The *Feed the Future Innovation Lab* for

Integrated Pest Management

Technical Workplan

Fiscal Year 2017

IPM IL | Integrated Pest Management Innovation Lab

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Project title: 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.), and summarize and analyze farm-level baseline survey data in Nepal

PIs: Norton, Sah

Site/Location: Nepal

Status: Continuing

Description: This activity will involve:
a) Crop/pest monitoring for *Tuta absoluta* and other existing and potential pests are currently being applied for tomato, onion, chili, okra, and beans, especially in the Feed the Future districts.
b) Farm-level survey data for all vegetables on the project (tomato, crucifers, cucurbits, eggplant, onion, chili, okra, and beans) that were gathered in the first year will be summarized in tables and analyzed as part of a PhD thesis (at Tribhuvan University) to assess which pest management practices are currently being applied, the extent of IPM adoption, constraints to IPM adoption, and IPM impacts, if any.

Expected outcomes: (1) increased knowledge of major pests affecting the targeted crops (2) baseline survey results summarized with information on major pests by crop, current pest management practices, and extent of IPM practice adoption. (3) Assessment of factors affecting IPM adoption.

Activity 2: Summarize and analyze farm-level baseline survey data in Bangladesh

PIs: Norton, Mian, Rahman

Site/Location: Bangladesh

Status: Continuing

Description: This activity will involve:
a) Crop/pest monitoring (pest defined as insects, diseases, weeds, nematodes, etc.) for *Tuta absoluta* and other existing and potential pests will continue for tomato, mango, and other vegetable crops, especially in the Feed the Future districts.
b) Farm-level survey data for all vegetables on the project that were gathered over a year ago will be summarized in tables and analyzed as part of PhD theses (at Virginia Tech and at BAU) to assess which pest management practices are currently be applied, the extent of IPM adoption, constraints to IPM adoption, and IPM impacts, if any.

Expected outcomes: (1) increased knowledge of major pests affecting the targeted crops (2) survey results summarized with information on current pest management practices and extent of IPM practice adoption. (3) Assessment of factors affecting IPM adoption and impacts of IPM practices already adopted.

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

PIs: Norton, Kim Hian

Site/Location: Cambodia

Status: Continuing

Description: This activity will involve:
a) Selected crop-pest monitoring will continue to verify crop-pest priorities identified in year 1. Special attention will be devoted the collection of plants with viral symptoms and to nematode data. Data collected in years one and two will be summarized. A second disease/virus survey will be conducted.
b) Farm-level baseline survey data will be gathered and summarized in tables and analyzed to assess which pest management practices are currently being applied on crucifers, cucumber, tomato, long bean, chili peppers, sweet peppers, bitter gourd, and eggplant, and the extent of IPM adoption.

Expected outcomes: (1) baseline survey results summarized with information on major pests by vegetable crop, current pest management practices, and extent of IPM practice adoption. (2) data from virus analysis and nematode analysis will also be summarized.

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

PIs: Norton, Sah (and all the site co-PIs)

Site/Location: Nepal

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

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

a) Testing of a fruit and shoot borer package that includes: area-wide lures, clipping shoots, and applying Spinosad and Coragen in 3 week intervals after first symptoms. These practices will be tested in on-farm trials in Banke for two seasons and the successful ones included in the eggplant IPM packages in subsequent years. NARC entomology scientists will be involved.
b) 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 will be involved.
c) Trapping of fruit flies with protein bait and cuelure will be tested on farm for cucumbers and bitter gourd. Especial attention will be given to assessing the economic benefits of the protein bait. NARC entomology scientists will be involved.
d) A chili package will be tested on farm that includes raised beds, compost amended with *Trichoderma* and *Pseudomonas*, and resistant varieties. One treatment will include grafting as well. NARC plant pathology scientists will be involved.
e) Testing on-farm a combination of neem and *Bt* to manage *Tuta absoluta.* This trial will occur in an area where *Tuta* has already been discovered through monitoring this year. NARC entomology scientists will be involved.
f) On-station testing of anaerobic soil disinfestation by NARC.
g) Using previously collected data on viruses, design and test virus management strategies for tomato production under greenhouse conditions. NARC plant pathology scientists will be involved.

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

Expected outcomes: Additional IPM practices on tomatoes, eggplant, chili, cucumber, and bitter gourd will 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 (and all the site co-PIs)

Site/Location: Bangladesh

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

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

a) Test management approaches (cloth bagging for fruit on the tree and bagging with brown paper bags) against mango fruit fly *Bactrocera dorsalis* (Second year) in three locations Gazipur, Khagrachari, and Chapainawabgonj. Add a treatment for mass trapping with protein-bait for the females and cuelure for the males (combined with picking up fruit on the ground) to be tested in northern Bangladesh (BARI Co-PIs: M.S. Hossain, M. Hossain, B.C. Sakara, M. Dhar).

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

c) Testing on-farm IPM practices that include neem and *Bt* to manage *Tuta absoluta.* This trial will occur in the area where *Tuta* was discovered this past year through monitoring this year (Panchagorh) and monitoring with Delta traps will continue in other areas such Jessore, Comilla, and Gazipur (BARI Co-PIs: M.S. Hossain, M.A. Goffar, M.K. Das, M.H. Hossain)

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

e) Test 2 IPM packages for Bitter Gourd on-station in Gazipur (Main BARI station) and at the Narsinghdi district Regional Horticulture Research Station of BARI (second season of test): Package 1 includes Tricho-compost, growing of seedlings under 60 mesh nylon net, Tricho-leachate, Bio-neem plus, yellow sticky plate trap, pheromone trap (cuelure) plus mashed sweet gourd trap for controlling fruit fly and pheromone trap for controlling fruit borer or tobacco, hand picking of red pumpkin beetle and of *Epilachna* beetle. Package 2 includes poultry refuse, growing of seedlings under 60 mesh nylon net, Tricho-leachate, yellow sticky plate trap, pheromone trap (cuelure) plus MSG trap for controlling fruit fly and pheromone trap for

controlling fruit borer or tobacco caterpillar, hand picking of *Epilachna* beetle. (BARI Co-PIs: M.A.T. Masud, B. Ahmed, Q.M. Ahmed, M. Samsunnahar, M.S. Hossain, S.M.A. Shiblee).

f) 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 (second year test). Viruses will be monitored to identify prevalent ones (BARI Co-PIs: M.A. Goffar, M. M.M.R. Salim, S. Hossain, M.S. Nahar).

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

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

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

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

PIs: Norton, Kim Hian (and all the site co-PIs)

Site/Location: Cambodia

Status: Continuing

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

a) Test cucumber IPM package on farm in Siem Reap. That package includes: *Trichoderma* seed/seedling/soil treatment, nursery nets, Pheromone traps – Fruit fly bait + Cuelure for fruit fly, Yellow traps, scout for pumpkin beetle; chemical pesticide at threshold; scout for downy mildew – apply fungicides as soon as it appears, staking, roguing for virus, and mulch
b) Test on farm in Siem Reap a Chinese Kale IPM package that includes: Hot water treatment + *Trichoderma* seed/seedling/soil treatment + Nursery nets + Pheromone traps (DBM, *Spodoptera*) + Yellow traps + Microbials Bt + Scout for larvae; Bt at threshold + Roguing for virus + Mulching

c) Test on station at RUA an IPM practice on Chinese Kale of T1=*Trichoderma*, T2=pesticides, T3=pesticides+*Trichoderma*. *Trichoderma* treatments will be applied three times: for seeding coating, at transplanting stage, and 15 days after transplanting. Treatments are assigned to a randomized complete block design with four replications (student replicated plots).
d) Test on station at RUA an IPM practice on cucumber of T1=*Trichoderma*, T2=pesticides, T3=pesticides+*Trichoderma*. *Trichoderma* treatments will be applied three times: for seeding coating, at transplanting stage and 15 days after transplanting. Treatments are assigned to a randomized complete block design with four replications (student replicated plots).
e) Tomato rootstock evaluation for *Ralstonia* resistance at RUA
f) Monitoring tomatoes in Siem Reap and Battambang for *Tuta absoluta* using pheromone traps
g) Test tomato IPM package in Siem Reap.
h) Monitor vegetables (cucumbers, tomatoes, chili peppers, eggplant and yard long beans) for viruses in all project sites and identify prevalent viruses.

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, 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) Finish developing a detailed plan for IPM vegetable and mango technology transfer, initiate its implementation
PIs: Norton, Kim Hian, Mian, Sah and other Co-PIs

Site/Location: Cambodia, Bangladesh, Nepal

Status: Continuing

Description: This activity will involve:
a) Completing a detailed plan and begin implementing it with 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.

b) Assessing the roles of researchers, public extension agents, input suppliers, NGO technicians, community-based marketing associations, independent crop consultants, women's groups, and others in scaling up IPM knowledge and adoption.
c) Coordinating with the USAID-supported Agricultural Value Chain projects in Nepal and Bangladesh (and in Cambodia when it exists) and providing information to them on vegetable IPM packages that relate to crops with which those projects are working and giving demonstrations to growers

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

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

PIs: Norton, Kim Hian, Mian, Sah and all Co-PIs

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 use of mobile phones apps in vegetable and mango pest diagnostics and IPM diffusion.

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, a PhD student in ag econ at BAU in Bangladesh, and a PhD student in ag econ at Tribhuvan U in Nepal. In addition, MS thesis research is being supported for 3 students at RUA in Cambodia. An MS student is also being recruited for August 2017 (will start after the PhD student in Ag Econ finishes).

Expected outcomes: Eventually the students listed above will complete PhD or MS degrees and return to their home countries (each except the gender studies 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 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 spread to among scientists and methods for pest diagnostics also spread.

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

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

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

Site/Location: Cambodia, Bangladesh, Nepal

Status: Continuing

Description: Yield, cost, income, and environmental (pesticide-related) impacts of IPM activities will be assessed. Survey and other household data from each country program will summarized and used in the

analyses along with data from the various on-farm trials. Farm-household- and market-level benefits will be calculated for IPM practices and packages where appropriate. These studies will be conducted as part of theses and dissertations and eventually published in papers.

Expected outcomes: Farm-level survey data summarized and preliminary economic, environmental, and gender analyses conducted.

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

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

Site/Location: Cambodia, Bangladesh, Nepal

Status: Continuing

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

Expected outcomes: Gender-related data from farm-level surveys in Nepal and Cambodia summarized, preliminary gender analyses conducted, and recommendations made for gender-sensitive IPM scaling strategies.

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

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

PIs: Norton, O'Rourke, Christie

Site/Location: Cambodia, Bangladesh, Nepal

Status: Continuing

Description: Review and analysis will be conducted 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. The amount of previous work on this topic differs by country. Previous analyses of polices and regulations will be reviewed for each country and identification made of key constraints and groups that might be involved promoting policy changes where warranted. In future years, a plan will be developed to inform policy-makers of policy changes that would be economically and environmentally beneficial in each country. (Co-PIs: M. Sayed Issa in U.S; Y. Mian in Bangladesh; L. Sah in Nepal; S. Kim Hian in Cambodia)

Expected outcomes: Policies affecting IPM summarized (from this year's workplan) this and eventually policy recommendations.

Graduate Students and Post-Doctoral Research Associates:

1. Name: Farhanaz Sharmin
Sex: Female
Nationality: Bangladesh
Discipline: Agricultural Economics
Site/Country: Bangladesh
Degree: Ph.D.
Start date: October 1, 2015
Completion date: August 2017.
IPM IL funds: 100% (Started program in 2014 on Bangladesh Associate award)
Advisor/PI: George Norton
Thesis topic: Effects of IPM Training on Knowledge Building, Adoption, and Pesticide Use in Bangladesh
University: Virginia Tech

2. Name: Arjun Kanel (Sandwich student)
Sex: Male
Nationality: Nepal
Discipline: Agricultural Economics
Site/Country: Nepal
Degree: PhD
Start date: October 1, 2015
Completion date: September 30, 2017.
IPM IL funds: 100% (Started program in previous phase of IPM IL)

Advisor/PI: George Norton
Thesis topic: Economic impacts of vegetable IPM in Nepal
University: Tribhuvan University (Sandwich program with Virginia Tech)

3. Name: Sadique Rahman (Sandwich student)
Sex: Male
Nationality: Bangladesh
Discipline: Agricultural Economics
Site/Country: Bangladesh
Degree: PhD
Start date: October 1, 2015
Completion date: September 30, 2017.
IPM IL funds: 100% (Started program in previous phase of IPM IL)
Advisor: George Norton
Thesis topic: Economic impacts of vegetable IPM in Feed the Future districts in Bangladesh
University: Bangladesh Agricultural University (Sandwich program with Virginia Tech)

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

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

6. Name: Ram Bahadur Khadka
Sex: Male
Nationality: Nepal
Discipline: Plant Pathology
Site/Country: Nepal
Degree: PhD
Start date: August, 2016
Completion date: October 2019.
IPM IL funds: 100% except for the tuition which is paid by Ohio State
Advisor: Sally Miller
Thesis topic: TBD
University: Ohio State University

7. Name: Mafruha Afroz (Sandwich student)
Sex: Female
Nationality: Bangladesh
Discipline: Plant Pathology
Site/Country: Bangladesh
Degree: PhD
Start date: March, 2013 (Started program in previous phase of IPM IL)
Completion date: September 2017.
IPM IL funds: 100%
Advisors: Md. Ismail Hossain Mian and Sally Miller
Thesis topic: Characterization of *Ralstonia solanacearum* & *Clavibacter michiganensis* sub sp. michiganensis of Solanaceous Crops and their Management
University: Bangabandhu Sheikh Mujibar Rahman Agricultural University (Sandwich with Ohio State University)

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

Short-Term Training planned

Annual meetings in Cambodia, Nepal, and Bangladesh
Disease diagnostic workshop in Cambodia

Publications planned:

Research articles: 1
Books and book chapters: 2
Extension articles: 2
Posters: 2

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

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

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

Collaborating Institutions:

Virginia Tech
Ethiopia – Ambo University
Amhara Regional Agricultural Research Institute
Ethiopian Institute of Agricultural Research
Haramaya University
CABI
Kenya – Kenya Agriculture and Livestock Research Organization
South Africa – ARC-PPRC
Tanzania – Sokoine University of Agriculture
Uganda – National Agricultural Research Organization

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

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

PIs: Wondi Mersie, Sintu Alemayehu, Tesfay Amare, Mulugeta Negari, Lisanework Nigatu and Birru Yitaferu

Site/Location: Wollenchiti, Guder, Haramaya and Kobo

Status: Continuing

Description: Four major rearing facilities were established to cover the west, east, central, and northern Ethiopia. The primary site will continue be in central Ethiopia at Wollenchiti, which has been operational since 2013; the other three will be in western Ethiopia at Guder (Ambo University –AU), eastern Ethiopia at Haramaya University (HU) and in northern Ethiopia at the Kobo a substation of the Amhara Agricultural Research Institute (ARARI). The Guder rearing facility will supply the leaf-feeding beetle *Zygogramma bicolorata* and the stem-boring weevil *Listronotus setosipennis* to western Ethiopia. The rearing facility at HU will supply both biocontrol agents to the eastern region of Ethiopia including to the *Parthenium* infested rangelands of the Somalia Region. The stations at Kobo will serve the Amhara, Afar, and Tigray regions. The Wollenchiti site will provide biocontrol agents to central Ethiopia and supplement all the other sites when necessary. Other small walk-in rearing cages will be established in the three regions to supplement the major facilities. These sub-rearing stations will provide bioagents to localities with heavy *Parthenium* infestations. Each major rearing site will have at least three rearing cages (5 m x 7 m). Two of the cages will be used for each bioagent and the third will serve as a nursery. *Parthenium* in pots will be grown in each of the rearing to rear the bioagents. Adults will be collected periodically and released in *Parthenium* infested fields. The sites will also be used to demonstrate the specificity of the bioagents to *Parthenium* to farmers and the community as a whole.

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

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

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

Site/Location: Guder and Haramaya

Status: Continuing

Description: This evaluation will have three parts: 1) collect baseline data on the seed bank and above-ground parts before the release of the bioagents; 2) measure the establishment, prevalence, abundance, and spread of the released biological agents over space and time after release; 3) determine the impact of the bioagents on weed, crop yield, and diversity of the seed bank, as well as on above-ground vegetation. These activities will be conducted at Guder and Haramaya. *Parthenium* before and after release and agent presence after release will be measured. **Abundance of *Parthenium*:** Number of plants; height; above-ground, below-ground and total biomass; number of flowers per plant; *Parthenium* seed bank. **Abundance of bioagent:** Number of adults, larvae, eggs per plant or pupae in a specified soil sample. **Extent of damage:** Number of defoliating plants; extent of defoliation on visual score of 0-5 (0=no defoliation; 5=complete defoliation); percent leaf area damage.

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

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

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

Site/Location: Ambo

Status: Continuing

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 for host-range evaluation. 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. Currently, emergence of adults from these pupation boxes is being monitored. The monitoring of adult emergence will continue for the coming three months. If there is no emergence of *Smicronyx* adult, a detailed evaluation of all the steps in culturing this bioagent will be conducted. If adults successfully emerge from pupation boxes, evaluation of the host range of the above agents will start with no-choice tests (test plant species only), followed by choice tests (with *Parthenium*) for those plant species where there is feeding, oviposition, or development on non-target species. Due attention will be given to indigenous genera and species of the tribe Helianthieae, with utmost attention being given to the endemic and cultivated taxa based on their affinity to *Parthenium hysterophorus* and having similar distribution and ecological preferences with the weed.

Expected outcomes: Data on the specificity of *Smicronyx* is generated. If data shows that *Smicronyx* is specific to *Parthenium* application for release permit will be submitted to the Ethiopian government.

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

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

Co-PI: Samora Macrice

Site: In and around Arusha, Tanzania

Status: Establishment was not confirmed – surveys will continue

Description: Two surveys were undertaken at all of the previous release sites – no establishment was confirmed. No larvae or adults were seen and there was no feeding damage. Will continue to undertake surveys in the remainder of 2016 and 2017

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

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

Co-PI: Samora Macrice

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

Status: Mass rearing site has been identified at TPRI, tunnels have been acquired and set-up and additional equipment purchased to undertake rearing of the biocontrol agent. Once facilities are in place insects will be shipped from South Africa.

Description: An agreement for TPRI to work with Sokoine University has been drawn up. Tunnels have been acquired and move to the identified site at TPRI. Pots, potting soil and other material required to grow *Parthenium* plants and rearing of the beetle have been purchased. Once everything is in place we will receive a shipment of beetles from South Africa and commence with rearing.

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

Co-PIs: Muo Kasina (Kenya) and Richard Molo (Uganda)

Site: If importation is approved the agents will be shipped to Nairobi, Kenya and Entebbe, Uganda. Mass rearing will take place at KARLO facilities in Kenya and at NARO in Entebbe.

Status: A Risk Assessment (RA) has been completed for the proposed importation of *Z. bicolorata* into Kenya and Uganda. Meetings have also been undertaken with the National Environmental Management Agency (NEMA) in Kenya to determine what the requirements are with regard to the release of potential biological control agents.

Description: In Kenya an application to introduce any agents has to be approved by KEPHIS in consultation with the Kenya Technical Standing Committee on Imports and Exports (KTSCIE). Obtaining a permit to introduce the beetle into quarantine in Kenya should be approved based on the compiled RA. However, based on past experience it is unlikely that KEPHIS or KTSCIE will approve the release of the agent based on the results of a desk-top RA alone – they will insist on additional testing. However, all avenues will be explored in the remainder of 2016 and 2017 to see if release can be approved based on the results of host range (HR) testing undertaken elsewhere. If introduction is not approved, additional resources will be sought in 2016/2017 in order to undertake HR testing in Kenya. If permission for release is granted the beetle will be imported from South Africa, mass reared and released in Kenya in 2017.

Uganda may face a similar scenario in that introduction will not be approved without additional HR testing. However, NARO has managed to acquire additional funds which will allow then to undertake additional HR testing if required to do so. It is envisaged that permission to import *Z. bicolorata* will be approved in late 2016 and that the beetles will be imported in early 2017 for additional testing. Depending on the number of native and crop species that need to be tested it is envisaged that the beetle will be released in the field towards the end of 2017.

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

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

Co-PIs: Samora Macrice, Muo Kasina and Richard Molo

Site: In all project countries – Kenya, Tanzania and Uganda

Status: Students that will undertake most of this research and set-up the demonstration trials have been identified in Tanzania – they have also registered for their degrees. In Kenya, students are being recruited to undertake research on *Parthenium.*

Description: Students in each of the three countries will undertake research to determine the impacts of *Parthenium* weed on crop and pasture production. These trials will be set-up in such a way so as to fulfill another function that of demonstration trials, to raise awareness of the impacts of *Parthenium* weed. It is envisaged that these trials will only commence later in 2016 and continue through into 2017.

Expected outcomes: Improved knowledge sharing, awareness and education on biocontrol of *Parthenium*, through increased capacity of stakeholders in Kenya, Uganda and Tanzania

Activity 5: Develop awareness materials such as publications and host workshops and meetings to raise awareness about the threat of *Parthenium* weed and the benefits of biocontrol.

Co-PIs: Samora Macrice, Muo Kasina and Richard Molo

Site: In all project countries – Kenya, Tanzania and Uganda

Status: A number of ideas have been discussed in order to raise awareness about the issue. In Kenya a number of meetings have been held with KALRO staff as to how best awareness should be raised. Some awareness material has been developed and disseminated in Kenya and Tanzania in the past. It is envisaged that awareness material will be developed and disseminated in 2016/2017 and a number of workshops held within that period.

Description: A number of meetings will be held in August/September 2016 to identify which forms of communication will work best to raise awareness about *Parthenium* weed and the benefits of biocontrol. This will result in the development and dissemination of awareness material in late 2016 and throughout 2017.

Expected outcomes: Improved knowledge sharing, awareness and education on biocontrol of *Parthenium*, through increased capacity of stakeholders in Kenya, Uganda and Tanzania

Graduate and undergraduate students sponsored by the project

1. Belaynesh Assema Belete; Gender: female; nationality: Ethiopian; discipline: gender studies; University: Haramaya University/Ethiopia, degree: M.S. start date: July 2016; completion date; June 2018; %funding: $5,000; advisor(s): Dereje Kifle, Maria Elisa Christie (Co-advisor), Lisanework Nigatu (Co-advisor); thesis title: Gauging women's interest and ability to participate in the adoption of bio-control agents for control of parthenium infestation in Tullo district, west Hararghe zone, Oromia Regional State, Ethiopia.

2. Tinsae Eshetu; Gender: female; nationality: Ethiopian; discipline: weed science; University: Ambo University/Ethiopia; degree: M.S.; start date: July 2016; completion date: June 2018; %funding; $5,000; Advisor(s): Lisanework Nigatu and Tesfay Amare; thesis title: Influence of soil type and moisture level on the survival, reproduction and effectiveness of the leaf-feeding beetle, *Zygogramma bicolorata against Parthenium hysterophorus.*

3. Gizachew Girma; Gender: male; nationality: Ethiopian; discipline: weed science; University: Ambo University/Ethiopia; degree: M.S.; start date: July 2016; completion date: June 2018; %funding; $5,000; Advisor(s): Lisanework Nigatu and Tesfay Amare; thesis title: Establishment, initial impact and persistence of *Zygogramma bicolorata* in *Parthenium* infested fields in central Ethiopia.

4. Leticia J. Musese, MSc – Sokoine University of Agriculture, Tanzania - Impact of *Parthenium* weed on rangelands – research will commence in late 2016

5. Joyce Christopher, MSc - Sokoine University of Agriculture, Tanzania - Monitoring of establishment, efficacy and host specificity of *Z. bicolorata* in the field - research will commence in late 2016

6. Hamis Wambura, MSc – Sokoine University of Agriculture, Tanzania - Impact of *Parthenium* weed on crop production – research will commence in late 2016

7. TBD, MSc – University of Nairobi, Kenya – Impact of *Parthenium* weed on rangelands – research will commence in late 2016

8. TBD, MSc – University of Nairobi, Kenya – Impact of *Parthenium* weed on crop production (the crop species evaluated is still TBD)– research will commence in late 2016

9. TBD, MSc – University of Makerere, Uganda – Impact of *Parthenium* weed on rangelands – research will commence in late 2016

Short term training planned

- Workshop will be held on mass-rearing of the leaf-feeding beetle *Zygogramma bicolorata* and the stem-boring weevil *Listronotus setosipennis*; location: Guder, Ethiopia; date; December 2016; type: hands-on demonstration of rearing techniques; number: 20; 12 males and 8 females.
- Workshops in Kenya, Tanzania and Uganda in early 2017 to raise awareness of the threats of *Parthenium* weed and the benefits of biological control. Workshops will be held in Arusha, Entebbe and Nairobi.

Publications planned

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

- A publication on the distribution and impact of *Parthenium* and other weeds in the Serengeti/Masai-Mara ecosystem will be submitted for publication in July 2016
- A publication on the socio-economic impacts of *Parthenium* weed in and around Arusha, Tanzania will be submitted for publication later in 2016
- A publication on the economic impacts of *Parthenium* weed in East Africa will be submitted for publication later in 2016

Book chapter: none
Poster: Challenges in rearing the leaf-feeding beetle *Zygogramma bicolorata* for mass-rearing.

- Posters and other awareness material will be developed and disseminated in late 2016

Conference Abstracts: Challenges in rearing the leaf-feeding beetle *Zygogramma bicolorata* for mass-rearing
Technical bulletin: None
Extension bulletin: Relationship between weed density and agent population

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

PI: Abhijin Adiga
Co-PIs: Madhav Marathe, Stephen Eubank, Achla Marathe
Collaborating Institutions:
French National Institute for Agricultural Research (INRA), France
Indian Institute of Horticultural Research (IIHR), India
Agroécologie et Intensification Durable des cultures Annuelles (CIRAD), Biopass, Senegal

Objective 1: Construction and analysis of the international commodity flow networks

Activity 1: Data collection and curation
PIs: Abhijin Adiga and others from VT
Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA
Status: Continuing
Description: This activity will lead to identifying, collecting and managing datasets that can be used to accurately model international commodity flow. It is critical to understanding the mechanism of trade, and in turn the most vulnerable countries in the context of *Tuta absoluta*. Data from FAOSTAT has already been collected. We aim to collect data on climate and modes of transport of commodities in this phase. We are exploring datasets and methodologies (example [Bacon et al. Gaps in Border Controls Are Related to Quarantine Alien Insect Invasions in Europe, 2012]) that can be used to estimate the quality of border interception in different countries. Our focus is on tomato and other major solanaceae crops that can host *T. absoluta*. Primary software: Python and SQLite.
Expected outcomes: Various country level datasets pertaining to trade will be identified and collected. Currently, we are focusing on open-source datasets for this work. The datasets collected from different sources will be stored in a standardized manner. For data sources that are public, links will be provided on the project webpage.
Activity 2: Network construction
PIs: Abhijin Adiga and others from VT
Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA
Status: Continuing
Description: Networks representing the commodity flow are being constructed. Each identified dataset will augment the networks leading to a more accurate representation of dynamics. This requires identifying inconsistencies in the data, cleaning up, and standardizing the notation across datasets. All the derived datasets (such as networks) will be consistent in notation. Primary software: Python.
Expected outcomes: Networks based on FAOSTAT have already been constructed for different vegetable crops, for different years. In this phase, more datasets will be used to augment these networks.
Activity 3: Network analysis

PIs: Abhijin Adiga and others from VT
Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA
Status: continuing
Description: Commodity flow networks are being analyzed from structural as well as dynamical perspectives. We are computing metrics such as in-degree, out-degree, betweenness-centrality, etc. to identify interesting patterns and assess the vulnerability of different countries. On the dynamics side, we are setting up epidemiology-style experiments (SEIR models). Coupled with data on the timeline of *T. absoluta* infestation, it will provide valuable information for calibration and causality studies. The analysis will be primarily focused on countries yet to be invaded by *T. absoluta*. However, the entire global trade will be studied to gain insights into the dynamics. Primary software: Python, Netlogo.
Expected outcomes: Results will be documented and submitted to an appropriate venue for possible publication.

Objective 2: Economic impact of *T. absoluta* infestation in Nepal and Bangladesh

Activity 1: Data collection and curation
PIs: Achla Marathe and others from VT
Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA
Status: Continuing
Description: *T. absoluta* was recently discovered in Nepal and Bangladesh. There is an urgent need to perform an economic impact analysis for these nations in the context of its invasion. Data being collected in this regard or as follows:

- Spatial-temporal spread of the pest
- Spatial distribution of tomato production
- Temperature (regions of interest 15◦C - 29◦C)
- Altitude (susceptible up until 1500m above sea level)
- Cost of insecticides, pheromones; amount needed per hectare: Supply, demand,
- Price elasticity, export, import

Datasets are being identified and collected. For more information, we will be contacting the USAID missions in these countries.

Expected outcomes: All available datasets will be collected and curated. For data sources that are public, links will be provided on the project webpage.
Activity 2: Economic impact modeling
PIs: Achla Marathe and others from VT
Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA
Status: Continuing
Description: The following will be calculated:

- Base yield per hectare (uncontrolled pest invasion).

- Direct loss due to cost of intervention (spraying, trapping etc.), and expected yield loss based on different exposure probabilities and different intervention/treatment/management options.
- Indirect loss: Change in consumer surplus, producer surplus and social welfare.

Expected outcomes: The results will be presented/published in appropriate venues.

Objective 3: Studying the potential dynamics of T. absoluta in North America

Activity 1: Data collection and curation
PIs: Abhijin Adiga and others from VT
Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA
Status: New
Description: The possible invasion of *T. absoluta* is a major concern for US and in general, North America. This study will focus on (1) identifying the pathways of entry, and (2) the dynamics of spread under various hypothetical scenarios. To this end, the following datasets are being collected/explored for North America:

- Climate and host/pest biological parameters
- Tomato production at county/state level
- Internal commodity flow
- Greenhouse production: locations and logistics

The host/pest biological data will be gathered using collaborators' existing data and lab & field experiments. These datasets will be used to construct pest risk maps, networks and model commodity flow, which in turn will be used to study the above-mentioned two points.

Expected outcomes: All available datasets will be collected and curated. For data sources that are public, links will be provided on the project webpage.
Activity 2: Model design
PIs: Abhijin Adiga and others from VT
Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA
Status: New
Description: The various data collected will be analyzed individually and in combination. We will survey existing methodologies on (1) modeling invasive species, (2) data integration, and (3) network science. A strategy will be chalked out to integrate various sources and define the modeling framework. We will leverage NDSSL's expertise and experience from other projects for the design.
Expected outcomes: The methodology, model and prescription will be documented in a report. Derived datasets will be made available through the project website. It will be published/presented in an appropriate venue in the next phase.

Objective 4: Construction and analysis of national/regional commodity flow networks

Activity 1: Data collection and curation
PIs: Abhijin Adiga and collaborators
Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA
Status: New
Description: To study the dynamics of *T. absoluta* spread in different regions, it is important to model the mechanism of tomato production and distribution within these regions. Unlike constructing country-level networks, these are hard to realize due to several reasons:

- data is not readily available
- country specific market dynamics require local knowledge
- need for modeling the network using various census/survey data

We will collect data on (1) major vegetable markets in countries of interest in Africa and Asia, (2) movement of fresh commodities between markets, and (3) the dependence of commodity flow on seasons and commodity price. In the current phase, tasks have been assigned to collaborators to explore required data in their respective regions. Also, we will contact USAID missions, value-chain projects, and ministries of focus countries to obtain required data.
Expected outcomes: Above data for target countries will be collected. Strategies for addressing gaps in data will be formulated.
Activity 2: Model design
PIs: Abhijin Adiga and collaborators
Site/Location: NDSSL, Biocomplexity Institute of Virginia Tech, Blacksburg, VA
Status: New
Description: This will overlap with Objective 3, Activity 2. The challenge here is to infer the networks and other model parameters under possible data gaps.
Expected outcomes: The methodology, model and prescription will be documented in a report. Derived datasets will be made available through the project website. It will be published/presented in an appropriate venue in the next phase.

Objective 5: Groundnut leafminer: collection of samples from various parts of Africa and Australia

Activity 1: Sample collection and analysis
PIs: Abhijin Adiga
Site/Location: None
Status: New
Description: This activity has two objectives:

- determine whether *A. Modicella* and *A. Simplexella* are the same species
- collect data on groundnut leafminer distribution in Africa

Larvae will be collected from groundnut and soybean fields in Uganda, Kenya, Tanzania, Malawi, Zambia, Mozambique, South Africa, and Australia. We will consider phylogenetic and anatomy-based methods to compare the samples.

Expected outcomes: Samples from above-mentioned regions will be collected and analyzed. Results will be presented/published.

Objective 6: 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: New
Description: In collaboration with another research project on *T. absoluta* (JEAI IBAO), we will genotype *T. absoluta* samples (using microsatellites and existing database, see Guillemaud et al., 2015) from North and West African countries.
Expected outcomes: Routes of introduction of the invasive pest and possible genetic structure in West Africa.
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.
Activity 3: Distribution and carrying capacity of host plants
PIs: (Serigne Sylla)
Site/Location: (Senegal)
Status: Continuing
Description: Prospection *of T. absoluta* in various agricultural and semi natural landscapes. The main host of *T. absoluta* is tomato, but other species of Solanaceae crops such as potato, fresh eggplant, pepper and chili are concerned. Greenhouse experiments (mesocosm) with tomato plants and other host plants identified in Senegal (including wild host plants) are carried out to evaluate the effect of host plants on the population parameters of *T. absoluta*. We test the oviposition preference (choice and no choice situations) of adults and the ability of larvae to develop on different host plants (carrying capacity). Another field study is conducted during the rainy season to explain observed decrease of populations at that time. The objective of the study is to identify factors that may explain the reduction of its population during the rainy season (climate, resources, natural enemies, etc.).

Expected outcomes: Host range of *T. absoluta* and larval performance on major host plants.
Activity 4: Impact of crop management and landscape context
PIs: (Thierry Brévault)
Site/Location: (Senegal)
Status: Continuing
Description: Monitoring of a network of 25 focal tomato fields in a highly-infested area (Niayes) on 3 crop cycles (2015-2017 seasons) to assess the effect of crop management (particularly insecticide use) and landscape context on *T. absoluta* abundance and biocontrol. Landscape composition and configuration is mapped using GIS.
Expected outcomes: Field data will be collected and analyzed.
Activity 5: Impact of natural enemies
PIs: (Serigne Sylla)
Site/Location: (Senegal)
Status: Continuing
Description: Dead larvae, parasitoids and predators collected in Activity 4 will be conserved (in vials containing ethanol 96 °) for further morphological and molecular identification (barcoding at UMR CBGP). If possible, the gut content of potential predators will be checked by NGS (next generation sequencing).
Expected outcomes: This activity will give reliable diagnostic tools for the identification of *T. absoluta* and its natural enemies, and will allow detection of new biological control agents and potential non-target effects of the release of biological control agents.

Objective 7: Identifying affected states in India, determining the source, mode, speed of spread Identifying the host range, severity

Activity 1: Identifying affected states in India
PIs: R. Asokan, V. Sridhar, Y. G. Prasad
Site/Location: IIHR
Status: New
Description: Identification is carried out based on pheromone trap catches in different temporal intervals and correlating with both biotic (natural enemies such as parasitoids, predators, insect pathogens) and abiotic factors. The same will be carried mainly in extensive tomato growing areas in different states. Two kinds of pheromone traps will be used: (i.) water trap; (ii.) Sticky trap. Efforts also will be made on other crops such as eggplant and potato growing areas adjoining tomato fields.

Expected outcomes: Data will be collected from different states. A map of *T. absoluta* distribution in India will be developed. The data will be used to construct ecological models and assess possible pathways of spread within India. Also, it will be used to assess possibility of *T. absoluta* invasion to neighboring countries and those that trade with India.
Activity 2: Determining the source, mode, speed of spread
PIs: R. Asokan, V. Sridhar, Y. G. Prasad, S. Venugopalan
Site/Location: IIHR

Status: new
Description: Collection of primary data from the Ports and also from the major whole sale markets for tomato and other Solanaceous vegetables. Also secondary data will be collected from NHB, APEDA, NHM etc.
Expected outcomes: Data will be collected, curated and stored in a DBMS.

Objective 8: Statistical modeling of spread

Activity 1: Lifecycle parameters of *T. absoluta* in India
PIs: V. Sridhar
Site/Location: IIHR
Status: continuing
Description: Determination of various life cycle parameters such as egg period, larval period, pupal period, adult longevity, total life cycle, construction of life tables, food consumption and digestion.
Expected outcomes: Data will be collected and used for statistical modeling (activity 2).
Activity 2: Statistical modelling
PIs: S. Venugopalan
Site/Location: IIHR
Status: new
Description: Various statistical techniques like linear and non-linear models will be tested for their suitability to understand the spread.
Expected outcomes: Modeling framework and outcomes will be documented for possible publication.
Activity 3: IR signatures
PIs: Y G Prasad
Site/Location: ATARI
Status: new
Description and expected outcomes: IR signatures will be identified specifically for *T. absoluta* in order to develop decision-making models.
Activity 3: Economic analysis
PIs: S. Venugopalan and Achla Marathe
Site/Location: IIHR and VT
Status: new
Description: Economic analysis of the yield loss will be carried out primarily for tomato based cropping system.

Expected outcomes: Data will be collected, analyzed and documented for possible publication.

Objective 9: Physiologically-based Demographic Models for *T. absoluta*

Activity 1: Data collection
PIs: Nicolas Desneux

Site/Location: INRA
Status: continuing
Description: We are characterizing key ecological parameters in order to design a PBDM model for *T. absoluta*. In particular, the following studies will be undertaken: Nutrition effects on developmental time, temperature effects on fecundity, thermal thresholds for juvenile development, and temperature and photoperiod diapause induction.

Expected outcomes: Data will be collected and documented. The data will be used to develop PBDM model for *T. absoluta*, which will help in (i) modeling the spread (as a substitute for CLIMEX based models), and (ii) inform decisions on interventions such as crop management, application of insecticides, etc.

Graduate and undergraduate students sponsored by the project

- Bryan Kaperick, male, US, Computer Science, US, BS, Aug. 2016, 100%, Abhijin Adiga,-, Virginia Tech.
- Sichao Wu, male, US, Computer Science, US, PhD, Aug. 2016, April 2017, 50%, Abhijin Adiga, undecided, Virginia Tech.
- To identify, Senegalese, Ecology, Dakar/Senegal, PhD, Dec-16, Dec-18, 100% funding, advisors Anaïs Chailleux and Thierry Brévault, Effect of landscape structure on crop colonization and biocontrol of Tuta absoluta populations, Université Cheikh Anta Diop de Dakar
- Serigne Sylla, Senegalese, entomology, Dakar/Senegal, PhD, feb-14, feb-17, 20% funding, advisors Nicolas Desneux and Thierry Brévault, Invasion of the tomato leafminer Tuta absoluta in Senegal: spatial dynamics, ecological niche and potential for biocontrol, Université Cheikh Anta Diop de Dakar
- Oumar Seydi, Senegalese, entomology, Dakar/Senegal, Master, 04/15/16, 10/15/16, 100% funding, advisors Serigne Sylla and Thierry Brévault, thesis title: Population dynamics of the tomato leafminer Tuta absoluta in relation to host plant availability during the rainy season, Université Cheikh Anta Diop de Dakar
- Mame Diarra Bousso, Senegalese, entomology, Dakar/Senegal, Master, 06/01/16, 12/01/16, 10% funding, advisors Anaïs Chailleux and Thierry Brévault, thesis title: Effect of temperature on the population dynamics of the tomato leafminer Tuta absoluta, Université Cheikh Anta Diop de Dakar
- TBD, France, Postdoc.
- Name, gender, nationality, discipline, site/country, degree, start date, completion date, %funding, advisor(s), thesis title, university

Short term training planned

TBD/India/date/type/number (male/female)

Publications planned

Theses: 2

Article:

Srinivasan Venkatramanan, Abhijin Adiga, Achla Marathe, Stephen Eubank, Madhav Marathe. Construction and analysis of international commodity flow networks: A study of tomato trade in the context of the South American tomato leafminer. In preparation.

Diatte M, Brévault T, Sylla S, Tendeng E, Sall-Sy D, Diarra K. New insect pest assemblage threatens field-grown tomato production in Senegal. Submitted to Entomologia Generalis.

Sylla S, Brévault T, Streito JC, Diarra K. First record of Nesidiocoris tenuis (Reuter) (Heteroptera: Miridae) as potential predator of the tomato leafminer, Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae), in Senegal. Submitted to African Entomology.

Sylla S, Brévault T, Diarra K, Bearez P, Desneux N. Life history traits of *Macrolophus pygmaeus* when feeding on various prey foods. Submitted to PLoSONE.

Sylla S, Brévault T, Bal AB, Chailleux A, Diatte M, Desneux N. Rapid spread of the tomato leafminer, Tuta absoluta (Lepidoptera, Gelechiidae), an invasive pest in sub-Saharan Africa. Submitted to PLoSONE.

Campos MS, Biondi A, Adiga A, Guedes RNC, Desneux N (2016). From the Western Paleartic Region to Beyond: Tuta absoluta, ten years after its Europe invasion. Journal of Pest Science, Invited.

Conference Abstracts

Four abstracts for possible publication

Technical bulletin

Two bulletins planned

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

PI: Nir Krakauer (City University of New York, USA)
Co-PIs: Tarendra Lakhankar (CUNY, USA); José Anadón (CUNY, USA); David Lohman (CUNY, USA); Ajay Jha (USA); Pramod Jha (Tribhuvan University, Nepal); Anjana Devkota (TU, Nepal); Bharat Shrestha (TU, Nepal); Sanjay Jha (TU, Nepal); Sundar Tiwari (Agriculture and Forestry University, Nepal); Minraj Pokhrel (AFU, Nepal); Naba Devkota (AFU, Nepal); Mohan Sharma (AFU, Nepal); Madan Shreshtha (Nepal Academy of Science and Technology, Nepal); Basanta Bhat (ECOSCENTRE, Nepal).
Collaborating Institutions: CUNY, IGATT, TU, AFU, ECOSCENTRE

Objective 1: Biodiversity-climate-IPM scholarship and research capacity development through fieldwork, data analysis, and interaction with Nepal and regional scholarly communities

Activity 1: Surveys and analysis of distribution of key species and climate and other drivers
PIs: Krakauer, Anadón, Lohman, TU/AFU faculty
Site/Location: Nepal (various locations in CHAL representing a range of elevations where the target species occur – 7 core field sites have been identified in Chitwan, Kapilvastu, Kaski, Syangja, Nawalparasi districts, and transects and surveys appropriate to the species type and distribution will also take place around and upward from the core areas)
Status: Continuing
Description: Research on biodiversity distribution and trends as related to climate. Emphasis on invasives and pest species and on livelihood and health concerns.

Currently planned focus species/groups:

Insects affecting maize and fall/winter vegetable cultivars: field observation and questioning, districts to be determined

Finger millet and buckwheat: Observations and interviews to determine village-level cropping patterns in Nawalparasi, Chitwan, Syangja districts combined with district-level secondary data from throughout CHAL

Invasive plants:

Lantana camara: sampling and transects in Kaski district

Water hyacinth: sampling and interviews around water bodies in Chitwan and Kaski; experimental work on use in compost

Parthenium hysterophorus: plant and soil samples along transects in Gorkha, Kaski, Palpa, Birgunj, Makwanpur districts

Ageratina adenophora: sampling along transects in Kaski, Makwanpur, Rasuwa

Chromolaena odorata: Sampling along transects in Kaski, Palpa, Makwanpur, Rasuwa.

Vultures: Record presence and activities via transect walks to 3.5 km elevation in Nawalparasi, Palpa, Kaski, Manang districts

Expected outcomes: Peer-reviewed publications and conference presentations; open data sets.
Activity 2: Convene Biodiversity and Climate International Conference in Nepal and participate in Technology for Climate-Smart Agriculture International Conference in India
PIs: P Jha, Krakauer, Lakhankar
Site/Location: Kathmandu and Nanded, India
Status: Continuing (planning for conferences began in Year 1)
Description: Hold January 2017 Conference on Biodiversity, Climate Change, and Impacts on Livelihood (icbcl17.org). Share science and development advances from across South Asia and beyond with researchers and stakeholders. Also participate in synergistic International Conference on Technological Advances in Climate-Smart Agriculture and Sustainability (tacsas.org) in India to strengthen regional partnerships and perspectives. Participation in these conferences will train our researcher partners in Nepal in taking part in global research networks as well as providing opportunities to forge governmental and private-sector partnerships to strengthen and scale up our rural capacity building and Women's Enterprise Program work.
Expected outcomes: Students trained in giving presentations and participating in the international science community. New collaborations launched and priorities identified. Journal special issues for research results.
Activity 3: Student training and mentorship
PIs: Krakauer, Lakhankar, P Jha, Devkota
Site/Location: Nepal (various locations in CHAL)
Status: Continuing
Description: Workshops on research tools and skills such as GIS, R, and species distribution modeling. One-on-one mentorship of student trainees for guiding specific research programs.
Expected outcomes: Mentoring of students on research processes and methods; strengthen ecology, agronomy, climate research communities in Nepal.

Objective 2: Appropriate climate adaptive IPM technology transfer and rural livelihood capacity building

Activity 1: Needs assessment and training for ecological enterprises
PIs: Ranbahat, Krakauer, Sharma, A Jha
Site/Location: Nepal (various locations in CHAL, primarily the 7 core field sites in Chitwan, Kapilvastu, Kaski, Syangja, Nawalparasi districts)
Status: Continuing
Description: Analyze survey results (community survey conducted in Year 1 around the core field sites to understand cropping patterns and management, perception of role of and trends in biodiversity and

climate, and economic limitations and opportunities) and work with community groups to identify needs for livelihood/enterprise training.
Expected outcomes: IPM and climate adaptive technology transfer and adoption, community groups with strengthened capacity to fund and provide logistics for improved ecologically sound and agriculture enterprises with stronger farm-to-market value chain, links with government and private-sector programs and resources (e.g. agriculture and livestock extension services, Agricare), enterprises created.
Activity 2: Demonstrate IPM strategies and provide training for sustainable agriculture and enterprise development
PIs: Devkota, A Jha, Ranbahat, Sunder Tiwari, B.S. Bhat
Site/Location: Nepal (various locations in CHAL, primarily the 7 core field sites)
Status: Continuing
Description: Demonstrations, trials, and monitoring of IPM and ecologically informed agricultural production strategies based on biodiversity conservation. Expected topics for demonstration and training include integrated pest management in grain and vegetable crops. The specific combination of training and demonstration to be offered at each site will depend on local needs as assessed through the community survey and ongoing consultation with the beneficiaries. Local-language educational materials such as phone apps, videos, newspaper articles, radio programs will be developed and published by the Nepal partners.
Expected outcomes: Adoption of ecological/IPM approaches in project area. Upscaling the most successful strategies to create opportunities for women through technical support for planning and establishing innovative rural businesses.

Graduate and undergraduate students sponsored by the project

- Dol Raj Luitel, M, Nepalese, Nepal, PhD, 2016, 2019, 100% funding, Mohan Siwakoti, *Impact of Climate Change on Finger millet in and altitudinal gradients of Chitwan-Annapurna transient landscape in central Nepal*, Tribhuvan University
- Seerjana Maharjan, F, Nepalese, Nepal, PhD, 2016, 2019, 100% funding, Anjana Devkota, *Ecology and management of Parthenium hysterophorus through biological methods in Central Nepal*, Tribhuvan University
- Anju Sharma, F, Nepalese, Nepal, PhD, 2016, 2019, 100% funding, Bharat Babu Shrestha, *Management of an invasive species Ageratina adenophora through restoration of native vegetation in Chitwan and Annapurna Landscape*, Tribhuvan University
- Pristi Dangol, F, Nepalese, Nepal, MSc, 2016, 2018, 100% funding, Bharat Babu Shrestha, *Change in Life History Traits of Invasive Weed, Lantana camara L. along the Elevation Gradient, Central Nepal*, Tribhuvan University
- Sanjeeb Bhandari, M, Nepalese, Nepal, MSc, 2016, 2018, 100% funding, Mohan Siwakoti, *Management issue and strategy on ruminant cattle and fodder production in water stressed for people's income and environmental quality*, Tribhuvan University

- Bidya Maya Shrestha, F, Nepalese, Nepal, MSc, 2016, 2018, 100% funding, Promod kumar Jha, *Impact of climate change on biodiversity utilization by small holder famer and gender issues*, Tribhuvan University
- Vishubha Thapa, F, Nepalese, Nepal, MSc, 2016, 2018, 100% funding, Kumar Sapkota, *Food access and threats to vultures in CHAL (Chitwan-Annapurna Landscape) in Nepal*, Tribhuvan University
- Ganga Shah, M, Nepalese, Nepal, MSc, 2016, 2018, 100% funding, Nanda Bahadur Singh, *Distribution of vulture species and its nesting site from low land to high land*, Tribhuvan University
- Sagar Khadka, M, Nepalese, Nepal, MSc, 2016, 2018, 100% funding, Sanjay Kumar Jha, *Management of Water Hyacinth in CHAL Area,* Tribhuvan University
- Bievakananda Mahat, M, Nepalese, Nepal, MSc, 2016, 2018, 100% funding, TBA, *Assessing Hygienic Behavior of Native Honey Bee Species in Terai, Mid-hills and High Hills of Nepal for Healthy Colony,* Agriculture and Forestry University
- Madhu Sudhan Ghimire, M, Nepalese, Nepal, MSc, 2016, 2018, 100% funding, Sundar Man Shrestha, *Integrated Management of Stemphylium Blight Disease of Lentil,* Agriculture and Forestry University
- Ramesh Upreti, M, Nepalese, Nepal, MSc, 2016, 2018, 100% funding, TBA, *Fruit thinning and defoliation effects on the quality and yield of Papaya var. Red Lady,* Agriculture and Forestry University
- Hom Nath Giri, M, Nepalese, Nepal, PhD, 2016, 2019, 100% funding, Moha Dutta Sharma, *Performances of late season cauliflower under different agronomical and IPM practices in CHAL areas,* Agriculture and Forestry University
- Ghanashyam Bhandari, M, Nepalese, Nepal, PhD, 2016, 2019, 100% funding, Resham Bahadur Thapa, *Climate change effect assessment on insect diversity and development of IPM technologies for maize based farming in Nepal,* Agriculture and Forestry University
- Sarita Sapkota, F, Nepalese, Nepal, MSc, 2016, 2018, 100% funding, Rajendra Regmi, *Assessment of biodiversity of dung beetle and estimate their ecological role in CHAL area,* Agriculture and Forestry University
- Pratiksha Sharma, F, Nepalese, Nepal, MSc, 2016, 2018, 100% funding, TBA, *Perception and adoption strategies of climate change in agriculture sector among Chepang community in Chitwan, Dhading and Gorkha districts of Nepal,* Agriculture and Forestry University
- Yashoda Panthy, F, Nepalese, Nepal, MSc, 2016, 2018, 100% funding, TBA, *An assessment on the impacts of climate change on cropping system and biodiversity in Chitwan District of Nepal,* Agriculture and Forestry University
- Aishwarya Bhattacharjee, F, Indian, U.S.A., PhD, 2015, 2019, 25% funding, Jose Anadon, *Vulture ecological services and connservation in the context of climate change,* City University of New York
- Tenzing Doleck, F, Nepalese, U.S.A., PhD, 2014, 2018, 25% funding, David Lohman, *Change in trophic networks involving pollinator clades along altitudinal gradients in the Himalayas,* City University of New York

- Behzah Asadieh, M, U.S.A., PhD, 2012, 2017, 20% funding, Nir Krakauer, *Precipitation and water resource pattern change projections with implications for ecology and agriculture,* City University of New York

Short term training planned

1-day farmer and local stakeholder trainings (typically 50 participants per venue – 50% average male/female participation goal)

SN	Training title	Date	Venue	Resource person	Remark
1	Climate change mitigation and adaptation measures	Feb 2017	Chyangchyangdi, Syangja	Dr. Anjana Devkota/ R A Mandal	
2	Invasive alien plant species impacts and management	August 2017	Gaidakot and Puranchaur (Pokhara)	Dr. Bharat B. Shrestha	Public education materials will be prepared
3	Biodiversity conservation and role of IPM	Distributed through year (5 trainings)	5 project districts	Devkota, Ranabhat, Sharma, Mr. Praseed Thapa, A Jha, Krakauer	Specific topics will vary based on needs assessment and consultation with community partners
4	Insect and plant disease management using IPM practices	same	same	same	
5	Enterprise creation / management / value chain	same	same	same	Strengthen cooperatives and women's groups and promote market opportunities such as organic farming
6	District level awareness program, coordinating with women's groups / co-operatives and extension	June 2017	5 project districts (250 participants per venue)	Devkota, Ranabhat, Sharma, Thapa	

Student and researcher trainings (typically 15-20 participants expected for each – 33% minimum female participation goal)

SN	Activities	Date	Location	Remarks
1	Experimental design and data analysis I	Nov 2016	CDB, TU	
2	Student training on current state of knowledge on respective topics	December 2016	CDB, TU	Each student will select topic from their research area
3	International conference	Jan 2017	Kathmandu	joint activity of all partner institutions
4	Training on species distribution modeling (Basic)	Jan 2017	CDB, TU	facilitated by CUNY team
5	Experimental design and data analysis II	March 2017	CDB, TU	
6	Progress review seminar I	April 2017	CDB, TU	
7	Training on species distribution modeling in relation to climate change	May 2017	CDB, TU	facilitated by CUNY graduate students
8	Progress review seminar II	September 2017	CDB, TU	
9	Research data collection and sampling techniques	December 2016	AFU	
10	Data analysis and scientific writing	March 2017	AFU	
11	Applied research concepts and grant writing	Spring/Summer 2017	AFU/TU	A Jha/Krakauer

Publications planned

Thesis
-
Article
2
Book chapter
-
Poster
10
Conference Abstracts

10
Technical bulletin
-
Extension bulletin
-
Other
2 edited journal special issues on regional development, ecology, and climate topics (primarily papers from conferences)

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: Dr. Le Quoc Dien (SOFRI); Dr. Le Xuan Vi (PPRI), Dr. Nguyen Duy Hung (FARVI); Dr. Ngo Thi ThanhTruc (CTU); Dr. Quyen Dinh Ha (VNUA); Ms. Phan Thi Thu Hien (PPD), Mr. Mai Van Tri (SOFRI), Naidu Rayapati (Washington State Univ.), and Maria Elisa Christie (VT).

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); CAB International (CABI); Virginia Tech (VT); University of Florida's Institute of Food and Agricultural Sciences (UF-IFAS); Washington State University (WSU).

Objective 1: Adapt and implement IPM packages for dragon fruit, mango, longan and lychee, out-scaling and up-scaling of successful locally developed IPM tactics in multi-locations

Activity 1: IPM for Dragon Fruit (DF)

PIs: Mr. Nguyen Thanh Hieu, Ms. Dang Thi Kim Uyen, Ms. Dang Thuy Linh, Ms. Nguyen Ngoc Anh Thu, Mr. Nguyen Huy Cuong, Mr. Mai Van Tri, Dr. Le Quoc Dien and Dr. Nguyen Van Hoa.

Status: Continuing

Time: October 2016 – September 2017

Description: Tien Giang, Long An (in the Mekong river delta region), and Binh Thuan (in the South East) are major producing provinces of DF in the country. DF is grown for both domestic market and exportation. Pests are one of major factors limiting production of DF in these areas.

IPM strategies are used continuously on the chosen Dragon fruit farms. Disease/pest incidence, damages, pesticide residues on fruits, beneficial organism population, productivity and quality of fruits will be recorded every 3 or 6 months depend on the characteristics. IPM package application in DF farms will be conducted by SOFRI.

- **Site/Location**: SOFRI is responsible for IPM application for dragon fruit (in Tien Giang, Long An and Binh Thuan provinces). 3 models (0.5 ha/model (0.25 ha treatment, 0.25 ha control) x 1 model/province)

- **Key pests**: Canker (*Neoscytalidium dimidiatum*), Anthracnose(*Colletotrichum gloeosporiodes*), Bacteria soft rot(*Erwinia chrysanthemi*), Fruit flies (*Bactrocera dorsalis* and *B. correcta*), mealy bug (*Pseudococcus neobrevipes* and *P. jackbeardsleyi*), and ants.

- **IPM package**: Cultural measures (Pruning infected branches, canopy management, sanitation, irrigation management, fruits bagging, application of enough inorganic fertilizer, composted organic manures with *Trichoderma* sp., and others); Physical measures (Using light traps, sticky

trap, fruit bagging, pressure washing, etc.); Biological measures (Using SOFRI-Protein (protein bait) and entomopathogenic nematodes for controlling fruit fly and pheromone traps for monitoring the fruit fly population; Using *Metarhizum* spp., *Paecilomyces* sp. for controlling mealybugs; SOFRI-Trukien (ant bait) for controlling ant; Using plant extractsfor controlling canker and anthracnose); Chemical measures (Substituting chemical pesticides for soft and permitted ones (complying with the U.S. markets), 'four rights, in using pesticides (right pesticide, right dose, right time, and right application).

Expected outcomes: Validation of pragmatic IPM packages for dragon fruit (Reducing volumes of *pesticides* applied, reduce number of pesticide sprays, replace less toxic pesticide of IPM models, reducing your impact on the environment).

Activity 2: IPM Package for Longan

PIs: Dr. Nguyen Van Hoa, Ms. Tran Thi My Hanh, Mr. Nguyen Huy Cuong, Mr. Mai Van Tri, Ms. Dang Thi Kim Uyen, Mr. Huynh Thanh Loc and Dr. Le Quoc Dien (in the South) and Dr. Le Xuan Vi and his colleagues (in the North)

Status: Continuing

Time: Oct. 2016 – Sept. 2017

Description: Longan production is also threatened by pests and diseases. Among these, Longan Witches' broom disease (LWB) associated with Eriophyid mite (*Eriophyes dimocarpi*) has recently become a big problem for longan production in terms of productivity reduction and wide epidemic. Fruit borer (*Conogothes punctiferalis*) and mealy bug also are limiting factors for longan production. Furthermore, fruit rot disease has risen to be a big problem for longan pre-harvest.

IPM strategies are used continuously on the chosen longan farms. Disease/pest incidence, damages, pesticide residues on fruits, beneficial organism population, productivity and quality of fruit… will be recorded every 3 or 6 months depend on the characteristics. IPM package application in longan farms will be conducted by SOFRI and PPRI.

- **Site/Location**: **SOFRI** responsible for IPM application for longan in Tien Giang, Vinh Long and Ba Ria-Vung Tau provinces and **PPRI** responsible for IPM application for longan in Hung Yen province. 4 models (0.5-1 ha/model (0.25-0.5 ha treatment, 0.25-0.5 ha control) x 1 model/province)

- Key pests: Longan Witches' broom disease(LWB), Fruit rot, Eriophyid mite (*Eriophyes dimocarpi*), Fruit borer (*Conogethes punctiferalis, Conopomorpha sinensis*), and mealy bug.

- IPM package: Cultural practices (Pruning infected branches, canopy management, sanitation, apply right inorganic fertilizer, cutting grass (mite hosts), etc.; Physical measures (Using light traps, fruit bagging, etc.); Biological measures (Using *Metarhizum* spp. fungi, *Paecilomyces* sp. fungi for controlling mealybugs, Ant-bait (SOFRI-Trukien) for controlling ant, applying plant extract, *Trichoderma* sp. fungi for controlling fruit rot, etc.); Chemical measures (Substituting

chemicalpesticides for soft and permitted ones (complying with the U.S. markets), 'four rights in using pesticides (right pesticide, right dose, right time, and right application).

Expected outcomes: Validation of pragmatic IPM packages for longan (Reducing volumes of *pesticides* applied, reduce number of chemicals and applicating times, replace less toxic pesticide by using IPM models, reducing bad impact on the environmental conditions, health, etc)

Activity 3: IPM Package for Mango

PIs: Mr. Mai Van Tri, Ms. Dang Thi Kim Uyen, Ms. Nguyen Ngoc Anh Thu, Mr. Nguyen Huy Cuong, Mr. Huynh Thanh Loc, Dr. Le Quoc Dien and Dr. Nguyen Van Hoa.

Status: Continuing

Time: Oct. 2016 – Sept. 2017

Description: Mango is an important fruit crop in Dong Nai and Dong Thap provinces with the two common varieties, Cat Hoa Loc and Cat Chu. Losses caused by pests and diseases are one of major constraints on production. IPM strategies are applied continuously on the chosen mango farms. The pest incidence, pest damages, pesticide residues in soil and on fruits, beneficial organism population, productivity and quality of fruitwill be recorded. **SOFRI** responsible for these IPM models.

-**Site/Location**: Dong Thap and Dong Nai provinces. 2 models (0.5 ha/model (0.25 ha treatment, 0.25 ha control) x 1 model/province)

Key pests: Bacterial black spot (*Xanthomonas campestris* pv. *mangiferaeindicae*), Anthracnose (*Colletotrichum* spp.), Fruit fly (*Bactrocera dorsalis, B. correcta*), Fruit borer (*Deanolis albizonalis*), thrips (*Scirtothrips dorsalis*) and scales.

IPM package: Cultural measures (Pruning infected branches, canopy management, sanitation, apply right inorganic fertilizers, etc.); Physical measures (Using yellow, red or blue sticky traps, light traps, fruit bagging, controlling grasses, etc.); Biological measures (Using entomopathogenic fungi, plant extractsfor controlling thrips and scales; Using plant extract, *Trichoderma* sp., *Bacillus* sp. for controlling Bacterial black spot and Anthracnose, etc.); Chemical measures (Substituting chemical pesticides for soft and permitted ones (complying with to the U.S. markets), 'four rights in using pesticides'.

Expected outcomes: Validation of pragmatic IPM packages for mango (Reducing volumes of *pesticides* applied, reduce number of pesticide sprays, replace less toxic pesticide of IPM models, reducing impact on the environment)

Activity 4:

Title: IPM Package for Lychee

PIs: Dr. Le Xuan Vi (PPRI), Dr. Nguyen Duy Hung (FARVI) and others from two Instititions

Status: Continuing

Time: Oct. 2016 – Sept. 2017

Description: Lychee is the major fruit crop in Northern part of Viet Nam. Lychee fruit are consumed as fresh fruit, dried fruit and canned products. Common pests in this crop are shoot borer (*Conopomorpha sinensis)* and stink bug (*Tessaratoma papillosa)*. Shoot borer is a major lychee pest, which causes fruit drop, to protect fruits, chemicals are over used causing chemical residues on harvested fruits. In addition, downy mildew (*Peronophthora lichii*) and anthracnose (*Colletotrichum gloeosporioides*) are two major diseases that attack and cause the decrease of lychee yield and quality.

IPM strategies are applied continuously on the chosen lychee farms. Disease/pest incidence, damages, pesticide residues on fruits, beneficial organism population, productivity and quality of fruit will be recorded every 3 or 6 months depend on the characteristics. These IPM models were conducted by PPRI and FAVRI.

- **Site/Location**: **PPRI** responsible for IPM application for lychee crop in Hai Duong and **FAVRI** responsible for IPM application for lychee crop in Bac Giang province. 2 models (0.5-1 ha/model (0.25-0.5 ha treatment, 0.25-0.5 ha control) x 1 model/province)
- **pests**: Shoot borer (*Conopomorpha sinensis*), Stink bug (*Tessaratoma papillosa*), Powdery mildew (*Peronophthora lichii*) and Anthracnose (*Colletotrichum* spp.).
- **IPM package**: Cultural measures (Sanitation, pruning infected branches, canopy management, apply right inorganic fertilizers, grass cutting, etc.); Biological measures (Using *Trichogramma, Chelonus* sp. For controlling =shoot borer; Using *Beauveria, Metarhizium*, and *Ooencyrtus phongi* for controlling stink bug; Using plant extracts for control of powdery mildew and anthracnose, etc.); Chemical measures (Substituting chemical pesticides for soft and permitted ones (complying with to the U.S. markets), 'four rights, in using pesticides.

Expected outcomes: Validation of pragmatic IPM packages for lychee (Reducing volumes of *pesticides* applied, reduce number of pesticide sprays, replace less toxic pesticide of IPM models, reducing your impact on the environment).

Objective 2: 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: Identification of the causal agent of LWB and strategy for management

PIs: Mr. Mai Van Tri,Ms. Tran Thi My Hanh, Mr. Nguyen Huy Cuong and Dr. Le Quoc Dien, Dr. Naidu Rayapati.

Site/Location: SOFRI, Tien Giang and Vinh Long provinces

Status: Continuing

Time: Whole year, Jan.-Dec., 2017

Description: Identification of the causal agent of LWB and strategy for management. Analyzing the results of deep sequencing LWB samples for identification of the causal agent; Study role of *Eriophyes dimocarpi* toward LWB on longan; Define the LWB spreading method by grafting and study management of LWB and mite *Eriophyes dimocarpi* on longan.

Expected outcomes: Identifying LWB causal agent for developing an more effective management of LWB.

Activity 2: The diversity of pathogen on anthracnose diseases on dragon fruit and mango

PIs: Dr. Nguyen Van Hoa,Ms. Dang Thi Kim Uyen, Ms. Nguyen Ngoc Anh Thu, and Mr. Mai Van Tri

Site/Location: SOFRI,Dong Thap and Dong Nai provinces

Time: Oct. 3016 – Sept. 2017

Status: Continuing

Description: The diversity of pathogen on anthracnose diseases on dragon fruit and mango will be conducted. Isolates of *Colletotrichum* spp. from DF (in Tien Giang, Long An, Binh Thuan) and mango (in Dong Thap, Dong Nai will be collected (continued). Process (DNA/RNA extractions…, fungus isolation; Maintain the culture library of anthracnose agents. **Expected outcomes:** Determine of the diversity of pathogen on anthracnose diseases on dragon fruit and mango.

Activity 3: Develop the new biopesticide for controlling of fruit crops pests

PIs: Dr. Le Quoc Dien,Mr. Mai Van Tri, Ms. Tran Thi My Hanh, Ms. Dang Thi Kim Uyen, Mr. Huynh Thanh Loc, Mr. Nguyen Huy Cuong, Ms. Dang Thuy Linh, Ms. Nguyen Ngoc Anh Thu, Mr. Do Hong Tuan (SOFRI) and others from PPRI.

Site/Location: SOFRI, Tien Giang, Vinh Long, Dong Nai, Dong Thap, Long An, Binh Thuan,Ba Ria-Vung Tau, Hung Yen, Bac Giang and Hai Duong provinces

Time: Oct. 2016 – Sept. 2017

Status: Continuing

Description: The new biopesticide such as entomopathogenic nematodes for control pupae of fruit fly on DF and mango, *Ooencyrtus phongi* for control of stink bug on longan and shoot borer on lychee, *Hirsutella thompsoni* for controlling of mite on longan will be tested. These beneficial organisms will be isolated and introduced, tested, reared, mass multiplied and released to field conditions. Plant extracts will be tested for control of fungal diseases on DF, mango and control of mite on longan and scales on mango (by SOFRI, PPRI, FAVRI and consulted by UF-IFAS, CABI) (one PhD. scholar, one MSc. Scholar).

Expected outcomes: One entomopathogenic nematode, one parasitoid, one entomopathogenic fungus developed; plant extracts effective incontrolling fungus diseases on mango and DF identified.

Activity 4: Design and selection of the suitable fruit bagging for longan

PIs: Dr. Le Quoc Dien,Ms. Tran Thi My Hanh, Mr. Huynh Thanh Loc

Site/Location: SOFRI, Tien Giang, Dong Thap, Long An and Binh Thuan province

Time: Oct. 2016 – Sept. 2017

Status: Continuing

Description:

-Key pests: Fruit borer, Mealybugs

-Methods: Select materials for fruit bagging that will made from six different materials will be analyzed for longan production. The suitable fruit bagging types for longan crop will be designed and selected (by SOFRI).

Expected outcomes: A better fruit bagging method for longan will be developed for controlling targeted pests.

Activity 5: The local registration, market requirements and SPS for mango export to US

PIs: Ms. Phan Thi Thu Hien (PPD), Dr. Le Quoc Dien and Dr. Nguyen Van Hoa

Site/Location: Tien Giang, Vinh Long, Dong Nai, Dong Thap, Long An, Binh Thuan, Ba Ria-Vung Tau, Hung Yen, Bac Giang and Hai Duong provinces

Time: Oct. 2016 – sept. 2017

Status: Continuing

Description: The local registration, market requirements (i.e. market analysis or assessment) and SPS for mango export to US will be conducted (by PPD).

Expected outcomes: Information of local registration, market requirements and SPS for mango export to US will be known clearly.

Objective 3: Putting research into use (RIU)

PIs: Dr. Nguyen Van Hoa Mr. Mai Van Tri, Ms. Dang Thi Kim Uyen, Tran Thi My Hanh, Mr. Huynh Thanh Loc, Mr. Nguyen Huy Cuong, Ms. Nguyen Ngoc Anh Thu, Mr. Do Hong Tuan (in the South) and Dr. Le Xuan Vi, Dr. Nguyen Duy Hung (in the North)

Site/Location: Tien Giang, Vinh Long, Dong Nai, Dong Thap, Long An, Binh Thuan, Ba Ria-Vung Tau (Southn), Hung Yen, Bac Giang and Hai Duong provinces (North)

Time: Oct. 2016 – Sept. 2017

Status: New

Description: With the results from above obectives, new bio-rational IPM technologies developed will be used to built up new IPM packages for each crop which is suitable for each of different agro-ecosystems and will be applied to farmer group/cooperative in each zone with incorporating with VietGAP standard and the input of these models will be supplied by An Giang Plant Protection Join Stock company (AGPPS), or/and Hoa Nong-Hoptri Ltd. Co.

Disease/pest incidence, damages, pesticide residues on fruits, beneficial organism population, productivity and quality of fruits… will be recorded every 3 to 6 months depend on the characteristics (by SOFRI, PPRI, FAVRI, PPD, and consulted by WSU UF-IFAS and CABI)

Site/Location: SOFRI responsible for xpansion of DF IPM models in Tien Giangand Long An, longan models in Tien Giang and Vinh Long, mango models in Dong Thap and Dong Nai, PPRI responsible for enlarge IPM application longan models in Hung Yen and lychee model in Hai Duong province. 8models (15 ha/model x 1 model/province)

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

Objective 4: Technology transfer and extension using innovative frameworks (plant clinics, fact sheets, pest management decision guides), mobile technology-driven agro-advisory services and mass media/entertainment education

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

Time: July – Sept. 2017

Status: New

Description: The Southern Horticultural Research Institute has partnered with government (national and local governments' extension systems, universities and other institutions) and non-governmental organizations (CABI-Plantwise project) in efforts to leverage resources and reach much larger audiences. Earlier with JICA-SOFRI project on citrus, many extension model farms have been built as well as the latest technologies have been transferred to local agricultural officers and farmers. In addition, in the Plantwise project with CABI, we develop a system of plant doctors in three provinces in the South and two provinces in the North of Vietnam, who can help farmers every fortnight with the fact sheets and pest management guidelines. This project will closely work with the implementers for scaling up the technology transfer and practices. This will include working with local entrepreneurs and agro-vets. The project will identify and support local entrepreneurs with potential for developing biopesticides and IPM product supply chains. Institutions/Universities will be trained in the production of bio-pesticides and new techniques. Information will be disseminated through extension system and by NGOs conducting farmer meetings, field trips, training sessions and using mass media. Successful IPM demonstration sites where new technologies will be used as tool for transferring and educating.

Site/Location: **NLU/SOFRI** will carry out training courses in Tien Giang, Vinh Long, Dong Thap, Dong Nai, Long An, Binh Thuan, Ba Ria-Vung Tau and **PPRI** will carry out training courses in Hung Yen, Bac Giang and Hai Duong province. 10 courses (1 course/province, 40-50 person/course (farmer, local extension staffs of IPM sites, etc.))

Content of training: Canopy and branch pruning for more ventilation and short canopy, leading to easy management of pest and diseases (5 courses)

Use of bio-pesticides (SOFRI-Protein, SOFRI-Trukien, *Paecilomyces* sp., *Bacillus subtilis, Ooencyrtus phongi,* Ento-Pro., *Pseudomonas fluorescens*, etc.) (5 courses).

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

Graduate and undergraduate students sponsored by the project

- PhD. scholar: Name: Ms. Dang Thi Kim Uyen, Nationality: Vietnamese, Discipline: Plant Pathology, Country: Viet Nam, Degree: PhD. Plant Protection, Start date: 2016, Completion date: 2020, Advisor(s): Assoc. Prof. Tran Vu Phen at Can Tho University and Dr. Nguyen Van Hoa.
- PhD. scholar: Name: Mr. Do Hong Tuan, Nationality: Vietnamese, Discipline: Entomology, Country: Viet Nam, Degree: PhD. Plant Protection, Start date: February, 2017, Completion date: February, 2021, at Can Tho University.
- MSc. scholar: There are two graduate students will be studying on gender and value chain (1 MSc. Student) and plant protection (1 to 2 MSc. Students) in 2017.
- Bachelors: Name: Mr. Hua Thanh Tu, Nationality: Vietnamese, Discipline: Plant protection, Country: Viet Nam, Degree: Bachelor of Plant Protection, Start date: August, 2016, expected completion date: April, 2017, Thesis title: Selection of suitable types for fruit bagging for longan in Tien Giang, at Nong Lam University.
- Bachelors: Name: Mr. Mai Hoang Anh Tuan, Nationality: Vietnamese, Discipline: Plant Protection, Country: Viet Nam, Degree: Bachelor of Plant Protection, Start date: August, 2016, Completion date: April, 2017, Thesis title: Study the effect of entomopathogenic fungi against Eriophyid mite *Eriophyes dimocarpi* on longan in Chau Thanh district, Tien Giang province, at Nong Lam University.
- Bachelors: Name: Ms. Le Thi Kim Ngoc, Nationality: Vietnamese, Discipline: Plant Protection, Country: Viet Nam, Degree: Bachelor of Plant Protection, Start date: August, 2016, Completion date: April, 2017, Thesis title: Study the effect of plant extract against Eriophyid mite *Eriophyes dimocarpi* on longan in Chau Thanh district, Tien Giang province, at Nong Lam University: NLU.
- Bachelors: Name: Ms. Nguyen Thi Kim Ha, Nationality: Vietnamese, Discipline: Plant Protection, Country: Viet Nam, Degree: Bachelor of Plant Protection, Start date: August, 2016, Completion date: April, 2017, Thesis title: Study on rearing method and capacity to consume Eriophyid mite of mite predators on longan in Chau Thanh district, Tien Giang province, at Nong Lam University.

Short term training planned

Title: Development of Integrated Pest Management (IPM) systems; Location: USA; Date: June, 2017 (7 days); Type: Training; Number: 1 person; Gender: Male

Title: New technology on detection and identification of new plant viral, Phytoplasma disease and insect identification; Location: USA; Date: July, 2017 (7 days); Type: Training; Number: 1 person; Gender: Female

Title: Study on mass production of making bio-product; Location: India; Date: July, 2017; Type:

Training; Number: 1 person; Gender: Male

Title: International Conference on Biodiversity, Kathmandu, Nepal; Date: 10-12 January, 2017; Number: 2 persons; Gender: Male and Female.

Publishing

Journal article: First report of new species of *Colletotrium* causing Anthracnose on dragon fruit in Vietnam.

Expected technical bulletin

- Manual of insects identification on dragon fruit crop
- Manual of insects identification on longan crop

Visits: CABI expert (4 trips-1st, 2nd, 3rd, 4th quarter); WSU expert (1st quarter); Mizellidae, LLC expert (2nd quarter) and VT expert (4th quarter).

Trip reports of each traveler need to be submitted after every trip (1st, 2nd and 3rd quarter)

Meetings

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

External monitoring and evaluation will be done in 2nd quarter

Project annual review and planning will be done in 4th quarter

Reports: PPRI and FAVRI will responsible to submit their activity report to SOFRI every 3 months. SOFRI will combine data from PPRI, FAVRI and itself to write the annual report to submit to USAID-VT.

Project Title: IPM for Rice, Maize and Chickpea in East Africa

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

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

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

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. In order to address the aforementioned 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. IPM packages compatible with sustainable intensification systems will be developed, tested and transferred to the end users along value chains. Appropriate technology transfer methods will be tested and applied through collaboration with National Agricultural Research and Extension System (NARES). The proposed IPM approach will include cultural, biological and host plant resistance to management of pests and diseases while minimizing economic, public health and environmental risks. Besides, developing and validating IPM packages, this project will scale up proven IPM technologies. The project will follow a participatory IPM or process oriented research for development approach based on coalitions of partners working together in the three project countries; Ethiopia, Kenya and Tanzania. Therefore, the objectives of this project are to increase production and productivity for maize, rice and chickpea value chains, by reducing crop losses through dissemination of effective IPM options. The long-term vision of this project is to prepare a fertile ground for a widespread dissemination of IPM in eastern and southern Africa, and to gather adequate empirical data to convince governments and donor institutions that the IPM technology has great potential in reducing crop losses and in enhancing food and nutrition security in the region.

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

Scientists involved: icipe (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Tebkew Damitie, Asrat Zewdie, Girma Demissie)
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 Kibah centers)
Task-3: Train extension agents and farmers on push pull system for maize stem borers; maize termite IPM; chickpea pod borer and wilt IPM.
Countries: Ethiopia (Hawassa and Bako for maize, Debrezeit for chickpea), Kenya (Nakuru, Naivasha and Bomet for maize) and Tanzania (Morogoro for rice and Tanga from maize)
Status: on-going
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 the push-pull system has been identified and being demonstrated against stem borers in Kenya in Naivasha and Nakuru and in Ethiopia in Hawassa and Adami Tulu in 2016 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.

Activity 1.4: Evaluation and assessment of IPM packages and implementation strategies

Scientists involved: icipe (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Tebkew Damitie, Asrat Zewdie, Girma Demissie).
Task-1: Identify and engage relevant stakeholders in evaluation of the IPM package (push pull system for stem maize borers; maize termite IPM; chickpea pod borer and wilt IPM) and implementation approaches
Task-2: Train extension agents and farmers on selected IPM technologies including (push pull system for stem maize borers; maize termite IPM; chickpea pod borer and rot/wilt IPM).
Countries: Ethiopia (Hawassa and Bako for maize, Debrezeit for chickpea), Kenya (Nakuru, Naivasha and Bomet for maize) and Tanzania (Morogoro for rice and Tanga from maize)
Status: New
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: New
Expected outputs: maize IPM and chickpea IPM presently being implemented will be evaluated with stakeholders, lessons would be drawn and trainings would be given to beneficiaries and extension agents

Activity 1.5: Scaling up proven IPM technologies

Scientists involved: icipe (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Tebkew Damitie, Asrat Zewdie, Girma Demissie)
Task-1: Disseminate proven IPM technologies (such as maize stem borers push-pull) through organizing field days
Task-2: Demonstrate and evaluate IPM technologies (integrated wilt/ root rot and pod borer management in chickpea; integrating botanicals, soil fertility and intercropping for termite control in maize; rice diseases tolerant varieties) to farmers and extension agents in multiple sites
Countries: Ethiopia (Hawassa and Bako for maize, Debrezeit for chickpea), Kenya (Nakuru, Naivasha and Bomet for maize) and Tanzania (Morogoro for rice and Tanga from maize).
Status: New
Description: Currently planted demo plots in Nakuru and Naivasha (Kenya) and Hawassa, Bako and East Shoa (Ethiopia) would be visited by farmers, extension agents and relevant stakeholders
Progress to date: New
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

Scientists involved: icipe (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Tebkew Damitie, Asrat Zewdie, Girma Demissie)
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: on-going
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: Three consultants (Dr Ferdu Azerefegn Ethiopia, Dr Christopher Materu Tanzania and Dr Birithia Kayume Kenya**)** identified and are currently developing a working document in assessing local pest diagnostic capacity and proposing the required capacity developing components.
Expected outputs: Local pest diagnostic capacity assessed and necessary capacity building proposed

Activity 2.2 Developing and testing diagnostic kits

Scientists involved: William Hutchinson from University of Minnesota; icipe (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Tebkew Damitie, Asrat Zewdie, Girma Demissie)
Task 1: visit to the project countries by Prof William Hutchinson; planning with local partners and icipe team
Countries: Ethiopia, Kenya and Tanzania
Status: new
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: Sub-grant given to University of Minnesota
Expected outputs: Mobile phone application designed and developed for pest diagnosis

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

Scientists involved: Dr Fathiya Khamisi, molecular Biologist *icipe*; Project team icipe (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Tebkew Damitie, Asrat Zewdie, Girma Demissie)
Task 1: Organize training on molecular methods in insect pest diagnostics at icipe Kenya
Countries: Ethiopia, Kenya and Tanzania
Status: new
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 molecular methods

Activity 2.4: Moved to next year

Objective 3: Improving IPM communication and education

Activity 3.1: Moved to next year

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

Scientists involved: icipe project team (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Tebkew Damitie, Asrat Zewdie, Girma Demissie)
Task-1: Organize annual planning of activities separately for rice, maize and chickpea by inviting relevant partners in the three countries; share IPM activities presentations from the three countries
Countries: Ethiopia, Kenya and Tanzania
Status: On-going
Description: Awareness creation is very important for uptake of the IPM technology; thus, information on maize, rice and chickpea IPM would be compiled and presented to the stakeholders during the annual planning workshop.
Progress to date: Stakeholders from the three countries were invited to the project launching and planning workshop, presentations were made by selected local partners on maize, rice and chickpea insect pests and diseases and their control tactics.
Expected outputs: improved awareness of the project and common understanding of stakeholders on IPM and major biotic factors in the three countries

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

Task-1: Develop and disseminate project summary brochures/flyers explaining the project objectives, implementing countries and local partners
Task-2: Develop and disseminate the project's current IPM practices (integrated wilt/ root rot and pod borer management in chickpea; integrating botanicals, soil fertility and intercropping for termite control in maize; rice diseases tolerant varieties; push pull for stem borer control) in appropriate language with implementing countries and local partners
Countries: Ethiopia, Kenya and Tanzania
Status: Ongoing
Scientists involved: icipe project team (Tadele Tefera, Menale Kassie), local partners (Charles Chuwa, Nsami Elibariki, Paddy Likayo, Tebkew Damitie, Asrat Zewdie, Girma Demissie)
Description: Awareness creation is very important for uptake of the IPM technology; the information on rice, maize and chickpea IPM would be compiled and promotional materials would be developed and disseminated.
Progress to date: Promotional materials were developed and disseminated to partners in Ethiopia and Kenya.
Expected outputs: Awareness created and information on the project and IPM disseminated

Activity 3.4: Moved to next year

Activity 3.5: Conduct training needs assessment in the target countries

Scientists involved: Menale Kassie and Josphat Korir

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: New
Description: asses local partners and farmers knowledges, skills, and abilities, and identify any gaps or areas of IPM training need.
Progress to date: New
Expected outputs: knowledge gaps identified and relevant training proposed.

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

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

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

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: New
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: New
Expected outputs: Policy gaps and institutional arrangements identified

Activity 4.3 and 4.3: pushed to next year

Graduate Students:

Recruited: 5 PhD 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-2
Baseline summary report -2

Performance Indicators for Monitoring and Evaluation:

ID	Description	Completion Date	Responsible
Outcome 1	Identify key partners, develop IPM technologies and define implementation strategies		
Activity 1.3	Design and establish adaptive on-station/on-farm IPM participatory trials	30-09-2017	Tadele Tefera, Menale Kassie, Students and local partners
Task-1	Identify available IPM technologies in target countries in collaboration with local partners	30-12-2016	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	30-09-2017	Tadele Tefera, Menale Kassie, Students and local partners
Task 3	Train researchers, extension agents and farmers on selected IPM technology(ies)	30-09-2017	Tadele Tefera, Menale Kassie, Students and local partners
Activity 1.4.	Evaluation and assessment of IPM packages and implementation strategies	30-9-2017	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	30-7-2017	Menale Kassie, Korir Josphat, Tadele Tefera, Local partners

Task -2	Train extension agents and farmers on selected IPM technology (ies)	30-8-2017	Menale Kassie, Korir Josphat, Tadele Tefera, Local partners
Activity 1.5	Scaling up proven IPM technologies	30-9-2017	Tadele Tefera, Menale Kassie, Students and local partners
Task-1	Disseminate proven IPM technologies through organizing field days	30-9-2017	Tadele Tefera, Menale Kassie, Students and local partners
Task-2	Demonstrate proven IPM technologies to farmers and extension agents in multiple sites	30-9-2017	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	30-11-2016	Tadele Tefera, local partners
Task 1	Assess local partners/institutions pest diagnostic capacity through onsite observation and onsite stakeholders' consultation	30-09-2017	Tadele Tefera, local partners
Activity 2.3.	Capacity building in training on pest and disease diagnosis	30-5-2017	Tadele Tefera, local partners
Task-1	Short-term training for scientists from participating countries in insect pest and disease diagnosis	30-5-2017	Tadele Tefera, local partners
Outcome 3	improving IPM communication and education	30-09-2016	
Activity 3.2	Create awareness and disseminate information on IPM to enhance responsiveness of the stakeholders.	30-12-2016	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	30-3-2017	Tadele Tefera, local partners
Activity 3.3	Develop promotional materials targeted to different stakeholders to enhance up-take of the IPM technologies	30-9-2017	Tadele Tefera, local partners
Task-1	Develop and disseminate project summary brochures/flyers explaining the project objectives, implementing countries and local partners	30-11-2016	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	30-12-2016	Tadele Tefera, local partners
Activity 3.5	Conduct training needs assessment in the target countries	30-11-2016	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	30-11-2016	Menale Kassie, Korir, local partners, Tadele Tefera
Outcome 4	Provide information and capacity building to reform and strengthen policies that influence integrated pest management	30-9-2017	Menale Kassie, Korir, local partners
Activity 4.1.	Identification of incentives and disincentives, policy gaps and institutional arrangements for adoption of IPM	30-9-2017	Menale Kassie, Korir, local partners
Task-1	Review all the agriculture policies relevant to IPM or crop	30-9-2017	Menale Kassie, Korir, local partners

	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; make recommendations on how to address the gaps	30-9-2017	Menale Kassie, Korir, local partners

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

PI: Buyung Hadi

Co-PIs: Virender Kumar, Il-Ryong Choi, Ricardo Oliva, Casiana Vera Cruz, Alexander Stuart, Nancy Castilla, Rica Joy Flor

Collaborating Institutions: GIZ ASEAN SAS, Nagoya University, Cornell University, GDA, CARDI, CEDAC, Virginia Tech

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

Activity 1: Adaptive research platform
PI: Virender Kumar, Il-Ryong Choi, Ricardo Oliva, Casiana Vera Cruz, Alexander Stuart, Nancy Castilla
Site/Location: Cambodia

Province	District	Village
Battambang	Banan	Otanon
	Trana Koul	Bangpring
Kampong Thom	Santouk	Pahnachi
	Steung Sen	Pou Backor
Takeo	Bati	Makak (may still change but same district)
	Trang	Ro Veang
Prey Veng	Paem Ror	Srou
	Paem sdach	Tom

Status: New
Description: The activity will include on-farm and on-station research. There is at least one GDA/PDA research station per province in which we'll do controlled experiments. Information gathered from the rice health survey in year 1 will be used as an input to guide the type of IPM components being tested in each province. The on-farm adaptive research cycle is farmer-directed (i.e. the farmers will have major input in choosing the technologies to be tested and in conducting the experiments) and will also act as demonstration farms of the IPM technologies. Field days will be conducted by the end of each cycle and surrounding farmer community will be brought in to evaluate the technologies. We plan to test a combination of two to three interventions per province to address the top pests and diseases in the area. The exact number of experimental plots will be decided after the completion of the rice health survey and in discussion with the collaborating farmers but as an estimate we plan to conduct two

experiments per province with each experiment consisting of at least three treatments replicated three times resulting in eight experiments involving a total of 72 experimental units (farm plots) across the country.
Expected outcomes: Validation data on a number of potential IPM components against different pests, weeds and diseases: biological control agents, Trichoderma, resistant varieties, trap barrier system, no early spray, drum seeder and mechanical weeder, ecological engineering.
Activity 2: Innovative research platform (MSc and PhD students)
PIs: Buyung Hadi, Ricardo Oliva, Virender Kumar, Nancy Castilla, partners from Royal University of Agriculture (RUA), Royal University of Phnom Penh (RUPP) and Nagoya University.
Site/Location: Center of excellence at RUA, experimental stations at the four provinces above.
Status: New
Description: We will continue at least one Cambodian PhD student at Nagoya University. Another Cambodian PhD student may start at Virginia Tech. At least 2 Master students will start at RUA and one Master student at RUPP. The PhD student at Nagoya University is working on the effects of trichoderma and resistant varieties on rice blast disease in Cambodia. The PhD student at Virginia tech will finish his 2 years of coursework before starting the field work in Cambodia. The Master students will work on rice health survey and the impact of bat predation on rice pest regulation. Bat farming is a rising economic activity in some Cambodian provinces.
Expected outcomes: At least five graduate students (two PhD and three Master) will start their study programs.

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

Activity 1: Provincial learning alliance
PIs: Rica Joy Flor, partners from GDA, CARDI and CEDAC.
Site/Location: Central location across chosen district at each province (above).
Status: New
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 2016-2017, we expect to learn about the potential roadblocks to rice IPM adoption and grass-roots interest in starting businesses that promote IPM activities (e.g., a village-based farmers' group that is interested in providing biocontrol products/services). We plan to conduct at least one provincial learning alliance meeting per province for a total of four meetings across the country.

Expected outcomes:

- Initial stakeholder assessment (list of province-level stakeholders relevant to pest management and sustainable practices) obtained through focus group discussions (end of 2016)
- Participatory impact pathways assessment (PIPA) workshop in each of 4 provinces to initiate the Learning Alliances (1st quarter 2017)
- Documented rice value chain input on the roadblocks to adoption of rice IPM package and potential common actions to overcome the roadblocks. This will be taken from the assessment of various stakeholders through the problem-cause analysis in the PIPA workshop.
- Documented grass-roots interest in starting IPM service provider business as an output of the learning alliance meetings.

Activity 2: Knowledge sharing activities
PIs: Buyung Hadi, CARDI, GDA, potential partners from IFAD or CAVAC
Site/Location: Phnom Penh
Status: New
Description: We plan to introduce Rice Doctor app in Khmer and to harmonize its content with CARDI and GDA's recommendations. We plan to achieve this either by introducing Rice Doctor module into an e-Agro expert system being developed and to be disseminated by IFAD's PADEE project or by modifying RAPiD, a diagnostics app based on Rice Doctor being disseminated by AusAID's CAVAC project.

Expected outcomes: A Rice Doctor app in Khmer with CARDI/GDA recommendation being freely disseminated among rice value chain actors in Cambodia. Rice Doctor is unique and has no peer. Rice doctor is an app that walk farmers/extension workers step-by-step through a series of questions on field symptoms of rice biotic and abiotic stresses. By the end of the questions, Rice Doctor app comes up with a narrowed down diagnostics and recommendation. Rice Doctor can be used directly on the field while doing observation on the symptoms/injuries. In effect, Rice Doctor can replace the need for farmers/extension workers to bring samples to CABI's plant doctor clinics. Seen another way around, based on our interaction with CABI plant doctors in Cambodia (some attended our rice health survey training), we can use Rice Doctor as a tool for CABI's plant doctors to improve their diagnostics accuracy.

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

Activity 1: Training opportunities on key skills in IPM validation and implementation
PIs: Buyung Hadi, Virender Kumar, Alex Stuart, Nancy Castilla, Ricardo Oliva, Ill-Ryong Choi, Cassiana Vera-Cruz, Rica Joy Flor, partners from GDA, CARDI and CEDAC, potential partners from CABI.
Site/Location: Phnom Penh, adaptive research platform sites (at four target provinces), IRRI.
Status: New/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 on-the-job training at IRRI. A list of planned short-term training for this workplan period is provided under a separate heading below.

The long term training opportunities are described above under objective 1, activity 2.

Expected outcomes

- At least 50 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 to continue conducting research and validation work to adapt IPM technologies to Cambodian contexts; farmers, farmer groups and NGO staff are expected to adopt the IPM technologies being tested in the project and also to take an active

part in disseminating these technologies either through words of mouth or through the development of grassroot IPM business provider.
- At least two PhD students and three Master students will start their graduate training.

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

Activity 1: National learning alliance on rice IPM policy and development of rice IPM curriculum and training materials
PIs: Harvey Reissig, Rica J. Flor, Virender Kumar, Buyung Hadi, partners from CEDAC and GDA.
Site/Location: Phnom Penh
Status: New
Description: The data from pesticide knowledge, attitude and practice survey will be analyzed and summarized. The data is gender disaggregated to allow insights into gender-difference in pesticide KAP among male and female farmers. The summary information will be used as a starting point for discussion at a national learning alliance on rice IPM policy. The national learning alliance will involve various stakeholders with the objective of identifying policy gaps and formulating potential solutions. An FFS curriculum on rice crop management is currently available in Khmer. We will work with GDA to revise the curriculum by introducing new elements of rice IPM (e.g. augmentative biocontrol, safety aspects of pest management options, etc.). Revised training materials will be translated into Khmer for use by national partners.
Expected outcomes:
- Policy recommendations on approaches to strengthen regulation enforcement and registration rules on IPM products.
- A curriculum and learning materials on rice IPM package.
- National Learning Alliance initiated, which will involve a network of national-level actors with shared interest for joint action on IPM policy-related activities (2017). By involving and indeed putting the national level actors (e.g. GDA, CARDI, federation of rice exporters, national organization of agricultural input, farmers' representatives) at the driver's seat of the national learning alliance, we expect the alliance to be a space where compromise and common solution can be achieved to positively influence the policy climate for country-wide IPM adoption. Focus will be given to encourage the incorporation of the alliance's output into the national policy.

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

Activity 1: Annual planning meeting – November 2016
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 2016. Progress in year 1 will be reviewed and activities for year 2 will be thoroughly discussed. Input from Management entity, USAID mission and other stakeholders will be solicited.
Expected outcomes: Progress review and concrete plan for 2016/2017.

Activity 2: Analysis and summary of baseline impact assessment data
PIs: Buyung Hadi, Rica J. Flor, George Norton, partners from GDA and CEDAC.
Site/Location: Phnom Penh
Status: Continuing
Description: Yield, cost, income, and environmental (pesticide-related) data from the baseline survey will be summarized. These data will be used initially for an analysis of factors affecting a) adoption of IPM practices that have already been adopted by farmers and b) pesticide use on rice. Later the data will be used for impact assessment.
Expected outcomes: Farm-level survey data summarized and an MS thesis.

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	9/2016	8/2019	Research costs	Sotaro Chiba, Buyung Hadi	Rice IPM components against rice blast, a dominant rice disease in Cambodia	Nagoya University
Khun Kimkhuy	M	Cambodia	Entomology	Cambodia	PhD	1/2017	12/2020	100%	Scott Salom, Buyung Hadi	TBD – will revolve around usage of augmentative biocontrol in rice IPM	Virginia Tech University
TBD	?	Cambodia	Plant pathology	Cambodia	MSc	9/2016	8/2018	100%	Khay Sathya, Nancy Castilla	Rice health survey in Cambodia	RUA
TBD	?	Cambodia	Plant pathology	Cambodia	MSc	9/2016	8/2018	100%	Ong Soceath, Ricardo Oliva	The effects of Rice IPM component on rice microbial diversity	RUA
TBD	?	Cambodia	Ecology	Cambodia	MSc	9/2016	8/2018	100%	Neil Furey, Alex Stuart	Quantifying the impacts of bat farming on rice pest regulation	RUPP
Sydni Jackson	F	USA	Economics	Cambodia	MS	5/2016	7/2017	100%	George Norton	Rice IPM Adoption and Impacts	Virginia Tech

Short term training planned

Short-term training	Target audience	Potential numbers to be trained	Length of training	Planned sites
Participatory training on basic IPM skills (e.g., diagnostics and monitoring, plant health basics) and validated IPM tactics	Lead farmers and early adopters	40 farmers and early adopters	Monthly meeting (~2 hours) across the rice season	Adaptive research sites
Conduct of adaptive research	GDA, PDA, CARDI, RUA	15 GDA, PDA, CARDI	4 day workshop	Phnom Penh

		and RUA staff		
Laboratory techniques in insect ID, rice plant pathology; experimental design, data analysis and management (as on the job training at IRRI)	GDA, CARDI, RUA	6 GDA, CARDI and RUA staff	2-4 weeks on the job training	IRRI
Technical and entrepreneurial skills for IPM service provider startups (the technical skills may include Trichogramma card production, weed management techniques, etc.)	NGOS, ag input providers, farmer organizations	20 farmers, GDA, PDA and NGO staff	4 day workshop	Phnom Penh/one of the adaptive research sites
Training on coordination and implementation of farm-household survey, using CSEntry	GDA, PDA (IPM network staff)	10 GDA and PDA staff	2 day workshop	Phnom Penh and 4 target provinces

Publications planned

Book

E. A. Heinrichs, F. Nwilene, M. Stout, B.A.R. Hadi and T. Freitas. 20xx. Rice Insect Pests and Their Management. Burleigh-Dodds.

Conference Abstracts

"Augmentative and conservation biocontrol options for rice IPM in Cambodia" - International symposium on biological control of arthropods, Langkawi, Malaysia, September 11-15, 2017

Extension bulletin

Rice IPM cards – in Khmer

East Africa Integrated Pest Management Innovation Lab: Research and Technology Transfer for Vegetable Crops

PI: John Cardina

Co-PIs and Collaborating Institutions:
Ferdu Azerefegne, School of Plant and Horticultural Sciences, University of Hawassa, Ethiopia
Luis Cañas, Department of Entomology, OSU
Danny Coyne, Soil Health Scientist, IITA, Kasarani, Nairobi, Kenya
J. Mark Erbaugh, Director of the Office of International Programs in Agriculture, OSU
Robert Gilbertson, Department of Plant Pathology, University of California – Davis
Matthew Kleinhenz, Department of Horticulture and Crop Science, OSU
Amon P. Maerere, Department of Crop Science and Production, 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
Henry Wainwright, Real-IPM, Thika, Kenya

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: Complete baseline survey initiated in FY 16.
PIs: Norton, Rakowski
Cooperators: Menale, Beth Ndungu, Simon Wepukhulu
Site/Location Tanzania, Ethiopia, Kenya
Status: Ongoing
Description: Conduct baseline survey to identify priority pests, pest management practices, knowledge of IPM, extent of current vegetable IPM adoption, who the adopters are (low or high income farmers, male or female), and why they adopt or do not. The crops of interest are: tomato, onion, and cabbage in Tanzania; tomato, onion, and French beans in Kenya; and tomato, onion, and brassicas in Ethiopia. The baseline surveys are being conducted jointly with the Grains IPM IL project in East Africa. The data from the surveys will be analyzed and summarized in a report. The Kenya data will be used in an MS thesis.
Expected outcomes: Preliminary farm-level data on economic, environmental, and gender status at selected sites will be collected and summarized to help prioritize pests and provide a baseline against which impacts can subsequently be measured.

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: Long-term training for graduate students.
PIs: Miller, Norton, Cardina, Cañas
Site/Location OSU, VirginiaTech
Status: Continuing/New
Description: One MS student has been recruited for Miller at OSU and Norton at VT; two additional MS students are being identified and will start in 2017. Students will enter U.S. with J1 visa and TraiNet. The OSU student will be working with beneficial microbes (e.g. *Trichoderma*) as components of media for disease-free seedling production, one of the areas of need identified by SUA faculty.
Expected outcomes: Initiation of graduate studies leading to theses and published papers in plant pathology, agricultural economics, horticulture, and entomology. The OSU students will be working with faculty with extension/research appointments and will receive training and experience in extension outreach methods. Student research will focus on IPM technologies directly applicable to vegetable production in their host country. We expect them to extend their findings through training and outreach activities when they return.

Activity 2: Short-term training in pest diagnostics and IPM practices.
PIs: Miller, Cañas, Cardina, Kleinhenz, Gilbertson,
Site/Location: Ethiopia, Kenya, Tanzania
Status: Continuing and New
Description: Pest diagnostics workshops for trainers, farmers, grower groups, including use of WhatsApp for image capture and handling, as well as use of IPM practices for prevention of – and in response to – disease, insect, weed, virus, and nematode problems.
Expected outcomes: Transfer of up-to-date IPM information to diverse audiences for prevention and management of pests; training in use of web applications for pest diagnosis.

Activity 3: Community of practice approach for consultation on pests and pest management.
PIs: Kleinhenz, Miller, Cañas, Cardina, Gilbertson, Ferdu, Coyne, Maerere, Mbaka, Sseruwagi, Wainwright
Site/Location: USA, Ethiopia, Kenya, Tanzania
Status: Continuing and New
Description: Develop Community of Practice (CoP) using conference calls to provide information on the IPM needs of the East African vegetable crop industries. Initial topics for discussion will include project-related tools and tactics, upcoming educational events, trial coordination, current IPM-related observations and troubleshooting. Later, topics will be chosen by stakeholders including value chain partners, and are expected to focus on monitoring, diagnosis, and management of current pest issues.
Expected outcomes: Documentation on calls, participants, gender participation, discussion topics.

Objective 3: Test prototype management technologies in on-station or on-farm trials with grower groups.

Activity: Evaluate IPM technologies identified in initial project meetings and modify to fit existing conditions.
PIs: Ferdu, Coyne, Maerere, Mbaka, Sseruwagi, Wainwright
Site/Location: Ethiopia, Kenya, Tanzania
Status: New
Description: At initial project meetings in each country we identified specific technologies that needed to be evaluated and assigned individuals to lead those evaluations in replicated experiments. Technologies include soil amendments, seedling protectants, biocontrols etc, some of which are available commercially and some of which need to be developed locally.

- The project will be implemented in the Feed the Future (FtF) priority areas in Morogoro (Central) and Iringa (Southern highlands) regions. The Project will develop, implement and scale-up IPM technologies for selected vegetable crops, which will focus on tomato, onion, cabbage and other brassica crops. Country coordination will be by Sokoine University of Agriculture (SUA) and will partner with the local government extension, NGOs/Associations: Seeds of expertise for the Vegetable Industry in Africa (SEVIA) and Tanzania Horticultural Association (TAHA).
- Assessment of specific practices for the management of major pests and production constraints will be conducted and initial work for IPM technologies development and evaluation will be conducted on station and on-farm. Assessment of the IPM technologies will involve researchers, farmers, traders and the other vegetables value chains stakeholders.
- Tomato bacterial wilt is being addressed by promoting improved basic cultural practices including crop rotation, raised beds to improve drainage, plant spacing that provides good air circulation, maintaining a soil pH of 6.2-6.5 and washing of tools that have been used in infected soil. PIs in Kenya and Tanzania will evaluate resistant cultivars, grafting onto wilt-resistant rootstocks, and possible biological controls.
- The invasive leaf-miner, *Tuta absoluta*, has become a problem throughout the region. Biocontrol is the tactic that we hope will eventually work for *Tuta*. The egg parasitoid *Trichogramma acheae* is showing promise in Spain, but it is not yet ready to implement in Africa. Participants at KALRO, working with RealIPM, will initiate work to evaluate the potential for biocontrol. Meanwhile, chemical controls are being widely used. Here IPM can play a role in promoting good timing and use of materials that are least disruptive to natural enemies. This will be the focus of work in Ethiopia. Two cultural controls that will be tested in Tanzania are destruction of crop residues after harvest, and the use of row covers for tomatoes in non-staked systems.
- Specific projects by country and crop include the following:

IPM RESEARCH FOR TANZANIA
CROP: TOMATO

	SPECIFIC PRACTICE	WORK PROPOSED
Grafting	Grafting on MT56 and wild solanum to prevent bacterial wilt;	Mtui**:** Evaluate grafting on wild solanum rootstock; work

		with Matt Kleinhenz on experimental design.
Transplant treatment	Drench with slurry of beneficial microbes	Mamiro: Study recipes for slurry and microbes (e.g. Trichoderma) to get consistent product.
Fruit treatment	Sodium hypochlorite dip	Mtui: has worked with this; will conduct further studies and demonstrations.
Cultural control of Tuta	Destruction of crop residues and row covers.	Rwegasira and Maerere: Test rotations, sanitation and row covers at SUA farm.

CROP: ONION

Variety selection	Resistant varieties needed; only 3 OP varieties now used. Need to evaluate hybrids.	Mtui and Maerere: Evaluate onion varieties, hybrids for resistance, yield, quality.
Soil treatments	For grubs, *Metarhizium* and or *Beauveria*	Rwegasira: Work with Real IPM to evaluate products for insects of interest.
Botanical pesticides	Neem or other botanicals to repel thrips.	Rwegasira to conduct literature search to see what might be tested.

CROP: CABBAGE

Microbial controls	Bioslurry for insect pests; biogas byproduct. Use the solution of byproduct for insects.	Rwegarsira and Kanyagha: Evaluate impact of biogas byproduct, adding Trichoderma, Bacillus in the process.

IPM RESEARCH FOR KENYA
CROP: TOMATO

	SPECIFIC PRACTICE	WORK PROPOSED
Grafting	Use resistant rootstock to reduce soil borne diseases e.g. bacterial wilt and RKN, using resistant cultivars	Kuria to evaluate rootstocks
Biocontrols	Parasitoid *Trichogramma acheae* needs to be tested for *Tuta absoluta*	RealIPM will get insect from Spain for testing.
Botanicals	Biopesticides such as neem and other botanicals for *Tuta absoluta*, *Helicoverpa*	Kambo will work with Real IPM to obtain products for evaluation.

CROP: CABBAGE

Biocontrols	*Trichoderma spp., B. subtilis*	Mbaka to test on seeds and seedlings for black-rot
Soil management	Liming, *Trichoderma*	Mbaka to lead tests for control of club-root
Microbial pesticides	*B. bassiana, M. anisopliae, Bacillus thuringiensis, Paecilomyces sp.*	Kambo will work with Real IPM to test products for DBM, aphids

CROP: BEANS

Microbial pesticides	*B. bassiana, M. anisopliae, Bacillus thuringiensis, Paecilomyces sp*	Muriuki will work with Real IPM and others to test products for white flies, thrips, black bean aphid
Biopesticides	Neem and other botanicals	Ngugi to work with Real IPM products for *Maruca* pod borers

IPM RESEARCH FOR ETHIOPIA

CROP: TOMATO

	SPECIFIC PRACTICE	WORK PROPOSED
Seedling production package	Burning beds to "heat treat" the soil, anaerobic disinfestation, steam disinfestation, biofumigation, and flooding.	Drs. Alemayehu and Ferdu will direct this research with graduate students.
Soil amendments	Identify and evaluate local *Trichoderma* strains for seedling treatments.	Alemayehu: isolate and culture locally-adapted strains; evaluate effectiveness for protection of tomato seedlings against fungal pathogens
Mulch	Straw and less digestible grasses	Ferdu: test mulches to suppress weeds and reduce herbicide use.
Biocontrol	*Metarhizium* and *Beauvaria*	Efficacy data are needed to get these registered in Ethiopia. Dr. Yebrah will conduct tests to demonstrate efficacy and Dr. Ferdu will work on getting products registered.

Reduced impact chemicals	Proper timing and use of materials for Tuta that are least disruptive to natural enemies.	Ferdu will lead evaluation of good IPM practices.

CROP: ONION

Botanicals and other 'soft' pesticides	'soft' pesticides for onion thrips	investigate the rotation of 'soft' insecticides and mixtures, e.g. timing and frequency of applications, starting with 'soft' materials before moving to others. Dr. Ferdu and graduate student are conducting this research
Effective weed management	Determine how to use pendimethalin in combination with appropriately timed hand weeding.	Test methods to decrease labor inputs for weeding onions. Dr. Yibrah will direct this study.
Biocontrols	*Metarhizium* for trips management.	Formulated products are available through RealIPM; Yebrah will evaluate efficacy and Ferdu will work on getting products registered.

CROP: BRASSICAS (cabbage and native brassicas)

Develop package for clean seedlings.	Specific practices include: anaerobic disinfestation, steam disinfestation, biofumigation, and flooding for soil pathogens; use of netting for insect exclusion.	Evaluate individual and combined practices for seedling production. Drs. Alemayehu, Yibrah, and Ferdu will direct this research.
Biocontrols	*Beauvaria* and Bt for control of DBM.	Evaluate formulated Beauvaria and Bt products; efficacy data needed to register in Ethiopia. Yebrah will conduct tests to evaluate efficacy.
Plant residues	*Brassica* residue effects in combination with soil solarization and/or flooding on crop pests.	Evaluate incorporation of brassica materials, which release glucosinolates that reduce pests in the next crop

		when used with solarization or flooding. Alemayehu will lead this project.

Expected outcomes: Results of field and laboratory experiments showing effectiveness of various technologies.

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

***Activity 1*:** Evaluate impacts of IPM training on IPM adoption and pesticide use.
PIs: Erbaugh, Maerere, Norton
Site/Locations: Tanzania and Kenya
Status: New
Description: Use baseline survey data to evaluate yield, environmental (pesticide-related), and gender impacts of pest management for farmers who have, or have not, received IPM training. Survey data from areas targeted for IPM training will summarized and used in the analyses. Data will allow us to explore the impacts of IPM adoption, who the adopters are (low or high income farmers, male or female), and why they adopt or do not, and farm performance for those who do vs those who do no adopt IPM.
Expected outcomes: Farm-level survey data including economic, environmental, and gender analyses of adopters vs non-adopters.

***Activity 2*:** Assess gender impacts of IPM practices, packages, and policies and means for improving sensitivity to gender-related issues in IPM diffusion activities.
PIs: Rakowski, Ndungu
Site/Location: Kenya, Tanzania, Ethiopia
Status: New
Description: Data from baseline surveys and qualitative analysis will analyzed from a gender perspective with respect to: 1) constraints to IPM adoption, 2) beliefs and perceptions about pest management practices, 3) household decision making on pest management practices, 4) access to extension services and other sources of information, 5) knowledge of pests, and pest management practices, and 6) benefits from and control of income from plots where IPM is used. The IPM diffusion process in each country will be examined from a gender perspective and recommendations made to facilitate IPM adoption among women.
Expected outcomes: Gender-related data from farm-level surveys and qualitative data gathering summarized, preliminary gender analyses conducted, and recommendations made for gender-sensitive IPM diffusion strategies.

Graduate Students and Post-Doctoral Research Associates:

1. Name: Muntasir Hasan
Sex: Male
Nationality: Bangladesh
Discipline: Agricultural Economics
Site/Country: Kenya
Degree: M.S.
Start date: May 2016
Completion date: July 2017.
IPM IL funds: 100% since May 2016 (Ag Econ Department paid for period of August 2015 to May 2016 prior to his starting on this IPM IL project)
Advisor/PI: George Norton
Thesis topic: Factors affecting adoption of vegetable IPM practices in Kenya
University: Virginia Tech

2. Name: Hellen K. Mbije
Sex: Female
Nationality: Tanzania
Discipline: Plant Pathology
Site/Country: Tanzania
Degree: M.S.
Start date: January 2017
Completion date: December 2019
IPM IL funds: 100% from January 2017 through December 2019; Plant Pathology department funds thereafter if needed.
Advisor/PI: Sally Miller
Thesis topic: The use of beneficial microbes (e.g. Trichoderma) for disease-free seedling production.
University: Ohio State