production of bio-pesticides and new techniques. Information will be disseminated through the extension system and by NGOs conducting farmer meetings, field trips, training sessions and using mass media.

Scale: 10 courses (1 course/province, 40-50 person/course (farmers, local extension staff of IPM sites, and others)).

Site/Location: **NLU/SOFRI** will carry out training courses in Tien Giang, Vinh Long, Dong Thap, Dong Nai, Long An, and Binh Thuan and **PPRI** will carry out training courses in Hung Yen, Bac Giang and Hai Duong provinces.

Content of training: Practices for production of bio-fertilizer and compost; Use of bio-fertilizer; Use of bio-product (SOFRI-Protein, SOFRI-Tru kien, *Trichoderma, Paecilomyces*, and *Bacillus subtilis*); Use of sticky yellow traps, sweet baits and pheromone traps.

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

Objective 4 Component 6: Monitoring and Evaluation of economic, environmental and gender impacts.

PIs: Dr. Doan Huu Tien (supported by Dr. Ngo Thi Thanh Truc, Mr. Nguyen Thanh Hieu, Dr. Tran Thi My Hanh, Ms. Dang Thi Kim Uyen, Dr. Nguyen Thi Kim Thoa, Mr. Huynh Thanh Loc in the South, and Dr. Le Xuan Vi, Dr. Quyen Dinh Ha in the North).

Time: Oct. 2018-Sep., 2019

Status: Continuing

Description: The monitoring and evaluating systems will be developed to manage the adaptation of farmers and local agricultural staff in the knowledge and participatory learning of IPM approaches. In addition, the pesticide residue will be analyzed and evaluated based on the data collected from Component 2 and 4 (pesticide tests) and expected to satisfy requirements of the U.S. and other countries. The populations of soil beneficial organisms will be recorded in VietGAP/IPM model farms and compared to traditional farms.

Gender impacts will be assessed 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; (4) targets for each indicator by year; and benchmarks for the development of organizational sustainability for the implementing partners.

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 data for 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 other key target groups to the extent feasible.

Expected outcomes: An increase of 20-30% number of farmers adopting new IPM technologies, gender equality in all activities and reduce the pesticide residue under the export market requirements/regulations.

Other activities

1) Graduate and undergraduate students sponsored by the project

- PhD. scholar: Name: Mr. Nguyen Thanh Hieu

Gender: Male
Nationality: Vietnamese
Discipline: Plant Pathology
Country: Vietnam
Degree: PhD. Plant Protection
Start date: 2014
Completion date: 2019
% funding: 20%
Advisor (s): Assistant Prof. Nguyen Van Tuatat Vietnam Academy of Agricultural Sciences (VAAS) and Dr. Nguyen Van Hoa at SOFRI
Thesis title: Studies on biology and epidemiology of canker disease (*Neoscytalidium dimidiatum*) and management on dragon fruit
University: VAAS.

- PhD. scholar:

Name: Ms. Dang Thi Kim Uyen
Gender: Female
Nationality: Vietnamese
Discipline: Plant Pathology
Country: Vietnam
Degree: PhD. Plant Protection
Start date: 2015
Completion date: 2020
% funding: 60%
Advisor (s): Associate Prof. Tran Vu Phen at Can Tho University and Dr. Nguyen Van Hoa at SOFRI
Thesis title: Study on anthracnose on Dragon fruit and management
University: Can Tho University.

- MSc. scholar:

Name: Ms. Luong Thi Duyen
Gender: Female
Nationality: Vietnamese
Discipline: Entomology
Country: Vietnam
Degree: MSc. Plant Protection
Start date: 2017
Completion date: 2019
% funding: 60%
Advisor (s): Dr. Nguyen Van Hoa at SOFRI and Associate Prof. Le Van Vang at Can Tho University
Thesis title: Study on Morphology and Biology of Ladybird (Coleoptera: Coccinellidae) on Dragon fruit
University: Can Tho University.

2) Short term training planned

Title: New technology on detection and identification of new plant viral, Phytoplasma disease and insect identification
Location: Taiwan
Date: April, 2019 (7 days)
Type: Training; Number: 2 persons; Gender: Female/Male.

Title: Study on mass production of bio-pesticides
Location: India
Date: May, 2019 (7 days)
Type: Training
Number: 2 persons
Gender: Female/Male.

Title: GIS technology
Location: Vietnam
Date: June, 2019 (1 day)
Type: Training
Number: 10 persons
Gender: Female/Male.

3) Publications planned

Thesis: One PhD. thesis (Thesis title: Studies on biology and epidemiology of canker disease (*Neoscytalidium dimidiatum*) and management on DF)

Article: Six International/National articles.

Poster: Five posters.

Conference Abstracts: Four International/National abstracts.

Technical bulletin: Manual of IPM insect pests and diseases on Dragon fruit crop. Manual of IPM insect pests and diseases on Longan crop. Manual of IPM insect pests and diseases on Mango crop. Manual of IPM insect pests and diseases on Lychee crop.

4) Other:

Visits: VT expert (1 trip-1st quarter).

Trip reports of each traveler need to be submitted after every trip.

Meetings

Project management meetings will be organized at SOFRI and field sites in 4th quarter (by VTU, SOFRI, PPRI, CTU, NLU, PPD)

Project annual review will be done in 4th quarter

Reports: Semi-annual report in 2nd quarter; Final report in 4th quarter.

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/Debela Diro (EIAR, Bako), Asrat Zewdie (EIAR, DZ); Paddy Likayo (KALRO); Charles Chuwa (Dakawa Research Center); Nsami Elibariki (National Biological Research Program).

Brief description of the project: Rice, maize and chickpea are staple food crops in Ethiopia, Kenya and Tanzania. However, the national yield average is low compared to other regions of the world due to biotic and abiotic factors. Among the biotic factors, insects, diseases, weeds and rodents play a major role in reducing yield. In Africa, farmers generally rely on cultural practices or insecticides to minimize crop losses. Insecticide use in many countries has increased, and misuse is also becoming more abundant. Sustainable IPM packages for grain crops need to be developed to reduce the use of pesticides, improve human and environmental health, enhance biodiversity, and increase the productivity of soil and crops. To address the challenges, this project has designed the following four Outcomes, including: (1) developing and testing IPM technologies and information under sustainable intensification systems; (2) developing and delivering pragmatic pest diagnostic toolkits; (3) improving IPM communication and education; (4) and provision of information and capacity building to reform and strengthen policies that influence integrated pest management.

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 (*Macrotermes* sp. and *Microtermes* spp); chickpea pod borer and wilt IPM; rice diseases and insect pests.
Countries: Ethiopia (Hawassa and Bako for maize, Menjar for chickpea), Kenya (Nakuru, Naivasha and Kericho 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/Debela Diro)

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 Nakuru and Kerich, in Ethiopia in Hawassa in 2018 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/Debela Diro).
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: rice IPM, 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; survey for egg and larval parasitoids of *Helicoverpa armigera*; 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: over 700 farmers are presently demonstrating push pull technology in Ethiopia, 300 farmers in Kenya and 50 farmers in Tanzania; about 250 farmers demonstrated rice IPM in Tanzania and about 100 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
Task 2: Training two lab technicians in ICRISAT, Niger, for mass production of factitious hosts and parasitoids; survey and identification of egg parasitoids of FAW
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; FAW egg parasitoids identified with rearing procedure.
Activity 2.2. Developing and testing mobile app for pest identification
Task 1: testing mobile app including WhatsApp for pest information sharing
Countries: Ethiopia, Kenya and Tanzania
Status: ongoing
Scientists involved: icipe (Desalegn Tadese, Tadele Tefera), 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.
Expected outputs: Simple mobile phone application including WhatsApp tested 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 and on management of FAW in East Africa 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 and FAW management options

Activity 2.4: Communication and data-network systems with partners
Task-1: Regional and national networking among university, research centers and scientists, regulatory officials and industry members to help mitigate the impacts of crop pests
Countries: Ethiopia, Kenya and Tanzania
Status: New
Experts involved: Desalegn Tadesse; local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Asrat Zewdie, Debelo/Girma Demissie)
Description: Awareness creation is very important on new and established pests; thus, information on maize, rice and chickpea pests be compiled and shared with stakeholders in the three countries.
Progress to date: New.
Expected outputs: improved awareness of maize, rice and chickpea pests in the three countries.

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, identify the audience, plan and design messages.
C**ountries**: Ethiopia, Kenya and Tanzania
Status: On-going
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 and in other events pertinent to the activities of the project.

Progress to date: The purpose of project communication and audiences identified, some key messages crafted. Helping the Rice, Maize and Chickpea IPM for East Africa project to achieve its research and development outcomes through communication and outreach is the main purpose of the project communication.

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 and experience sharing events 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 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: Stakeholders from the three countries were invited to the project annual planning and review workshop (see the proceeding), presentations were made by selected local partners on maize, rice and chickpea insect pests and diseases and their control tactics. Besides, 27 workshops, 37 trainings and 12 farmers field days in the three countries to create awareness and introduce the project packages and stimulate target beneficiaries/partners to demonstrate the practice of adopting the technology and to create a sense of community or common purpose among its partners. Officials from local government, donors, farmers (adopters and non-adopters) and media attended and covered the events. Showcase on the Maize and Chickpea IPM organized during the Trade Fair on Value Chain Activity in Ethiopia (Finote Selma town) from 27-28 January 2018. The event covered by several local media. Communication materials and promotional items demonstrating the activities of the project displayed and network with important actors involving in the value chain established. It was covered by local media (Amhara TV and radio).

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: On-going

Scientists 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; the information on rice, maize and chickpea IPM would be compiled and promotional materials would be developed and disseminated.

Progress to date: Promotional materials (project brochure, Chickpea and Rice IPM leaflets, flyers, banners, posters, etc.) were developed and disseminated to partners in Tanzania, Ethiopia and Kenya. Besides, success stories on Maize IPM developed.

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. Developing digital communication platform through WhatsApp for information sharing about pests.

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: the construction of IPM project microsite is underway by icipe HQ, training was provided on the site management before the launching of the site. In addition, the project is developing digital communication platform for sharing information about pest (species and basic biology) accompanied by quality pictures through WhatsApp. The initiative is led by Professor John Cardina, Ohio State University. WhatsApp sub-network and working groups and local partners are selected to install the system. So far, 209 (82 Ethiopia, 44 Kenya and 83 Tanzania) local partners who have smartphone for the digital communication identified from the three countries.

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.

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 Completed in Kenya and Ethiopia
Scientists involved: Menale Kassie, Korir Jospaht (PhD student)
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: Report produced on policy and regulatory review of pesticides, biological control agents and IPM technologies in Ethiopia and Kenya.
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: Mmeasuring willingness to pay and economic benefits of the IPM options for maize, rice and chickpea
Countries: Ethiopia, Kenya and Tanzania
Status: Partially completed. Study on willingness to pay to IPM technologies carried out. Economic benefits of some IPM technologies will be carried in 2019 once follow up surveys and case studies conducted.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 (WTP) to IPM technologies assessed among farmers in Kenya and Ethiopia and Tanzania. A paper on determinants of WTP and potential adoption drafted. Also, survey reports that documents farmers' WTP and potential acreage allocation to IPM practices produced.
Expected outputs: Baseline survey reports that capture WTP and potential adoption of IPM technologies and economic benefits of the IPM options for maize, rice and chickpea identified
Task-2: Conduct follow up survey and case studies by gender in selected countries in 2019.
Countries: Follow up surveys in Ethiopia and Kenya and case studies in Ethiopia
Status: Ongoing
Scientists involved: Menale Kassie, Tadele Tefera, Bayu Enchalew (RA) and Korir Jospaht (PhD student)
Description: Follow up survey is important to understand the economic and social benefits generated by the project in the targeted countries. Targeted studies such case study will help to complement quantitative analysis and understand role of IPM technologies in empowering women.
Progress to date: Revising baseline survey instrument is ongoing

Expected outputs: Follow up survey data and survey instrument.
Activity 4.3. Conduct evidence based policy dialogue to improve adoption of IPM
Task-1: Organize a policy workshop based on findings from social and biological science research
Countries: Ethiopia and Kenya
Status: ongoing
Scientists involved: Menale Kassie and Tadele Tefera
Description: Sharing evidence to stakeholders will enable informed decision making and accelerate scaling up of technologies.
Progress to date: Evidence is being generated
Expected outputs: A report on policy workshop

Students:
Recruited: 5 PhD and 3 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
Papers in Journal -5
Study reports (1)

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	30-09-2019	Tadele Tefera, Menale Kassie, Students and local partners
Task-1	Identify available IPM technologies in target countries in collaboration with local partners	30-12-2019	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	30-09-2019	Tadele Tefera, Menale Kassie, Students and local partners

Task 3	Train researchers, extension agents and farmers on selected IPM technology(ies)	30-09-2019	Tadele Tefera, Menale Kassie, Students and local partners
Activity 1.4.	Evaluation and assessment of IPM packages and implementation strategies	30-9-2019	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	30-7-2019	Menale Kassie, Korir Josphat, Tadele Tefera, Local partners
Task -2	Train extension agents and farmers on selected IPM technology (ies)	30-8-2019	Menale Kassie, Korir Josphat, Tadele Tefera, Local partners
Activity 1.5	Scaling up proven IPM technologies	30-9-2019	Tadele Tefera, Menale Kassie, Students and local partners
Task-1	Disseminate proven IPM technologies through organizing field days	30-9-2019	Tadele Tefera, Menale Kassie, Students and local partners
Task-2	Demonstrate proven IPM technologies to farmers and extension agents in multiple sites	30-9-2019	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 2.2	Developing and testing Mobile app for pest identification	30-9-2019	Desalegn, local partners
Task 1	Testing WhatsApp for pest info sharing	30-9-2019	Desalegn, local partners
Activity 2.3.	Capacity building in training on pest and disease diagnosis	30-5-2019	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
Activity 2.4	Communication and data-network systems with partners	30-09-2019	Tadele Tefera, Desalegn Tadese, local partners

Task-1	Regional and national networking among university, research centers and scientists	30-09-2019	Tadele Tefera, Desalegn Tadese, local partners
Outcome 3	improving IPM communication and education	30-09-2019	Desalegn Tadese, Tadele Tefera, local partners
Activity 3.1	Develop tailor made communication plan for IPM to address different stakeholders	30-4-2019	Desalegn Tadese, Tadele Tefera, local partners
Task-1	Identify the purpose of the project communication, identify the audience, plan and design messages.	30-4-2019	Desalegn Tadese, Tadele Tefera, local partners
Activity 3.2	Create awareness and disseminate information on IPM to enhance responsiveness of the stakeholders.	30-9-2019	Desalegn Tadese, 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	30-9-2019	Desalegn Tadese, Tadele Tefera, local partners
Activity 3.3	Develop promotional materials targeted to different stakeholders to enhance up-take of the IPM technologies	30-11-2019	Desalegn Tadese, Tadele Tefera, local partners
Task-1	Develop and disseminate project summary brochures/flyers explaining the project objectives, implementing countries and local partners	30-11-2019	Desalegn Tadese, 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	30-2-2019	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	30-9-2019	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 documents or in the form of notifications, speeches, or in any other form	30-9-2019	Menale Kassie, Korir, local partners
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	30-9-2019	Menale Kassie, Korir, local partners
Activity 4.2.	Conduct a cost benefit analysis for IPM options for maize, rice and chickpea	30-9-2019	
Task-1	Measuring willingness to pay and economic benefits of the IPM options for maize, rice and chickpea	30-9-2019	
Task-2	Conduct follow up survey and case studies by gender in selected countries in 2019	30-9-2019	
Activity 4.3.	Conduct evidence based policy dialogue to improve adoption of IPM	30-9-2019	
Task-1	Organize a policy workshop based on findings from social and biological science research	30-9-2019	

Travel Matrix-Tadele Tefera (based in Ethiopia)

Month	**Kenya**	**Tanzania**	**Purpose**
Oct	X		Harvesting trials
Dec		X	Selecting rice demo sites; supervising student works
Jan		X	Planting rice field trials
Feb	X	X	Students trials visit
Mar	X	X	Site selection & Planting maize
Apr	X	X	Monitoring of field trials
May	X	X	Students and local partners research monitoring
June	X	X	monitoring of field trials

July	X	X	Follow up visits to the project sites
Aug	X	X	Training extension and farmers
Sep	X	X	Data collections

Travel matrix- Menale Kassie (based in Kenya)

Month	**Ethiopia**	**Tanzania**	**Purpose**
Oct	X		Maize RCT data collection
Nov	X		Chickpea data collection
Jan		X	Train extension agents, data collection for M & E
May	X		
June	X		Field visit and evaluation
July		X	Data collection
Aug	X		Data collection and evaluation
Sep	X		Field visit and evaluation of trials

Travel matrix- for FAW Management Training participants (20-25) from Ethiopia and Tanzania

Month	Kenya	Purpose
Jan/Feb	X	FAW Management Training

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

PI

Buyung Hadi

CO PIs

Virender Kumar, Ricardo Oliva, Alexander Stuart, Nancy Castilla, Rica Joy Flor

Collaborating Institutions

Nagoya University, Virginia Tech, GDA, CARDI, CEDAC

Objective 1

Title

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

Activity 1

- **Title:** Adaptive research platform
- **PI:** Virender Kumar, Ricardo Oliva, Alexander Stuart, Nancy Castilla
- **Site/Location** Cambodia

- **Status**
  - Continuing
- **Description**
  In wet season 2018, we started to do large scale (>0.5 Ha) demonstrations of IPM packages across the country. Over 20 farmers are participating in these demonstrations. The farmers gave input on which component of the package they'd like to adopt and how they want to adopt it (e.g. we allow farmers to 'tinker' with or partially adopt the technology). A list of IPM components that are available for farmers to adopt, validated in 2016-2018, is given in table 1. In 2018/2019, we expect over 60 farmers will participate in the demonstrations.

  Table 1. List of IPM components available for farmers' adoption in 2018/2019.

Target biotic stress	IPM components
Weeds	• Mechanical direct seeding (line sowing) with reduced seed rate either using drum seeder or Eli seeder. • Correct timing and reduced frequency of post-emergence herbicide. • Use of certified seeds (with reduced weed seed contamination)
Diseases	• Use of resistant variety (e.g. CAR 14). • Application of *Trichoderma harzianum*.
Insects	• Use of entomopathogenic fungi (e.g. *Metarhizium* sp., *Beauveria* sp.) • Ecological engineering scheme
Rodents	• Trap barrier system • Targeted use of rodenticide (e.g. bromodialone, zinc phosphide)

- **Expected outcomes**
  Data on cost-benefit of adopting the IPM package (instead of components). The adaptation and adoption process kick-started among farming communities.

Activity 2

- **Title** Innovative research platform (MSc and PhD students)
- **PIs** Buyung Hadi, Ricardo Oliva, Virender Kumar, partners from Royal University of Agriculture (RUA) and Nagoya University.
- **Site/Location** Experimental stations at the four provinces above, CARDI.
- **Status**
  - Continuing
- **Description**

We will have two Cambodian PhD students continuing their studies at Nagoya University. The MSc student at Battambang University working on integrated weed management should be finishing his study. Another MSc student at RUA working on entomology will continue. The MSc student at Virginia Tech should be finishing his study.

- **Expected outcomes**
  At least 5 graduate students (2 PhD and 3 Master's) will continue/finish their study programs.

Objective 2

Title

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

- **Title** 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 2018-2019, we expect to directly connect IPM solution suppliers (e.g. biocontrol agent suppliers) with the farming communities to start the scaling out process of the IPM package.

- **Expected outcomes**
  - Increased awareness among farmers of the availability and efficacy of biocontrol agents and other IPM solutions.

Objective 3

Title

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

- **Title** Training opportunities on key skills in IPM validation and implementation

- **PIs** Buyung Hadi, Virender Kumar, Alex Stuart, Nancy Castilla, Ricardo Oliva, Rica Joy Flor, partners from GDA, CARDI and CEDAC, Viamo.
- **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. As a value added activity in 2018/2019, we plan to pilot an interactive voice recording (IVR) to help diagnose key weeds, pests and diseases in Cambodia and to push IPM solutions. The IVR will be developed by Viamo in collaboration with Cellcard, a large Cambodian communication technology provider. Agricultural suppliers and extension workers are the main audience for the IVR training. The IVR usage will be monitored through 2019.

- **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 Rice weed, pest and disease diagnostics, and usage of biological control in rice IPM.
    - Raised awareness and usage of the diagnostics IVR is expected to increase accuracy of diagnostics among agricultural suppliers and extension workers. The data gathered through IVR can also be used as a monitoring platform for pest and disease incidence in the country.

Objective 4

Title

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

Activity 1

- **Title** Supporting the National Agricultural Laboratory in implementing the registration policy for biocontrol agent
- **PIs** GIZ, Rica J. Flor, Buyung Hadi, partners from NAL and GDA.
- **Site/Location** Phnom Penh
- **Status**
    - Continuing
- **Description**

  The registration procedure for biocontrol agents have been endorsed by the minister of agriculture, forestry and fisheries. However, the capacity within the national agricultural laboratory to implement the procedure is still very limited. We will conduct a consultancy

meeting with NAL to assess the gaps in skills necessary to implement the procedure and conduct training for NAL employees as necessary.

- **Expected outcomes**
  - Increased capacity of NAL employees to implement the registration procedure of biocontrol agents.

Objective 5

Title

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

Activity 1

- **Title** Annual planning meeting – November/December 2018
- **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 2018. Progress in year 3 will be reviewed and activities for year 4 will be thoroughly discussed. Input from Management entity, USAID mission and other stakeholders will be solicited.
- **Expected outcomes**
  - Progress review and concrete plan for 2018/2019.

Activity 2

- **Title** Conduct endline survey.
- **PIs** Buyung Hadi, Rica J. Flor, George Norton, partners from GDA.
- **Site/Location** Phnom Penh
- **Status**
  - New
- **Description**
- End line survey will be conducted in the same districts/villages where the baseline survey was done. The survey aims to detect any perceptible change in the knowledge, attitude and practice of farmers in the target villages toward ecologically-based pest management methods.
- **Expected outcomes**

A measure of change in knowledge, attitude and practice of farmers that can be used to learn about the effectiveness of the method used to disseminate the technologies in the target villages.

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	Sept. 1 2016	Aug. 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	Sept. 1 2017	Aug. 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	Sept. 2016	Aug. 2018	Research cost	Srean Pao, Virender Kumar	Integrated weed management	Battambang University
Makara pakphea Keo	F	Cambodia	Entomology	Cambodia	MSc	April 2018	Sept. 2019	Research cost	RUA professor, Buyung Hadi	Farmers' survey on the scope of ecological engineering in Cambodia	RUA
Corey Grant	M	USA	Entomology	Cambodia	MSc	Sept. 2016	Aug. 2019	100% (Through Virginia Tech's portion of	Doug Pfeiffer	Ecological engineering	Virginia Tech

								the funds)			

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

Publications planned

Conference abstract

International Rice Congress 2018
Rica Joy Flor et al. 2018. Lock-in mechanisms affecting the spread of Integrated Pest Management (IPM) in Cambodia.
Buyung Hadi et al. 2018. EPIC: A partnership for rice IPM research and dissemination in Cambodia.
Alex Stuart et al. 2018. Rodent management techniques for Cambodian rice production.

ESA meeting 2019
Buyung Hadi et al. 2019. From on-farm research to policy making: lessons learned from a USAID rice IPM project in Cambodia.

Extension bulletin

Rice IPM cards – in Khmer

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

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

Beginning October 1, 2018 –
Project PI: Dr. Luis Cañas, Department of Entomology
Associate Professor
Co-Chair, Master of Plant Health Program
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CO PIs

John Cardina, Professor, Department of Horticulture and Crop Science, OSU;
Ferdu Azerefegne, School of Plant and Horticultural Sciences, University of Hawassa, Ethiopia;
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
Dr. Juma Samuel Kabote - Department of Development Studies
Dr. R. O. Majubwa – Horticulturist

Dr. M. W. Mwatawala – Entomology
Dr. K. P. Sibuga – Weed Science
E. R. Mgembe - Horticulturist

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
Simon Wepukhulu, Biometrician
Samson Kihara – Plant Pathologist

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;

WORK PLAN FOR TANZANIA

I. Sokonie University of Agriculture (SUA)

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 manuscripts for publication from the baseline survey.
Responsible person: S. J. Kabote
Description: Significant effort was made in Year 1 to conduct a baseline survey in 15 project target villages in the three districts of Morogoro rural, Mvomero, Kilosa (in Morogoro region) Iringa rural and Kilolo (in Iringa region). A structured questionnaire was used with the aim to

identify priority pests and management practices used by farmers. Data are being analyzed to make comparisons among villages and crops. In Year 4, preparation of manuscripts for publication to share results of this work will be finalized. The paper will be published in *African Journal of Food, Agriculture, Nutrition and Development.*

Activity 2
Title: Conduct follow-up surveys on IPM knowledge and adoption.
Responsible person: S. J. Kabote
Description: A standard survey will be conducted in areas where IPM activities have been conducted on onion (Ulaya Kibaoni, Lumuma, Mangalali, Ruaha Mbuyuni villages) and on tomato (Mlali and Msufini villages). Respondents will include representative farmers who participated in the project and a corresponding group who did not. Farmers will be asked about basic knowledge of pests (insects, diseases, and weeds), IPM, and pest management practices, as well as about practices they used in the last season. A manuscript will be prepared for publication to share results of this survey about IPM knowledge and adoption. The paper will be published in *Journal of Integrated Pest Management.*

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
Responsible person: A. P. Maerere
Description: Five graduate students have been trained and supported by project funds:
1. Hellen Elias Kanyagha (Female)
Degree registered for: Ph.D. (March 15, 2017 - July 2019)
Discipline: Plant Pathology
University: Ohio State University
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.
IPM IL funds: 100%. (Plant Pathology Department will pay if extension needed)
Supervisor: Sally Miller, Department of Plant Pathology, Ohio State University.

2. Zuwena E. Msuya (Female)
Degree registered for: MSc (2017/2018)
Discipline: Plant Protection
University: Sokoine University of Agriculture
Proposed dissertation title: Evaluation of bio-insecticides against white grub (*Coleoptera melolonthidae*) attacking onion (*Allium cepa* L)
General objective: To reduce damage caused by white grub (*Coleoptera melolonthidae*) attacking onion (*Allium cepa* L)
IPM IL funds: 10%
Supervisor: M. W. Mwatawala

3. Reagan Nyoni (Male)
Degree registered for: MSc (2018/2019)
Discipline: Plant Protection
University: Sokoine University of Agriculture
Proposed dissertation title: Comparative effectiveness of weed management practices in controlling the parasitic weed *Cuscuta spp*. in onion
General objective: to develop integrated weed management package for onion.
IPM IL funds: 10%
Supervisor: K. P. Sibuga

4. Peter A. Maerere
Degree registered for: MSc (2016/2017)
Discipline: Plant Protection
University: Sokoine University of Agriculture
Dissertation title: Assessment of selected control measures and establish the host preference for tomato leaf miner (*Tuta absoluta*) (Meyrick) in Morogoro, Tanzania.
General objective: to develop management practices for the tomato leafminer (*Tuta absoluta)* (Meyrick) (Lepidoptera: Gelechidae)
IPM IL funds: 10%
Supervisor: M. W. Mwatawala

Goals for FY 19: Students will prepare/finalize preparation of draft manuscripts for publication of their research work.
Five undergraduate students have also received project support for research. At least one will have generated data that is of sufficient quality to contribute to a publication. In addition, academic staff advisors will prepare reports, which will be used to prepare publication manuscripts. The academic staff will prepare a manuscript addressing the question: What makes a successful research experience for undergraduate students in Tanzania? This will be published in the *Journal of Extension Education*.

Undergraduate Students

Name	Gender	Degree Program	Expected completion date
1. Nangale, Allan	Male	BSc. Agric. General	November 2018
2. Magembe, Shigela	Male	BSc. Agric. General	November 2018
3. Michael, Michael Olaf	Male	BSc. Agric. General	November 2018
4. John Richard	Male	BSc. Agric. General	November 2018
5. Msogoya K. Gaetan	Male	BSc. Horticulture	November 2018

Activity 2
Title: Short-term training of farmers and trainers.

Responsible person: R. O. Majubwa
Target audience: farmers and trainers near Morogoro, Mlali, and Iringa.
Target time: December 2018 and July 2019.
Description: The training will focus on two core areas of SUA's strength: Seedling health and IPM systems integration. Three training events are planned, located in Mvomero district, Iringa rural district, and at the SUA Hort Farm. Audience will be farmers and extension agents in the project areas. The training will focus on IPM techniques recommended by IPM packages for tomato, onion, and cabbage. SUA staff will establish and maintain plots with crops managed using these two approaches:

1. Seedlings produced by standard farmer practice; pest management using standard farmers pesticide application practices;
2. Seedlings produced using highest level of healthy seedling methods; pest management using best IPM practices (the use high quality clean seeds, seedling trays, sterilized forest soil incorporated with Trichoderma; the use of low tunnel netting to exclude insect pests, proper watering and fertility management).

The training will demonstrate the methods for healthy seedling production. Participants will visit the plots to see how these are integrated into the production system. Efforts will be made to encourage participation by women as well as men. Participants will be given pre- and post-tests to evaluate levels of IPM knowledge, practices used, intentions to change practices, and lessons learned. A manuscript describing the training and the participant learnings will be prepared. The paper will be published in *African Journal of Crop Science.*

Activity 3
Title: Short-term training for trainers, value chain cooperators, and consultants.
Responsible person: H. D. Mtui and L. Cañas (USA).
Target audience: extension personnel, trainers working with MnM and TAHA.
Target time: April, 2019.
Description: The training event will be conducted in conjunction with the Project's Annual Meeting planned for April 2019. The focus of the training will be "Plant Health – Prevention, Diagnosis, & Management." An international team of instructors will provide training on system approaches for reducing plant pests (healthy seedlings, grafting, Trichoderma etc), basic approaches to diagnosing plant insects pests, diseases and disorders. Methods for arriving at pest management recommendations will be demonstrated.
In preparation for this training, SUA staff will prepare plots with a range of biotic and abiotic disorders, which will be used for diagnosis. Emphasis will be on plant health communication to enhance effectiveness of the Plant Health Network using WhatsApp.

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

Activity 1
Title: Repeat and finalize all ongoing prototype IPM technology activities.
Description: Ongoing experiments will be finalized, data recorded, and analyzed. No new activities will be initiated; all efforts will be on repeating, where necessary, ongoing experiments

which need additional testing. Manuscripts will be prepared for publication from completed research. All pesticides used will be those approved in corresponding PERSUAP.

Studies to be repeated and finalized include:

a. Evaluation of efficacy of crude plant extracts for the management of the tomato leaf miner.

Responsible person: G. M. Rwegasira

Description: Tomato leaf miner (*Tuta absoluta*) is a serious pest of tomato and other solanaceous vegetables. The occurrence of Tuta has intensified the use of synthetic pesticides in tomato production. There are several pesticides with various active ingredients used for management of Tuta. However, their effectiveness is questionable. This prompted farmers to use different pesticide mixtures and botanical concoctions. There is therefore a need to:

i. To conduct a survey in major tomato growing areas to identify botanicals and other control measures against Tuta.
ii. To evaluate the effectiveness of available pesticides and botanicals used for the control of Tuta on-station.
iii. To widen the existing IPM package for tomato to include specifically Tuta management.

Preliminary observations revealed that farmers are using a range of botanical extracts to manage Tuta. However, their effectiveness is claimed to be variable and no any published data are available. An IPM system trial will incorporate applications of plant extracts found to be effective as part of Tuta management program.

b. Development and evaluation recipes for bio-slurry and bio-pesticides

Responsible person: D. P. Mamiro

Description: Development and evaluation recipes for bio-slurry and bio-pesticides (*Trichoderma, Bacillus*, etc.) to get consistent products/recipes for control of root diseases as transplant treatment for tomato, cucurbits, onion, and brassicas. In addition, identification of the beneficial microorganisms present in bio-slurry and effectiveness for use in vegetable pest management was done.

Objectives: (1) To explore the efficacy of bio-slurry and bio-pesticides such as *Trichoderma* and Neem cake in reducing populations of root knot nematodes in tomato fields in Morogoro (2) To explore the efficacy of bio-slurry and bio-pesticides in reducing populations of nematodes in cucumber fields in Morogoro.

Treatments: (1) Bio-slurry, (2) Neem cake, (3) *Trichoderma* spp., (4) Marigold and (5) Control (untreated plots)

Results to date:

In the first (dry) season, control of nematodes in tomato roots was better achieved by neem cake and Trichoderma, which reduced the populations by 51.6%, compared to the control plots. Neem cake showed variable results. For instance, neem cake had significantly ($P < 0.0001$) lower numbers of nematodes in cucumber (75.2% fewer than control) with the other treatments, bio-slurry and Marigold, being ineffective. In cucumber, populations of nematodes in plots treated with neem cake were significantly higher in comparison to that treated with *Trichoderma*. Bio-slurry significantly increased the population of nematodes in tomato plots by 50%. Nematode

populations significantly dropped in the second season. As a result, treatments were ineffective when compared to the control.

Since the results we promising, the study in FY19 will be modified as follows:

- To make sure the bio-sully treatment is free from contaminant, a test for presence or absence of *Escherichia coli* will be done before drawing conclusions.
- Types of nematodes affected by the tested treatments will be identified to find out whether the free-living nematodes are also affected.
- Anaerobic soil disinfection (ASD) will be tested and compared with the other treatments (bio-slurry, Trichoderma, neem cake, marigold).

c. Evaluate the host preference and farmer treatments for tomato leaf miner (Tuta absoluta).

Responsible person: G. M. Rwegasira

Description: Host preference of a given pest is an important aspect for effective pest control. A graduate student (Mr. Peter) completed his research with a general objective of assessing selected control measures and establishment of the host preference for tomato leaf miner (*Tuta absoluta*). In Year 4, a manuscript will be finalized and published. All chemicals used will be included in corresponding PERSUAP.

Results to date:

- Host preference on *Tuta absoluta* distribution

The number of *T. absoluta* moths that emerged from the collected host samples differed significantly between the suspected host plants in Mlali and Dakawa. Significantly higher numbers were recorded on tomato plants (Fig. 1 and Fig 2, respectively).

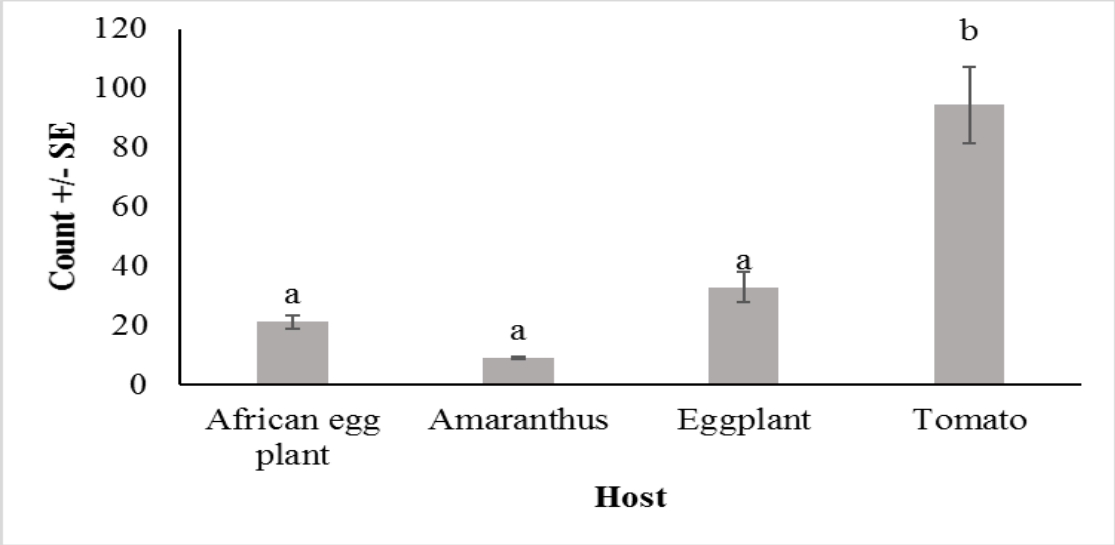

Figure 1: Mean (±SE) count of *Tuta absoluta* moth in different hosts in Mlali.

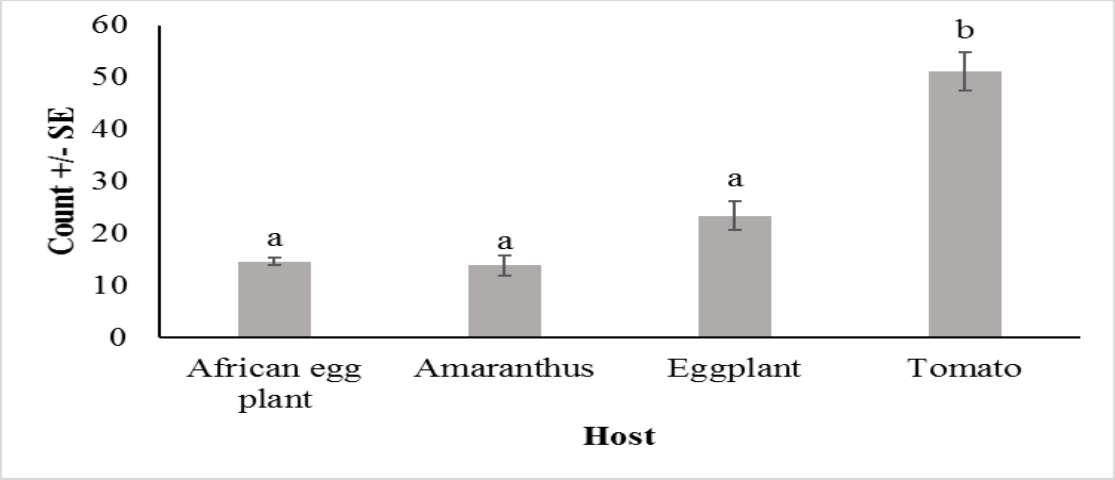

Figure 2: Mean (±SE) count of *Tuta absoluta* moth in different hosts in Dakawa**.**

- Efficacy of applied treatments on the population of *Tuta absoluta*

In the first season, no significant differences between treatments was observed between the bio-pesticide and synthetic insecticide regarding the counts of *Tuta absoluta* moths.

In Mlali, there was significant difference in population levels of the moths ($F_{(3)}$= 5.323, P = 0.003226). The difference in pest populations observed between untreated plots (131.5 mean population of moth per plot) and in treated plots with Antario (67.5 mean population of moth per plot) was highly significant (P= 0.0039) as per Tukeys' HSD post hoc test. The mean separation also demonstrated that application of either synthetic or bio-pesticide was significantly effective in controlling the moth population (Fig 3).

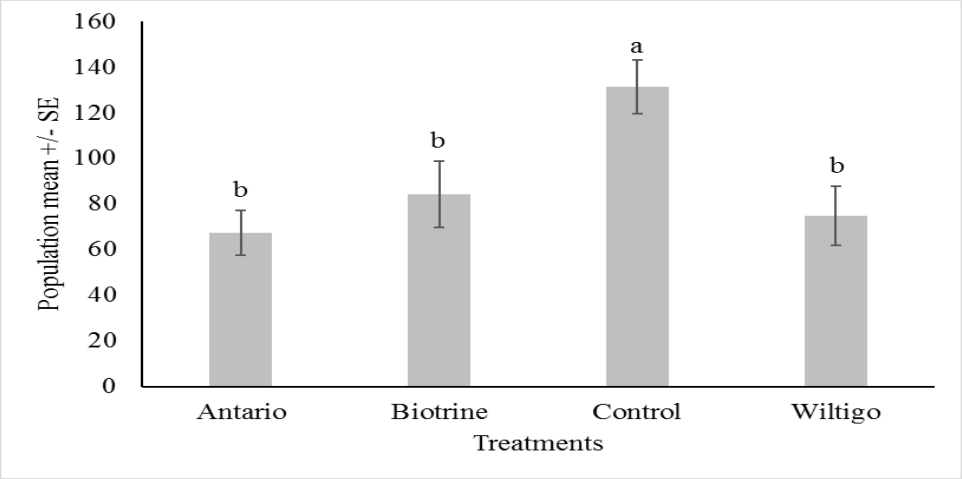

Figure 3: Mean (±SE) count of *Tuta absoluta* moth against applied treatments in Mlali

Activities for FY-19: Data have been analyzed and a manuscript is in preparation for publication.

d. Tomato grafting for management of bacterial, fungal and nematode root diseases

Responsible person: E. R. Mgembe
Description: Finalize trials to evaluate effects of tomato grafting on Solanaceous rootstocks with resistance to nematodes, bacterial and fusarium wilts.

Trials will be conducted to evaluate five rootstocks - Shelter RZ (Rijk Zwaan Limited), MT 56 (IPM Project), Hawaii 7996, BF Oktisu 101 and R3034-3-10-N-UG (AVRDC – World Vegetable Center in Arusha).

Grafting trials will be conducted on station to assess the compatibility of the rootstocks with two commonly grown open pollinated varieties (Tanya and Mwanga) and two most popular hybrid varieties (Assila and Anna). Assila is a popular open field variety while Anna is the most grown greenhouse variety in Tanzania. Each commercial variety will be grafted on twenty seedlings of each rootstock. The grafted seedlings will be kept in a chamber with 85 – 95% RH and 20 – 25ºC for healing.

Successful grafts will be used in pot experiments to determine their differential resistance to nematodes, bacterial and fusarium wilts. The pot experiments will be conducted in a plant pathology screen-house. Experimental design is being done in collaboration with Dr. Matt Kleinhez (OSU). For the test, consideration will be given to select a small number of only commercially-available rootstocks and testing their compatibility with and performance when grafted to a larger number of scion varieties. In this case, rootstocks would include key disease resistance packages and scions would be locally relevant. Collaboration has been established with M. Ravishankar of the WVC.

i. Bacterial wilt
Pure cultures of *Ralstonia solanacearum* will be obtained from Plant Pathology Laboratory at SUA. The pure cultures will be streaked on a CPG agar plate and incubated at 28 °C for 48 h. Pure mucoid colonies of the bacterial will be suspended in sterile deionized water (dH2O) and adjusted using mass spectrometer to OD 600 nm = 0.1, corresponding to approximately 108 colony-forming units (CFU)/mL). There will be three concentrations (10^8, 10^7 and 10^6CFU/mL) of *R. solanacearum* suspensions to ascertain the range of infestation that the rootstocks can tolerate. A 200 mL of each bacterial suspension will be poured into plastic pots filled with 2 kg of steam sterilized forest soil. The sterilized soil will be thoroughly mixed before transplanting. Transplanting will be done when the grafted seedlings attain 3 – 5 leaf stage. There will be three pots per treatment. The experiment will be arranged in a randomized complete block design with four replications. Evaluation will be done weekly until fruit set. Growth and disease incidence and severity data will be recorded.

ii. Fusarium
Fusarium spores will be obtained after isolation from infected tomato plants or infested soil. Before using the spores to test the grafted tomato plants, pathogenicity test will be performed on susceptible Tanya tomato variety to ascertain their pathogenicity. The most virulent isolate (i.e. the fast and most severe wilt-causing isolate) will be used to inoculate the grafted tomato plants. Fusarium wilt disease incidence and severity will be observed. Fusarium wilt severity will be scored as described by Grattidge and O'Brien (1982) (0 = 0-24% of leaves are yellow and wilted, 1 = 25-49% of leaves are yellow and wilted, 2 = 50-74% of leaves are yellow and wilted, 3 = 75-

99% of leaves are yellow and wilted and 4 = 100% of leaves are yellow and wilted). {Grattidge, R., and R. G. O'Brien. "Occurrence of a third race of Fusarium wilt of tomatoes in Queensland." *Plant Disease* 66, no. 2 (1982): 165-166.}

iii. Nematodes

Meloidogyne javanica will be isolated from the horticulture unit farm and propagated on greenhouse-grown susceptible tomato plants cv. Cal J. Pure culture will be initiated from single egg mass. Egg masses will be hand-picked from infested roots using a small needle to establish a single mass line in monoxenic pure cultures. Tomato seeds will be germinated in steam-sterilized sandy soil in seed tray, and 2-wk-old seedlings will be transplanted singly into plastic pots. Plants will be inoculated at the fourth true leaf stage with single nematode egg mass around the tomato root. After 8-10 weeks of infection, eggs will be recovered from tomato plants by shaking *M. javanica*-infected roots in 1:9 dilution of bleach for 3 min in a flask. Eggs will be collected onto a 25 mm mesh and will be bleached twice for 10 minutes with a 1:5.7 dilution of bleach supplemented with 0.02% Tween 20. Eggs will be rinsed six times with sterile ddH2O till excess bleach is off. Collected eggs will be hatched at room temperature for 3 days on micro sieves. Freshly hatched juvenile 2 stage (J2) worms will be collected as inoculums for experimentation. There will be three levels of nematode suspensions with different initial populations (Pi); 500, 1000, and 2000. Grafted seedlings at the 3 – 5 leaf stage will be transplanted into plastic pots filled with 10 kg of steam sterilized forest soil. Nematodes will be inoculated one week after transplanting and each Pi level will be replicated three times. The experiment will be arranged in a randomized complete block design. Evaluation on plant growth will be done weekly until fruit set while the actual nematode infestation will be assessed by quantifying the final population (Pf) , counting number of galls, rating the gall index (GI), counting number of eggs-masses after Floxine B-staining. Egg Mass Index (EMI) will be determined using a scale: 0=0, 1=1-2, 2=3-10, 3=11-30, 4= 31-100 and 5=greater than 100 galls or egg masses per root system (Taylor, A. L., and J. N. Sasser. 1978. "Biology, identification and control of root-knot nematodes." North Carolina State University Graphics).

e. On-station trials on cucumber production in a protected environment.

Responsible person: E. R. Mgembe

Description: Fruit flies (*Bactrocera cucurbitae*, *Dacus* spp. and *Ceratitis capitata*), cucumber beetles, spider mites, thrips and whiteflies are important pests of cucumber. Due to the serious damage caused by these pests, there is increasingly application of pesticides in cucumber production. The use of plastic high tunnels can reduce damage caused by these pests and hence improve productivity and quality of the fruits. However, production of cucumber in the plastic tunnel has been limited by lack of parthenocarpic cucumber varieties. Recently, some cucumber varieties have indicated the ability to be grown in the high plastic tunnel without assistance of bees to facilitate pollination. It is important, therefore to test the performance of the available hybrid varieties under different growth environments. The experiment will include at least two parthenocarpic cucumber varieties and two most popular cucumber varieties commonly grown by farmers. These varieties will be grown under high tunnel and open field adjacent to the high plastic tunnel. The seedlings will be transplanted on plots arranged in completely randomized block design with three replications. The plot size will be 2 m wide by 10 m long. Plants will be staked in both environments. Pest occurrence will be recorded and control measures implemented when needed. Plant growth, yield and yield components data will be collected.

Activity 2.
Title. Repeat and finalize the on-farm evaluation of bio-pesticides.
Responsible person: D. P. Mamiro
Description: Trichoderma, *Metarhizium*, and *Beauveria* products from Real IPM were tested for their effectiveness in controlling nematodes in tomato, cucurbits and the white grubs in onion. This study will be repeated at two sites and results analyzed for preparation of a manuscript for publication.
Objectives: (1) To assess effectiveness of bio-pesticides in management of nematodes in tomato and cucumber (2) To assess effectiveness of bio-pesticides in management of white grubs in onions
Treatments: Tomato and cucumber (1) *Trichoderma* spp., (2) Control (untreated plots)
Onions (1) *Metarhizium* spp. (2) *Beauveria* spp. (3) Control (untreated plots)
Activities for FY-19: The on station trial results were promising. In FY 19, an on farm trial will be conducted to ascertain results previously obtained in on station trials. Any publications?

Activity 3.
Title: Repeat and conclude on farm demonstrations on IPM technology package for tomato.
Responsible person: H. D. Mtui
Description: Demonstrations will be conducted on a farm in Mlali, Mvomero and Kilolo Districts. The IPM package for tomato will include the use of healthy seedlings, appropriate seedbed preparation, mulching, staking, appropriate use of pesticides and fertilizer application, and the use of resistant varieties. Two farmer-chosen adopted varieties namely Kipato, Assila, and or Imara will be involved. The seedlings will be raised under IPM health seedling production techniques (objective 2, activity 2) and open field growth conditions (as farmers practice) for comparison. Any pesticide used, will come from the list of approved pesticides according to the corresponding PERSUAP.
At transplanting, the demonstration plots will be arranged in Randomized Complete Block Design with four replications. The treatments will include seedling production techniques, mulching, staking, a combination of staking and mulching and plots sprayed weekly (farmers practice). Plot size will range from 4 to 6 m wide and 5 to 10 m long depending on available space. Mulching will be done one week after transplanting while the seedlings will be staked 3 weeks after transplanting. With an exception of plots under farmers practice, the other plots will be sprayed when necessary after scouting. Whenever pesticides are needed, they will be applied according to label instructions. Weeding will be done using hand hoe in non-mulched plots and hand pulling in mulched plots. Ten plants from the middle of each plot will be tagged and used for data collection. Yield and yield components data will be collected at each harvest. A manuscript will be prepared for publication.

Activity 4
Title: Finalize and prepare manuscripts for publication for on-farm trials on onion variety evaluation.
Responsible person: H. D. Mtui
Description: Data will be analyzed and reported by location so that GxE (germoplasm x location) interactions as well as specific location differences in treatment responses and

participant preferences can be highlighted. A manuscript will be prepared for publication on this work. The paper will be published in *Journal of Integrated Pest Management*.

Objective 4: IPM Communication Network.

Activity 1

Title: Development of the Plant Health Network in villages in Tanzania.

Responsible person: R. O. Majubwa

Description: Network nodes will be set up in villages where SUA field work is being done, especially in Mlali, Iringa, Ruaha Mbuyuni, and others. The language can be English or Kiswahili. Real IPM, MARI, and OSU will cooperate to allow participants to join and function on the network. Online diagnosis of vegetable disorders (biotic and abiotic) is an important tool for reducing over-use of pesticides. With the current expansion of cellphone network in Tanzania, it is possible to share quality images between farmers and experts for diagnosis and recommendation of control measures. Farmers in the project sites will be trained in the use of smartphones for plant health diagnostics. Training will be provided on how to capture images, access information, and link to wider network. One smartphone with at least 12MP will be provided to each group. A common WhatsApp group will be formed to include all farmer groups regardless of their major crop of interest. All farmers with smartphones will be encouraged to join the network. The farmers groups will be linked to PI organizations through group leaders. The network will also be linked to plant health clinics, value chain partners, and others practitioners involved in this project.

List of Presentations and Publications:

Presentations:

i.) East Africa Vegetable IPM Innovation Lab - 2018 Annual Meeting, Addis-Ababa Ethiopia - Tanzania, SUA: Progress Report

ii.) East Africa Vegetable IPM Innovation Lab - 2018 Annual Meeting, Addis-Ababa Ethiopia - Tanzania, SUA: Tanzania: Plans and ongoing activities for 2018

iii.) IPM and Postharvest Handling of Vegetables: Horticulture Innovation Lab – Training of Trainers Workshop May, 2018 Morogoro

Publications to be completed and submitted by September 2019:

i.) **Mamiro, DP et al.** Onion (*Allium cepa* L) variety evaluation for pest resistance and yield in Tanzania. The paper will be published in *African Journal of Crop Science*.

ii.) **Mtui, HD et al.** Practical IPM Package for tomato (*Solanum lycopersicum* L) production in Tanzania. The paper will be published in the *Journal of Integrated Pest Management*

iii.) **Rwegasira, GM et al.** Temporal distribution and economic significance of *Plutella xylostella*L. on cabbage (*Brassica* spp) in Eastern and Southern Tanzania. The paper will be published in the *African Journal of Crop Science*

iv.) **Rwegasira, GM et al.** Comparative incidence of *Plutella xylostella*L on Chinese cabbage (B*rassica rapa subsp. chinensis*) and Cabbage (*Brassica oleraceae var. capitata*) in Morogoro under natural infestation. The paper will be published in the *Journal of Entomology*

v.) **Rwegasira, GM et al.** IPM strategy for minimizing impacts of *Plutella xylostella L* and spread of fungal diseases in Cabbage; the case of overhead irrigation and organic mulches. The paper will be published in the *Journal of Applied Entomology*

vi.) **Rwegasira, GM et al.** Suppression of root knot nematodes in tomato (*Solanum lycopersicum*) and cucumber (*Cucumis sativus*) fields by using *Trichoderma* and botanical pesticides. The paper will be published in the *African Journal of Crop Science*

Institutional Development
A to Z Textile Mills Ltd, Arusha are collaborating in developing protected vegetable production facilities. Netting structures were donated to the Department of Crop Science and Horticulture. They are currently being used for demonstration of technologies. A to Z has provided materials for constructing low tunnels for the project on farm demos/trials and the "Nanenane" agricultural exhibition on healthy seedling production.

Partners
In addition to A to Z Textiles, Mboga na Matunda and TAHA are among the important value chain actors in Tanzania. There has been excellent collaboration between the project and TAHA for a long time. Linkage with MnM is yet to materialize, although we have made contact with their staff in Morogoro and Dar es Salaam.

II. Mikocheni Agricultural Research Institute (MARI)

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 2: Conduct short term training and capacity building

Title: Short-term training of farmers and trainers.
PI: Sseruwagi, Ndunguru (MARI)
Site/Location: Tanzania: Morogoro, Mvomero, Iringa, Ilula and Kilolo districts
Crops: Tomato
Priority pests: Viruses, whiteflies, aphids, hoppers
Status: On-going
Audience: Farmers, private seedling producers, Extension and local leaders.
Description: Conduct short term hands-on training in demos and in mother-baby trials for farmers and agricultural extension agents on:

a. Healthy seedling production
b. Good agricultural practices (GAPs)
c. IPM strategies (information about strategies will be taken from developed IPM packages for corresponding crops)
d. Safe use of pesticides

Progress: About 169 farmers and 19 extension personnel were trained in field identification, monitoring, and IPM of vegetable viral diseases and insect vectors.
Planned activities: Train farmers and stakeholders (extension, private seedling producers) in healthy vegetable seedling production, field disease diagnosis, scouting, GAPs, IPM of vegetable viral diseases and associated insect vectors and safe use of pesticides in the 10 villages/demo sites in Morogoro and Iringa, and in the mother-baby trials in 4 villages in Bagamoyo.

Activity 3: Knowledge sharing and transfer/scaling out

Title: IPM Communication for diagnosis and management recommendations
PI: Murunde (Real IPM); Sseruwagi, Ndunguru (MARI
Site/Location: Tanzania: Morogoro, Mvomero, Iringa, Ilula and Kilolo districts
Audience: Farmers, Private Seedling Producers, Extension and Local Leaders.
Description**:** Expand the WhatsApp IPM Diagnosis and Management Network to all ten (10) villages/farmer groups in the project areas. The WhatsApp group links the village/group networks to PI organizations: MARI and SUA through Village/Group Leaders and Extension Officers.
Progress:
a. Plant Health Network: A WhatsApp group named: '*Kilimo Cha Mboga Kisasa*', which means 'Modern vegetable farming,' was created to enhance communication on vegetable production and IPM for farmers and extension in Morogoro and Iringa. The farmers and extension were trained on how to capture images, access information and link to the wider East Africa WhatsApp network. The membership of the farmers' network currently stands at 47 active members.

b. A guide for IPM of tomato viral diseases and insect vectors was drafted and samples distributed to farmers in demos in Morogoro and Iringa for validation and improvement.

Planned activities:
a. Expand the WhatsApp group by creating awareness and recruiting more vegetable farmers, extension, scientists and other players in vegetable production to share and communicate pest and disease problems and IPM.
b. Disseminate training materials to farmers and stakeholders (Extension, Agricultural Officers) in soft and hard copies. Soft copies will be shared on the WhatsApp group**.**
c. Advocate for policy on safe use of insecticides and safer but efficient alternatives to insecticides in vegetable production and IPM.

Objective 3: Evaluate prototype IPM technologies in on-station and on-farm trials
Activity 1: Evaluate IPM technologies in on-station and on-farm trials
Title: On-farm evaluation of IPM strategies for vegetable virus diseases
PI: Sseruwagi, Ndunguru (MARI)
Site/Location: Tanzania, Bagamoyo district.
Crops: Tomato
Priority pests: Viruses, whiteflies, aphids, hoppers
Status: Second season assessment
Audience: Farmers, Private Seedling Producers, Extension and Local Leaders.
Description**:** Three improved IPM strategies: (1) approved chemical pesticides, (2) natural botanicals and (3) plastic mulch were evaluated against farmer practices in 'Mother-Baby Trials' for control of insect pests and viral diseases on tomato 2017 and 2018. The trials were set up as randomized blocks with four replications. Good agricultural practices (GAPs) included: healthy seedling production in an insect proof screen house, isolation, roguing, staking, pruning and adapted varieties. IPM components were used depending on the site, pest history and status of the crop. The baby trials will evaluate farmer practices.
Progress: A second season of the validation of tomato viral disease IPM technologies to established with 'Mother-Baby' trials in July 2018 to run for 8 weeks until end of August 2018.

Planned activities:
a. Analysis of 1st and 2nd season data for validation trials of tomato viral disease IPM technologies in 'mother and baby' trials - Oct 2018**.**
b. Produce and disseminate tomato viral diseases and insect vectors IPM packages and training materials: leaflets, brochures, manuals in soft and hard copies – Nov 2018 to Mar 2019**.**
c. Writing and publication of IPM strategies validation data - Feb 2019.

Below are the proposed manuscripts to be submitted for publication:
1. Molecular diversity and distribution of viruses and insect vectors affecting vegetables in Tanzania – *Plant Disease*
2. Assessment of farmers' knowledge of viruses and insect vectors affecting vegetables and their management – *Crop Protection*
3. Evaluation of IPM of tomato viral diseases and associated insect vectors – *Journal of Pest Science*

WORK PLAN FOR KENYA

I. Kenya Agricultural and Livestock Research Organization (KALRO)

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: Complete manuscripts for publication
Description: Share draft of survey report with the rest of the team members by end of May, brand and print final document by end of July, 2019.

Activity 2
Title: Workshop on Policy.
Description: Organize a one-day stakeholders' workshop to discuss policy obstacles to IPM adoption. We will first share current findings and discuss inclusion of biopesticides in Vegetable IPM. Then we will brainstorm on how to influence policy on IPM in vegetable production.
Audience: 50 persons drawn from The County Agriculture Department (Representative from main tomato, French bean and cabbage growing Sub-Counties); Pest Control Products Board (PCPB), Kenya Plant Inspectorate Services (KEPHIS), Horticulture Crops Directorate (HCD), Kenya National Federation of Farmers (KENAF), Agro chemical Companies (Real IPM, Koppert Biologics, Osho, Amiran, Juanco, Finlays Horticulture, Kenya biologics, Dudutech), researchers, farmers, Extension agents, exporters).
Expected Outcome: Roadmap for development of a national IPM policy drawn.

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
1. Ms. Cecilia Ngugi, Ph.D. student at Jomo Kenyatta University, to complete her study by July 2019, and publish two papers on the use of entomopathogenic nematodes for management of *Tuta absoluta* in tomato.
2. Mr. Joshua Kinene to complete his study by January 2019, and publish one paper from his work on evaluation of plant extracts in their use in management of root knot nematodes in French beans.
3. Dennis Nyamu to complete his studies at Ohio State University by September 2019, and publish one paper on validation of growth regulators for Tuta absoluta management.
Expected outcomes: Graduate study leading to theses and published papers in peer-reviewed journals.

Activity 2
Title: Short-term training of farmers and trainers.

Leaders: Mbaka, Kambo, Ndungu, Kuria, Muriuki, Kihara, Wepukhulu
Status: on-going
Audience: 20 trainers (15 lead farmers and 5 field extension farmers) to be trained in house and in the field, 1000 farmers (Drawn from different sub-counties and the three groups; Mbogoni, Nthambo and Mbuiru-Mwanjati) will be trained in the field
Description: Conduct training on:

a. IPM systems and technologies (Production under high tunnels; grafting).
b. Compost making using Trichoderma at farm level.
c. Training in pest and disease identification and use of WhatssApp for pest and disease diagnostics.
d. Diagnostic training for 30 people (students, extension field workers, researchers and lead vegetable farmers) at KALRO-Kandara.
e. Farming as a business and marketing to enable vegetable farmers identify and evaluate markets and marketing channels and thus market their products successfully as a group.
f. Group dynamics to assist group members understand the importance of cooperation among themselves and create a relaxed and positive atmosphere where farmers will support each and continue to work together after the project period.

Expected outcome: Farmers and extension field officers are able to include production and grafting in IPM Packages**;** farmers are able to identify pests and diseases and use WhatsApp for communication; Farmers are able to do farming as a business and groups remain cohesive.

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

Activity 1.
Title: On-farm validation of *Trichoderma* and biofertilizer.
Leaders: Sylvia Kuria, Jesca Mbaka, Samson Kihara and Simon Wepukhulu.
Description: We will repeat and validate the on-farm study with *Trichoderma* and evaluation of "Plantmate" biofertilizer for their efficacy in management of bacterial wilt, nematodes and other tomato diseases. Experimental site: Chuka Sub-County, Tharaka Nithi County, Kenya
Audience: 48 farmers belonging to Mbuiru-Mwanjati and Mbogoni Horticultural Growers' Self Help Groups

Methods: The experiments will be laid out in a RCBD replicated four times.
Treatments:

1. *Trichoderma harzianum* (Triunum)
2. *Trichoderma asperellum* (Real Trichoderma)
3. *T. harzianum* + *T. asperellum* (Triunum + Real Trichoderma)
4. Plantmate (Basal fertilizer) mix of plant and animal waste fermented with effective microbes
5. Control (drenching with water only)

Soil samples will be collected for microbial analysis prior to planting. Bacterial wilt incidence and nematode galling will be recorded every two weeks. Incidence of any other diseases and their severity will be recorded every two weeks. Data will be subjected to analysis of variance (ANOVA) using the procedure GLM of SAS. The experiment will be repeated for one season and a manuscript submitted for publication.

Activity 2.

Title: On-farm validation of selected biopesticides for management of tomato pests.
Leaders: Caesor Kambo and Simon Wepukhulu
Description: We will repeat and validate studies on *Tuta absoluta*, tomato leafminer (*Liriomyza trifolii*) and other arthropod pests of tomato.
Location: Chuka Sub-County, Tharaka Nithi County, Kenya
Audience: 54 farmers belonging to Mbogoni and Mbuiru- Mwanjati Horticultural Growers' Self Help Groups.
Methods: Experimental design: RCBD replicated 4 times. The farmers will raise tomato seedlings (Variety Kilele). Pheromone traps will be placed in the fields for detection of first appearance of Tuta. There will be 6 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. Foliar spray with Coragen 20SC (Chlorantraniliprole 200g/L)
6. Control (water spray)

Data pest populations and damage will be recorded every week with participation of farmers. At harvest, fruits will be sorted and marketable yields determined. Data will subjected to ANOVA using GLM of SAS. The experiment will be repeated for one season and a manuscript submitted for publication.

Activity 3.
Title: On-farm validation of the efficacy of T*richoderma* and *Bacillus* strains for management of black rot and soft rot of cabbage.
Leaders: Mbaka, Muriuki, Kihara, Wepukhulu.
Locations: Chuka Sub-County, Tharaka Nithi County, Kenya
Audience: Farmer groups, Nthambo Horticultural Growers' Self Help Group (24 Farmers)
Methods: Experimental design-split plot design replicated four times.
The cabbage variety Queen alleged to have tolerance to black and soft rot and the susceptible variety Gloria will be planted in the same plots Farmers will plant cabbage as per standard practice in well-prepared field soil. These treatments will be applied:

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)

Plants will be drip irrigated. Healthy seedlings will raised in germination trays with coco peat and/or peat moss 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.
The experiment will be conducted in the wet and dry seasons and a manuscript prepared for publication.

Activity 4.
Title: On-farm validation of four biopesticides and a trap crop in the management of the Diamond back moth, cabbage moth (*Crocidolomia pavonana*) and aphids in brassicas.
Leaders: Muriuki, Kambo.
Location: Chuka Sub-County, Tharaka Nithi County, Kenya
Audience: 24 farmers belonging to Nthambo Horticultural Growers' Self Help Group
Methods: Experimental design-RCBD Replicated four times. The treatments are as follows:
1. *Beauveria bassiana* (Biopower 1.15 EC)
2. Azandrachtin (Neemraj Super 3000)
3. *Bacillus thuringiensis* (Dipel DF)
4. Tomato as trap crop
5. Foliar sprays with Karate 2.5 WG (Lambda cyhalothrin 25 g/Kg)
6. Control (Spray with only water)

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. Data will be subjected to ANOVA using SAS. The experiment will be repeated for one season and a manuscript submitted for publication. All pesticide used will be those approved in corresponding PERSUAP.

Activity 5.
Title: On-farm validation of selected bio pesticides for their efficacy on management of arthropod pests of French beans.
Leaders: Kambo, Kihara, 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
Methods: Experimental design will be RCBD replicated four times. There will be 6 treatments:
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. Decis Forte EC (Deltamethrin 100g/L)
6. Control (water spray)

French bean variety Julia will be planted in 3 by 3 m plots with one-meter paths. Data on pest counts will be recorded. At harvest, the pods will be sorted and recorded as marketable and unmarketable yields. Data will be analysed using the SAS statistical package. The experiment

will be repeated for one season and a manuscript written and submitted for publication. All pesticide used will be those approved in corresponding PERSUAP.

Activity 6.
Title: On-farm validation of three biopesticides for their efficacy in the management of foliar diseases and nematodes in French beans.
Leaders: Kihara, 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
Approach: Farmers will grow French beans as per standard practice on their farms. Plots consisting of 4 rows 3 m long will be replicated 4 times in a randomized Complete block design. There will be four treatments:
1. *Trichoderma asperellum* (Real Trichoderma)
2. Azdirachtin (Nimbecidine EC)
3. *Paecilomyces lilacinus* (Bionematone)
4. Control (Foliar spray with water only)
Treatments will be applied as per the labels. Results will be assessed by weekly observations of plants for damage. Tagged leaves will be evaluated for damage. Samples of suspect diseases will be taken to the laboratory 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. This experiment will be repeated for one season, a manuscript written and submitted for publication.

Objective 4: Evaluate packages to determine project impacts, including enhanced farmer knowledge of pests, adoption of IPM strategies, and reduction in pesticide use and associated environmental benefit, and increased farm productivity and incomes and associated gender benefits.
Activity 1.
Title: Conduct a cost return analysis of vegetable IPM packages
Leaders: Ndungu, Wepukhulu, Norton.
Locations: Kenya
Description: A cost-return analysis on promising vegetable IPM technologies will be done together with the farmers and introduce them to the principles of record keeping and its importance. Information on costs of inputs and activities for each IPM package will be collected and recorded during major farm operations such as nursery bed preparation, land preparation, planting, fertilization, pest management, weeding and harvesting. Data (quantities and prices) will be collected on inputs like seeds, fertilizer, bio pesticides or other IPM inputs, labor, machinery use, and water, as well as output quantities, prices. Complete enterprise budgets will then be constructed. This analysis will assist in evaluating the impact of the promising IPM options. This activity will be done for two seasons and completed.

Activity 2:
Title: Survey of Adoption of Integrated Pest Management (IPM) use for selected vegetables in Tharaka Nthi County, Kenya

Leaders: G. Norton, Ndungu B.W, Mbaka J., Wepukhulu S., Muriuki S., Kuria S., C; Kihara S., and C. Kambo, D. Nyamu.
Location: Chuka, Tharaka Nithi County. Kenya
Description: Crop-specific IPM packages for target crops have been developed and tested by researchers at KALRO. Farmers have also been trained on proper pests, disease identification, IPM management strategies, and their benefits. A rapid rural appraisal will be done to determine the level of IPM adoption of these IPM practices among the farmers. Data collection tool will be developed so as collect gender disaggregated data on enhanced farmer knowledge of pests, adoption of IPM strategies, reductions in pesticide use and constraints to adoption. This data will help in capturing project indicators as well as evaluate adoption of IPM packages. The data will also be used to determine project impacts by assessing associated environmental benefits, increased farm productivity and incomes, and gender disaggregated benefits- A manuscript will be written from the collected data and submitted for publication.

Activity 3.
Title: Complete and submit manuscripts for publication.
To empower our trained trainers to sustainably keep training even after project period, we will prepare and print 43 fact sheets on French bean, tomato and cabbage/kale pests and diseases. Three training modules on the same above will also be prepared and distributed electronically. Expected output includes writing Semi -annual and annual reports, 8 manuscripts, two success stories.

Student activities supported through KALRO:
Name: Ceciliah Ngugi PhD Student, Jomo Kenyatta University.
Dissertation title: Characterization and evaluation of entomopathogenic nematodes for management of *Tuta absoluta* on tomatoes.
Objectives and activity:
1: To determine infectivity of Five EPN isolates on *T. absoluta*
Manuscript describing results sent to Journal of Crop Protection for review.
2. Characterize of EPN isolates (morphological and Molecular methods). Morphometric and EPN DNA extraction and sequencing are in progress. Expect to prepare manuscript by October 2018.
3: Identify the EPN Symbiotic bacteria and evaluate its efficacy on *Tuta absoluta*.
EPNs culture maintenance methods have been developed. Symbiotic bacteria isolation, culturing and identification (molecular and morphological) are ongoing.
4: Isolate and evaluate efficacy of bacteria insecticidal protein on *T. absoluta*.
Collection and maintenance of *Tuta absoluta* for this study are ongoing, as is maintenance of EPNs.
Publications expected:
1. Laboratory screening for infectivity of selected indigenous entomopathogenic nematode isolates on *Tuta absoluta*.
2. Morphological and molecular characterization of entomopathogenic nematode isolates from Kenya.

Denis Nyamu (Male)
Degree registered for: M.S. (August 2017 - December 2019)

Discipline: Entomology
University: Ohio State University
Proposed thesis title: Insecticide resistance in populations of American tomato moth Tuta absoluta (Lepidoptera; Gelechiidae) on commonly used insecticides.
General objective: To find if Tuta absoluta is showing signs of becoming resistant to insecticides and find out which IPM techniques are being used for its control.
IPM IL funds: 100%.
Supervisor: Luis Canas, Department of Entomology, Ohio State University.

Name: Joshua Kinene Njenga, M.S. Student, Chuka University
Thesis title: Determination of the Efficacy of Neem, Tithonia, and Tephrosia Leaf Extracts in Management of Root-knot Nematods in French beans.
Objectives:
1. Determine phyto-chemical constituents in the leaf extracts of Neem, Tithonia and Tephrosia toxic to root-knot nematodes.
2. Determine the nematicidal activity of the leaf extracts of Neem, Tithonia and Tephrosia against the root-knot nematodes in vitro.
3. Evaluate the comparative performance of the leaf extracts of Neem, Tithonia, Tephrosia and Vydate (Oxamyl 10% L) on root-knots nematodes management in both pot and field experiments.
Summary of results to date:
Data have been collected on the active phyto-chemical constituents in the leaf extracts of neem (Azadirachta indica), Tithonia (Tithonia diversifolia), and Tephrosia (Tephrosia purpurea).
A preliminary in vitro experiment on the nematicidal activity of the leaf extracts was completed.
Plant data (field and lath house pot experiment) have been collected on agronomic characteristics.
Activities in progress:
Thesis submission to the graduate school expected November 2018.
Finalize publications based on research work on 2nd and 3nd objective.
Planning for a farmer's workshop on "Training on French beans Root-knot Nematode Identification and adoption of IPM (Botanicals) as a pest control strategy." The audience will be farmers in Chuka county.
Publications expected:
1. Evaluation of Plant Extracts on Egg hatching and Juvenile Mortality of French bean Root-knot Nematodes (Completed waiting for review for publication)
2. Evaluation of Neem (Azadirachta indica) Tithonia (Tithonia diversifolia) and Tephrosia (Tephrosia purpurea) extracts for the management of French-beans Root-knot nematodes in a controlled lath-house pot experiment
3. Field Evaluation of Neem (Azadirachta indica) Tithonia (Tithonia diversifolia) and Tephrosia (Tephrosia purpurea) extracts for the management of French-beans Root-knot nematodes.

Partnerships: Farmer groups, Mbogoni, Nthambo and Mbuiru Mwanjati Horticultural Growers in Tharaka Nithi County

II. Real IPM

Objective 2. long- and short-term training and capacity building in IPM systems.
Activity 1.
Title: Real IPM participation in training
Location: Four locations in Kenya:
Kiambu County; 9-17 July 2019; Audience: vegetable farmers (50-100)
Kirinyaga County; 23-31 July 2019; Audience: vegetable farmers (20-30)
Nyeri County; 1st -10th August; Audience: farmers in KALRO working groups (100-150)
Nairobi; 10th -17th August; Audience: diverse farmers (100-150)
Desecription: We will participate in training on diagnostics of vegetable pests and abiotic disorders. Our expertise is in biological products and in connecting participants to the Plant Health Network using WhatsApp and an online diagnostic database when and where appropriate. We will work initially with farmers with whom we have an ongoing consulting relationship. They will be asked to bring others to the training. We will initiate an online connection using a bulk SMS message approach, as has worked in the past. Farmers will receive training in basic pest diagnosis, focusing on pests of tomato, cabbage, and French beans. Village groups will form Plant Health Network nodes, and will be linked to the main network through a lead farmer.

Objective 4: IPM Communication.
Activity 1:
Title: IPM Communication for diagnosis and management recommendations.
Leader: Murunde (Real IPM)
Site/Location: Tanzania, Kenya, Ethiopia
Status: on-going
Description:
1. Expand the WhatsApp IPM Diagnosis and Management Network to two more villages and 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.

III. IITA

Objective 2. long- and short-term training and capacity building in IPM systems.
Activity 1.
Title: IITA participation in pest diagnostic training
Title: D. Coyne
Date and location: June 2019 – Morogoro Region, Tanzania
Focus of training: Basic education for trainers in nematode identification, biology, and management.
Description: Provide new knowledge to trainers in Morogoro, Mlali, and Iringa and to create awareness on nematode issues in vegetable crop production. One-hour practical demonstration

on basic techniques of diagnosis and management, with discussion followed by three hours formal presentations.
Audience: extension, ministry of agriculture, TAHA, M&M personnel, students.

Activity 2.
Title: IITA assistance in graduate student education.
Description: Provide ongoing assistance to graduate students in Kenya (Jomo Kenyatta Univ. and Chuka University) conducting research using nematodes. See KALRO description for student information.

Objective 4: IPM Communication.
Activity 1:
Title: IPM Communication for diagnosis and management recommendations.
Description:
1. Work with Real IPM to expand the WhatsApp IPM Diagnosis and Management Network to villages and farmer groups where nematodes are a particular problem. Provide educational materials, images, and management recommendations for village/group networks linked to the main network hub, and for the web site associated with the network.

WORK PLAN FOR ETHIOPIA

Hawassa University

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
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.

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
Description:
Two graduate students undertaking MS thesis research under the project. A summary of students is given below.

Name	Gender	Degree program	Discipline	University	Expected graduation
Kumsa Dida	Male	MSc.	Plant Protection	Hawassa	January 2019
Feysisa Bekele	Male	MSc.	Plant Protection	Hawassa	July 2019
Tsion Tekele	Male	MSc.	Plant Protection	Hawassa	October 2019
Endale Girma	Female	MSc.	Plant Protection	Hawassa	October 2019

Graduate Student Thesis topics:
Kumsa Dida: Effect of netting duration on incidence of pepper viruses in the rift valley of Ethiopia. To be submitted to *Archive for Phytopathology and Plant Protection*.
Feysisa Bekele: Weed management and comparative effectiveness of herbicides on onion in the Rift Valley of Ethiopia. To be submitted to *African Journal of Food, Agriculture, Nutrition and Development*
Endale Girma: Evaluation of selected non synthetic pesticides against major pests of pepper and tomato in the central rift valley of Ethiopia.
Tsion Tekele: Survey, characterization and biocontrol of *Pyrenochaeta lycopersici*, the cause of tomato corky root rot.

Activity 2.

Title: Farmer and trainer training planned for FY-2019.
1. Audience: Trainers, including extension personnel, ministry personnel, plant health clinic workers, crop protection workers, graduate students, and junior researchers.
Description: 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.

2. Audience: Vegetable farmers from Alaba, Butajira, Meki, Ziway, and Hawassa.
Description: 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.

3. Audience: Technical staff from plant health clinics in Hawassa, Ziway, and Meki, graduate students, extension staff.
Description: Conduct training on laboratory and field diagnostics, assessment, sampling of diseases and insect pests.

Activity 3:
Title: IPM Communication for diagnosis and management recommendations
PI: Azerefegne, Beyene, Chala (Hawassa)
Site/Location: 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 Hawassa University web site associated with the project.
The site will provide users with information on pest identification, biology, control etc., and will be sustained beyond the life of the project.

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

We will repeat studies that have shown promise so that results can be published. No new experiments are planned.

Activity 1.
Title: Research/demonstration on 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.
Results to date: Good results were recorded for Meki and Koka in the dry season and wet season. With a threshold of 10 thrips per plant, we needed only 2 and 1 spray, respectively, for effective management. The control plots were sprayed weekly.
Plans for FY-19: The study will be repeated with a modification of the threshold, recognizing that older plants can tolerate more thrips than older younger plants. Therefore, the threshold will begin at 10 and increase by 5 with every additional five leaves. Results will be analyzed and a manuscript is expected for publication in *Crop Protection*.

Activity 2.
Title: Efficacy and economic evaluation of weed control methods on onion. (Feyisa – Grad Student, Yibrah and Azergenge)
Location: Two farms each in Hawassa and Ziway.
Methods. Treatments include pendimethalin application followed by 1, 2, 3, and 4 weedings, plus a weedy and weed-free check. 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.
Results to date: Preliminary results suggested that weedings could be reduced to one per season without yield loss. But the study was halted due to travel restrictions.
Plans for FY-19: Repeat the experiment so the student can finish the thesis, prepare a manuscript for publication, and graduate.

Activity 3.
Title: Performance of *Trichoderma* on pepper and tomato seedlings. (Alemayehu, Azerfegne)
Locations: On two farms each around Hawassa and Ziway where there are problems of soil borne diseases.
Audience: Four influential farmers each associated with 6 – 8 farmers in surrounding growing areas.
Methods: In the first phase of the study, a greenhouse pot experiment evaluated different formulations of *Trichoderma*. In the second phase, on-farm experiments will be conducted with similar treatments of *Trichoderma*. Treatments applied to on-farm plots in a completely randomized design replicated three times include Trichoderma from Real IPM, Koppert, and Ambo Research Center, plus an untreated control. Disease incidence (percent bacterial wilt) is 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).
Results to date: Previous results showed the Real IPM Trichoderma to be more effective than other formulations.

Plans for FY-19: The study will be repeated and data analyzed by site and season.

Activity 4.
Title:. 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.
Location: Hawassa vegetable farm.
Methods: Treatments are durations of netting: 0, 20, 40, 60 days, and to flowering, followed by spraying with dimethoate 40% EC as needed. The data will be assessments of the disease prevalence and severity, and population of vectors, pepper performance.
Results to date: Results varied by location, but the most consistent trend was that pepper yield increased with netting duration.
Plans for FY-19: The study will be repeated and results reported in a publication to be submitted to *Archives for Phytopathology and Plant protection*.

Activity 5.
Tilte: 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.
Methods: There will be two treatments: 1) standard farmer practice, and 2) IPM package system. 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.
Results to date: The experiment was initiated but terminated in FY-18 due to travel restrictions.
Plans for FY-19: The experiment will be conducted at four farms, which should provide sufficient site-replication. Results will be analyzed and written up for an IPM package bulletin that can be available to farmers.

Objective 4: Draw on project findings and impacts to inform national and regional policies that support IPM implementation to benefit the health of people

Activity 1:
Title: Policy development
Description: We will conduct an informal survey of project personnel and cooperators to learn about policies that have advanced or hindered IPM adoption. This includes procurement of IPM technologies for testing, demonstration, and crop production. It will also address access to non-pesticide materials at the farmer level, as well as availability of IPM-oriented formal and non-formal education. Results will be used to prepare a manuscript discussing policies that promote or interfere with IPM adoption in the three countries, and suggested policy alternatives to

alleviate restrictions. The manuscript will be submitted to the *Journal of Integrated Pest Management*.

Publications planned

Theses: Two theses in preparation from project research.
Articles: One article expected from each graduate student. Others listed above.
Extension bulletin: Vegetable Crops IPM Package, based on the study comparing farmer practice with the IPM package approach to management.

WORK PLAN FOR USA PARTICIPANTS

I. Virginia Tech

Co-PI: George Norton

Objective 1: Conduct participatory and survey 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, Erbaugh
Site/Location:Tanzania, Ethiopia, Kenya
Status: Ongoing
Description: Journal article manuscripts out of the previous MS thesis for Kenya and baseline surveys for Kenya and Ethiopia were prepared in FY 2018. In FY 2019, these manuscripts will be revised and submitted to journals.
Expected outcomes: Two journal articles to help guide the IPM program efforts in each country with respect to priorities and targeting of factors to influence audiences. The articles also will spread information from the project to a broad scientific audience.

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 student
PI: Norton
Site/Location: Virginia Tech
Status: Continuing MS student
Description: An MS student at Virginia Tech was selected and began work in June 2018 on impact assessment for selected IPM practices (See Objective 4 below) of the East Africa Vegetable IPM project. He will continue in 2019.
Expected outcomes: Graduate study leading to a thesis and published paper.

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, roguing, and nursery nets.
PIs: Norton, Erbaugh (OSU), Maerere (SUA), Ndungu (KALRO), Rakowski (OSU)
Site/Locations: Tanzania and Kenya
Status: Continuing

Description: A follow up survey (for adoption and impact assessment) will be conducted in the areas where the project has worked. We will survey at least 300 farmers using a properly drawn sample (randomized villages and farms within the region so we can get a valid comparison between adopters and non-adopters). We will also target our cooperating farmers as a subgroup and then use propensity score matching to control for observable differences between our cooperators and other farmers. Using results of the previous baseline survey, field trial data, the new targeted follow-up farm-level survey, regression analysis, and village-level focus groups, we will evaluate economic, environmental (pesticide-related), and gender impacts of specific IPM practices on tomatoes, cabbage, and beans. We will explore the impacts of IPM on farm households and at a county level.
Expected outcomes: Farm-level and county-level economic, environmental, and gender impacts evaluated for specific IPM practices for specific crops in the target countries. An MS thesis will also be completed and a journal article manuscript and a brief prepared.

Graduate Student:
Name: Ryan O-Reilly
Sex: Male
Nationality: US
Discipline: Agricultural Economics
Site/Country: Kenya
Degree: M.S.
Start date: June 2018
Completion date: May 2020.
IPM IL funds: 100% from June 2018 to September 2019 (project end date)(Student will be paid on another project after September 2019 if necessary)
Advisor/PI: George Norton
Thesis topic: Impacts of IPM for vegetables in Kenya
University: Virginia Tech

II. University of California-Davis

Co-PI: Robert Gilbertson

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: Short-term training of trainers and graduate students
PI: Gilbertson
Site/Location: Tanzania
Description: Participate in diagnostic training following the project annual meeting, planned for April, 2019. Provide specific training in virus identification, approaches to diagnosis and management, and methods for sample collection and analysis.