

The Feed the Future Innovation Lab for

Integrated Pest Management

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Executive Summary

For the past six months, April to September, 2016, the IPM Innovation Lab (IPM IL) has kept a very busy schedule. We've been implementing and managing our eight projects along with organizing additional special activities such as surveys, workshops, and country visits, just to name a few.

In April, the IPM IL participated in the planning meetings of the following projects: the Exportable Fruit Crops IPM project in Ho Chi Minh City, Vietnam; the Rice IPM in Cambodia project in Phnom Penh; the Grains IPM for East Africa project in Addis Ababa, Ethiopia; and the Vegetable Crops IPM for East Africa project in Dar es Salaam, Tanzania, Thika, Kenya and Hawassa, Ethiopia.

The Management Entity also organized a *Trichoderma* production and use workshop in Phnom Penh, Cambodia and two *Tuta absoluta* awareness workshops, one each in Phnom Penh and Siem Reap. Dr. Jonathan Eisenback and Dr. Paulo Vieira of Virginia Tech conducted a survey of plant parasitic nematodes of rice and vegetable crops in Cambodia and found that the rice root nematode, *Hirschmanniella mucronata*, was very common in rice fields. They also found the reniform nematode, *Rotylenchulus* sp. on the roots of vegetables, which was the first time this nematode had been reported there. In addition, IPM IL Associate Director Dr. Amar Fayad and Dr. Naidu Rayapati of Washington State University conducted a Plant Virus Diseases workshop at the Royal University of Agriculture in Phnom Penh.

The IPM IL, with the support of the USAID Value Chain project, helped send a team consisting of scientists, extension agents, NGOs and private company representatives from Bangladesh to India so that the Bangladeshi visitors could learn about the biocontrol technologies there. The team visited biocontrol research laboratories, the University of Agricultural Sciences in Bangalore, the Tamil Nadu Agricultural University, along with a private company that produces bio-pesticides and a nursery that uses coconut pith for production of vegetable seedlings. In June, IPM IL Director Dr. Rangaswamy Muniappan and *Parthenium* project PI Dr. Wondi Mersie presented in front of the Virginia Tech Board of Visitors. Dr. Muniappan gave an overview of the work of the IPM IL, and Dr. Mersie spoke about biocontrol of *Parthenium*. In July, the Technical Advisory Committee (TAC) and Program Planning Committee (PPC) meetings were held at the Inn in Virginia Tech in Blacksburg, VA. Dr. Lawrence Datnoff and Dr. George Norton were elected as chairs of TAC and PPC, respectively. The PIs or other representatives from every project attended along with nearly every member of the TAC. At the International Congress of Entomology in Orlando, FL this past September, the IPM IL organized two symposia one on IPM Components and Packages for Tropical Crops and another

on the Global Spread and Management of the South American Tomato Leafminer, *Tuta absoluta*. Scientists from CGIAR and AIRCA centers, FAO, USDA-APHIS, USAID and IPM IL sub-awardees presented papers in these symposia. Additionally, a booth with IPM IL posters and literature was displayed for the nearly 7,000 international participants who attended this congress.

Outside of our own projects, we also enjoyed a fruitful collaboration with the Sorghum and Millet Innovation Lab (SMIL) at Kansas State University. Through our sub-award work with the SMIL in collaboration with ICRISAT-Niger and INRA-Maradi, Niger, it has been proven that the local egg parasitoid in Niger, *Trichogrammatoidea armigera*, will attack the eggs of the pearl millet stem borer, *Coniesta ignefusalis*. Currently, attempts are being made to mass rear *T. armigera* in the laboratory for field releasing to control both pearl millet stem borer and head miner in Niger. This is a very important discovery for food security in Niger. Millet is the staple crop of the country and the pearl millet stem borer is a destructive pest.

We have also been working hard on outreach and spreading our message. Stories involving the work of the IPM IL have been covered by local, national and international electronic and print media such as the Virginia Tech News, the Roanoke Times, the Richmond Times Dispatch, the New York Times, The News Press in Florida, Civil Eats, NPR, Bloomberg News, and the BBC.

Research Progress Summary: Research Project Reports

1. Strengthening production and export of Vietnamese fruit crops through innovative and market-orientated IPM

Principal Investigator: Nguyen, Van Hoa, Southern Horticultural Research Institute, Vietnam

Collaborating Institutions: Virginia Tech, CAB International, University of Florida, Washington State University, Plant Protection Research Institute, Fruit and Vegetable Research Institute, Plant Protection Department, Nong Lam University, Can Tho University, and Vietnam National University of Agriculture

Collaborating Scientists: Dinh Thi Yen Phuong, Le Quoc Dien, Nguyen Thanh Hieu, Trinh Xuan Hoat, Le Xuan Vi, Quyen Dinh Ha, Le Dinh Don, Phan Thi Thu Hien, Ngo Thi Thanh Truc, Nguyen Guy Hung, Dang Thi Kim Uyen, Huynh Thanh Loc, Dang Thuy Linh, Mai Van Tri, Le Cao Luong, Truong Thi Ngoc Chi, Russell Mizell, Maria Elisa Christie, Naidu Rayapati

Description: This project targets four major crops in Vietnam: dragon fruit (*Pitaya*, *Hylocereus* spp.), mango (*Mangifera* spp.), longan (*Dimocarpus longan*) and lychee (*Lychee chinensis*). These four key crops collectively represent the major portion of Vietnamese fruit export to the United State (U.S.) markets. Despite the huge potential, Vietnamese fruit production and export still have many key issues and challenges that need to be addressed. These issues are caused by pests and diseases; limited fruit acreage that are certified under the GAP (Good Agricultural Practices) scheme; poor quality of fruits; and the high costs of post-harvested irradiation treatment and lack of MRLs (Maximum Residue Levels) for the key fruits exported to the U.S. Thus, managing some of the key pests and diseases is pivotal to decreasing losses as well as increasing productivity and export value especially beneficial for the small land holder agro-ecosystem. This project addresses the major production-limiting pests and diseases by developing ecologically-based Integrated Pest Management (IPM) strategies and taking a system in the context of market-driven imperatives for these four targeted fruit crops.

Situational analysis encompassing stock-taking and assessment of current fruit production, pest lists, issues, and effectiveness of prevalent pest management measures.

We interviewed farmers to analyze and assess the production status of longan, dragon fruit, mango and lychee crops.

Longan: 150 farmer households, 4 nurseries and 4 agricultural offices of 5 provinces (Tien Giang, Vinh Long, Dong Thap, Hung Yen and Baria-Vungtau) were interviewed. A total 45 soil samples, 25 longan disease samples and 19 insect samples were collected from these provinces to be analyzed.

Dragon fruit: 120 farmer households in three provinces (Tien Giang, Long An and Binh Thuan) were interviewed and 127 dragon fruit disease samples and 18 soil samples were collected.

Mango: 60 farmer households of two provinces (Dong Nai and Dong Thap) were interviewed. A total 45 soil samples, 25 mango disease samples and 25 insect samples were collected from these provinces to be analyzed.

Lychee: 60 farmer households of two provinces (Hai Duong and Bac Giang) were interviewed. A total 22 soil samples, 13 lychee disease samples and 10 insect samples were collected from these provinces to be analyzed.

In total, 390 households were interviewed. Survey data and general status on the fruit production in Vietnam have been analyzed. The soil samples, disease samples and insect samples were analyzed. Based on this study, the Pest Management Strategic Plan (PMSP) was developed for the four crops (dragon fruit, mango, longan in the South and longan, lychee in the North).

Situational analysis focusing on gender in four value chains (longan, mango, dragon fruit and lychee) in 10 provinces in Vietnam.

Longan: 8 focus group discussions and 14 key informant interviews of women union, producer association, leader of group buyers and traders and wholesalers of 3 provinces (Tien Giang, Vinh Long, Baria-Vungtau and Hung Yen) were interviewed.

Dragon fruit: 6 focus group discussions and 15 key informant interviews of the women's union, producer association, leader of farmer group, buyers/traders and wholesalers of 3 provinces (Tien Giang, Long An and Binh Thuan) were interviewed.

Mango: 4 focus group discussions and 7 key informant interviews of women union, producer association, leader of farmer group, buyers/traders and wholesalers of 2 provinces (Dong Thap and Dong Nai) were interviewed.

Lychee: 4 focus group discussions and 5 key informant interviews of women union, producer association, leader of farmer group and buyers/traders of 2 provinces (Bac Giang and Hai Duong) were analyzed.

In total, 116 women and 168 men were interviewed either in one of 22 Focus Group Discussions or one of 41 key informant interviews of women's union, producer association, leader of farmer group, buyers/traders, and wholesalers of 11 provinces were interviewed.

Implementation of IPM Packages

We used 11 orchards (0.5-1 ha) as field models to test the selected IPM strategies and applied the IPM package for longan (Vinh Long, Tien Giang, Ba Ria-Vung Tau), dragon fruit (Long An,

Tien Giang and Binh Thuan), mango (Dong Nai and Dong Thap) in the South and Hung Yen (for longan), Hai Duong and Bac Giang (for lychee) in the North of Vietnam. In those models, the target pests are being controlled on longan (LWB disease, mite *Eriophyes dimocarpi*, stink bug *Tessarotoma* sp., fruit borer *Conogethes punctiferalis* and *Conopomorpha sinensis*), on dragon fruit (canker *Neoscytalidium dimidiatum*, anthracnose *C. gloeosporioides*, fruit fly *Bactrocera dorsalis* and thrips), on mango (Bacterial black spot *X. campestris* pv *mangiferae*, anthracnose *Colletotrichum* spp., fruit fly *Bactrocera dorsalis*, fruit borer *Deanolis albizonalis*, leaf hopper *Idioscopus niveosparus* and thrips *Scirtothrips dorsalis*), on lychee (Powdery mildew *Peronophthora lichii*, anthracnose *Colletotrichum* spp., stem end borer *Conopomorpha sinensis* and stink bug *Tessarotoma papillosa*). Disease/pest incidence, damage, pesticide residues of fruit, beneficial organism population have been recorded before and after treatments. Soil samples and irrigation water samples of those models were tested.

Identification of the causal agent of Longan Witches' Broom and strategy for management

Longan leaf and branch samples (from both uninfected plants and plants with Longan Witches' Broom (LWB) symptoms) were sent to Washington State University and the National Plant Germplasm Inspection Station, U.S. for identification of the causal agent of LWB. There is not enough evidence from RNA-seq and PCR to identify the causal agent of the LWB. Other than the partial rRNA seqs the 151nt input sequence shows 88-89% nt identity with NCBI accessions of "Tenericutes" to Lethal wilt oil palm phytoplasma. However, all symptomatic samples had negative result by PCR with primers designed to detect longan phytoplasma

Determine LWB spreading method by graft. These results showed that LWB was unable to spread via grafted knots.

Study on role of *Eriophyes dimocarpi* to LWB on longan. The result showed that *E. dimocarpi* was not the direct cause of LWB on longan, rather they were vectors that transmit to healthy young plants.

The diversity of pathogen on anthracnose diseases on dragon fruit and mango

Among 25 disease samples collected, we identified eight isolates of *Colletotrichum* spp. on mango in Dong Thap and Dong Nai. Out of 175 samples collected, we identified 67 isolates of *Colletotrichum* spp. on dragon fruit in three provinces (Tien Giang, Long An and Binh Thuan). These isolates were analyzed.

Morphological, biological, and biotechnological characteristics of plant pathogens *Colletotrichum gloeosporioides* and *Colletotrichum truncatum* causal agent of anthracnose on dragon fruit (in Tien Giang, Long An and Binh Thuan) and Morphological, biological and biotechnological characteristics of plant pathogens *Colletotrichum gloeosporioides* and *Colletotrichum acutatum* causal agent of anthracnose on mango (in Dong Thap and Dong Nai) were recorded. In addition, a phylogenetic tree of causal agent of dragon fruit anthracnose disease was built.

Applications of entomopathogenic nematodes and other beneficial organism to control plant pests

Results from studies on control of fruit borer *Conogethes punctiferalis* by entomopathogenic nematode *Heterorhabditis* sp.: showed that 100% *C. punctiferalis* died in the *Heterorhabditis* sp. treatment compare to 20% death rate of the water control treatment in lab. condition. In addition, establishing artificial medium to rear entomopathogenic nematode *Heterorhabditis* sp. was carried out.

Stink bugs infested by parasitoids *Ooencyrtus phongi* and by entomopathogenic fungus (*Paecilomyces* spp. and *Metarhizium* spp.) were collected in the fields. Method for rearing *O. phongi* is also being developed. The efficacy of *Paecilomyces* spp. and *Metarhizium* spp. to control longan stink bug and mealy bug were investigated in lab and net-house condition.

Twenty isolates of *Bacillus* spp., six isolates of *Streptomyces* sp., five isolates of *Paecilomyces* spp., four isolates of *Metarhizium* spp. and one *Trichoderma* sp. isolate were collected from the orchards of dragon fruit, mango and longan in Tien Giang, Long An, Dong Thap and Vinh Long. In addition, effects of four kinds of nutrient medium to the growth and development of *Paecilomyces* spp. fungi was performed. Effect of *Streptomyces* sp. and *Bacillus* spp. on *Colletotrichum truncatum*, *Colletotrichum gloeosporioides* on dragon fruit in lab. conditions were assessed.

Efficacy of *Amblyseius* spp., *Paecilomyces* spp., garlic extract and onion extract have been studied on the management of longan mite *Eriophyes dimocarpus* that transmits LWB disease. Study on effect of plant extracts for controlling *Aspidiotus destructor* Signoret (Hemiptera: Diaspididae) on mango crop was conducted.

Design and selection of the suitable types for fruit bagging for dragon fruit and longan

Dragon fruit: The effect and the use of fruit bags that were made from ten different materials were analyzed for dragon fruit production. Among these ten materials, Taiwanese paper and Vietnamese white chiffon cloth (“vải voan trắng”) provide better protection for dragon fruits against canker (caused by *Neoscytalidium dimidiatum*) and anthracnose diseases (caused by *Colletotrichum* spp.) and no adverse effect on the fruit quality. Dragon fruits bagged by Taiwanese paper at 18 days after blooming were protected against canker and anthracnose diseases. In addition, these bagged fruits had bright skin color and nice bracts. Even though dragon fruits that bagged by the white chiffon cloth did not have bright skin color, the canker and anthracnose diseases were limited. Furthermore, chiffon bags allowed dragon fruits were bagged at 12 days after blooming that earlier than Taiwanese paper bagging six days. The earlier bagging the better disease controlling. It is inexpensive, easy, and ecofriendly to bag dragon fruits with chiffon bags.

Longan: Selection of six different materials of fruit bags on longan crop to control insect pests were carried out at Hoa Ninh commune, Long Ho district, Vinh Long province.



Dr. Maria Elisa Christie with a fruit grower in Vietnam

2. Innovative Scientific Research and Technology Transfer to Develop and Implement Integrated Pest Management Strategies for Vegetable and Mango Pests in Asia

Principal Investigator: George Norton, Virginia Tech

Collaborating Institutions: Virginia Tech, Penn State University, Ohio State University, North Carolina A&T, Washington State University, Bangladesh Agricultural Research Institute, Dhaka University, iDE Nepal, National Agricultural Research Council, Agricultural and Forestry University, Himalayan College of Agricultural Sciences and Technology (HICAST), the Center for Environmental and Agricultural Policy, Research, Extension, and Development (CEAPRED), iDE Cambodia, Royal Agricultural University

Collaborating Scientists/Researchers: George W. Norton, Megan O'Rourke, Maria Elisa Christie, Edwin G. Rajotte, Cristina Rosa, Sally Miller, Manny Reyes, Naidu Rayapati, Yousuf Mian, Shahadath Hossain, M.S Nahar, M. Masud, M. Hoq, Luke Colavito, Sulav Paudel, P. Sharma, B. Mahto, Michael Roberts, Seng Kimhian, N. Chhay, Khun Kimkhuy

Description: The Asian Vegetable and Mango IPM IL program implements ecologically-based, participatory IPM in Cambodia, Nepal, and Bangladesh, with a focus on pests of tomato, eggplant, cabbage, cauliflower, beans, cucurbits, Chinese cabbage, onion, and mango (the latter only in Bangladesh).

Cambodia

Field trials were established for Chinese kale and cucumber for the growing season (wet season) that began in early June. IPM packages for the two crops are being tested with 12 cooperative farmers in Soutr Nikum, Pouk, and Siem Reap districts. Three experiments including the effects of *Trichoderma* on Chinese kale and cucumber and of *Ralstonia solanacearum*

rootstock tolerance are being tested by our scientists and students at the Royal University of Agriculture (RUA) in Phnom Penh. These experiments are being implemented by five students under the supervision of an entomology lecturer and a plant pathology lecturer from the RUA Agronomy Department.

Insects and diseases of tomato were also monitored in farmers' fields in Siem Reap. A baseline survey questionnaire and protocol was prepared and will be implemented in January to assist with further prioritization and impact assessment, including gender impacts. A workshop was conducted at RUA that included lectures on plant virus diseases affecting vegetable crops in Cambodia and practical aspects of management of viral diseases, with hands-on demonstration of diagnosis of plant viruses based on symptoms and serological assays.

Two workshops were completed to raise awareness of the South American Tomato Leafminer, *Tuta absoluta*, one in Phnom Penh and other in the Siem Reap province. The workshops were prepared in close collaboration with the General Directorate of Agriculture (GDA), particularly with Department of Plant Protection, Sanitary and Phytosanitary. Both workshops were chaired by Mr. Srun Sokhom, Deputy Director General of GDA. There were 45 participants from all departments and laboratories under GDA, the three agriculture universities under the Ministry of Agriculture, Forestry and Fisheries, and the Cambodian Agriculture Research and Development Institute (CARDI). The universities were RUA, the National School of Agriculture Preaek Leap, and the National School of Agriculture Kampong Cham. Representatives from several NGOs also attended the workshop. At the sub-national level, there were 40 participants from six Provincial Departments of Agriculture (PDAs), including all four Feed the Future provinces: Siem Reap, Battambang, Kampong Thom, and Pursat and two neighboring provinces: Oddar Meanchey and Banteay Meanchey. Representatives from all 12 district offices of Agriculture in Siem Reap province were invited together with people from NGOs such as CARITAS, ADDA, AGRISUD and CADF-iDE. A monitoring and management strategy for *Tuta absoluta* in Cambodia was developed and a National Network Committee will be formed under the leadership of GDA.

Bangladesh

(1) Management approach for mango fruit fly -- An experiment was conducted in farmers' fields in three locations: Gazipur, Rajshahi, and Chapainawabgonj from February to July 2016 to assess the optimal control measures for managing mango fruit fly. Results indicated that bagging of mango with China brown paper bags reduced fruit fly infestation and increased marketable yield the most, but a protein hydrolysate bait trap followed by a methyl eugenol pheromone trap provided the greatest net economic benefits.

(2) Monitoring of tomato leafminer -- An extensive survey was completed in farmers' fields in Jessore, Comilla, and Panchagorh to monitor the presence of tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) from April to August 2016. In May 2016, the tomato leafminer, *T. absoluta* was trapped in the tomato field at Panchagorh district. This is the first record of *T. absoluta* in Bangladesh and its identity was confirmed at Arizona State University,

USA. The *Tuta* incidence was low at the location, but the invasive species may spread to other regions of Bangladesh and cause serious crop damage in future.

(3) Biology, yield loss, and integrated management of white mold of country bean – The objectives of this activity were to collect isolates of *Sclerotinia sclerotiorum* for study and to test the effectiveness of fungal and bacterial antagonistic agents against white mold pathogen. (in vitro). Several types of interactions between the pathogen (*S. sclerotiorum*) and antagonistic agents were observed. An interaction between *Bacillus amyloliquefaciens* Egg 25 and the pathogen was noted as Grade 2 type (intermingling growth where the pathogen being observed in the bio-control agents are either above or below its colony). The interaction between *Bacillus subtilis* PB18 and *S. sclerotiorum* on PDA media was also noted as Grade 2 type. The interaction between the pathogen and *Pseudomonas* sp. was Grade 3 type (intermingling growth where the pathogen under observation has ceased the growth and is being overgrown by bio-control colony), and interaction of pathogen with *Bacillus subtilis* B20 was recorded as Grade 4 type (slight inhibition with a narrow demarcation line (1-2 mm)). The interaction between *Trichoderma* isolates and the pathogen was noted as Grade 3 type. All antagonistic agents regardless of fungus (*Trichoderma*) and bacteria (*Bacillus* and *Pseudomonas*) significantly reduced radial growth of *S. sclerotiorum*. In the case of bacterial antagonism, the minimum radial growth of *S. sclerotiorum* towards antagonism was recorded in *Bacillus subtilis* B20 followed by *Pseudomonas* sp., *Bacillus subtilis* PB18 and *Bacillus amyloliquefaciens* Egg 25. The radial growth of *S. sclerotiorum* was the maximum in the control (in absence of an antagonistic). In the case of fungal antagonism, radial growth of *S. sclerotiorum* towards *Trichoderma viride* and *T. harzinum* was the minimum on PDA media. However, the radial growth of *S. sclerotiorum* was higher in the presence of *Trichoderma virens*, although it was significantly lower than in the control treatment. Radial growth of mycelium of *S. sclerotiorum* was inhibited by 93.42%, 92.25%, 67.50%, 61.65%, and 50.83% in *Bacillus subtilis* B20, *Pseudomonas* sp., *Bacillus* sp. BVC38, *Bacillus subtilis* PB18 and *Bacillus amyloliquefaciens* Egg 25 treated dual culture petri-plate, respectively.

(4) Suitable rootstock for grafting tomato to combat bacterial wilt and development of an IPM package for summer tomatoes – An assessment of the suitability of three alternative rootstocks was conducted along with a non-grafted control and evaluations were made for their susceptibility to bacterial wilt-BW (*Ralstonia solanacearum*), virus (transmitted by *Bemisia tabaci*), and root knot nematode-RKN (*Meloidogyne* sp.) as measured through grafting success, seedling survival, survival under field conditions (percent plant stand), and yield. The treatments also included ones with and without a tomato IPM package for summer tomato production. The trial was conducted in farmers' fields, at the vegetable research farm of the Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur, and in Dhunat, Bogra during the summer season. The maximum percent of grafting success, seedling survivability and plant stand was for tomato grafted with BARI Brinjal 8. The same treatment also gave higher fruit yield and lower disease incidence. In the farmers' field trial, the highest average tomato yield per tunnel was obtained from the IPM practice. There were 5.0 to 21.0% virus infestations recorded irrespective of grafted and non-grafted seedling at 45-90 DAS. No bacterial wilt was observed in grafted-seedling-based treatments with IPM practices.

(5) Impact assessment – Two PhD students have completed their data collection and are in the process of analyzing their data to assess impacts of vegetable packages on income and pesticide use.

Nepal

Trials and other activities included evaluation of anaerobic control of soil diseases in the nursery bed, area wide lures were tested for *Spodoptera*, *Helicoverpa*, and *Tuta*, *Leucinodes* along with *Tuta Absoluta* monitoring. An ESFB management trial was conducted. Pest survey/monitoring was conducted for onion and capsicum/chili to help us decide on the IPM package for next year. Efficiency evaluation of various *Trichoderma* products available in the Nepalese market was conducted. Study of the temporal and spatial distribution of major insect pests like EFSB, *Helicoverpa*, *Spodoptera*. A PhD student from Tribhuvan University conducted a baseline survey for use with impact assessment.

Lessons Learned

Scaling-up IPM diffusion requires close collaboration among our public and private sector partners who address vegetable and mango technology diffusion. *Tuta absoluta* continues its spread through South Asia and is likely to reach South East Asia, including Cambodia, by next year. In Nepal, pest monitoring data generated need to be correlated with weather and the cropping season and a *tuta* action plan created. *Tuta* survey data collection needs to be expanded in close collaboration with NARC, and subsequently a research component undertaken for *tuta* management. Efforts to work out a mechanism to bring about that collaboration are needed. New field trials should be set up to target a *Tuta* IPM package.

Institutional Development

Host country agricultural research and educational institutions (BARI, Dhaka U, and BAU in Bangladesh; GDA, RUA, and Battambang U in Cambodia; NARC, AFU, Tribhuvan U in Nepal) were involved in the IPM implementation along with appropriate NGOs and private sector companies. Students from RUA, BAU, AFU, HICAST, and Tribhuvan U are involved in thesis research. Procedures for IPM planning and implementation, including experimental design and field surveys were strengthened in the host country institutions. Partners -- BARI, Dhaka U, Isphani, and BAU in Bangladesh; iDE-Cambodia, GDA, RUA, and Battambang U in Cambodia; iDE-Nepal, NARC, AFU, Tribhuvan U, HICAST, Agricare, and CEPRED in Nepal

Scaling Partnerships

Meetings and agreements to cooperate from public sector extension agencies, private companies, and USAID Feed-the-Future Agricultural Value Chain projects in each country

Partnerships made – USAID HARVEST and New Zealand CODES projects, GDA (Cambodia), USAID AVC, Department of Agriculture Extension, Isphani (Bangladesh), USAID KISAN, ENBAITA, and PAHAL projects, Agricare, Dept of Agriculture (Extension), Tribhuvan U., AFU. HICAST, Nepal

Technology Transfer

Technologies Transferred -- *Trichoderma* use in Bangladesh and Cambodia.

Technologies scaled – Tricho-compost for several vegetables for soil disease control, pheromone traps for gourds and eggplant for fruit flies, grafting for control of bacterial wilt and nematodes, sveral IPM packages.

Technologies ready to scale – Anaerobic soil disinfectant technique in the nursery bed.



Associate Director Dr. Amer Fayad in Cambodia to conduct a workshop on plant viruses and diseases.



Dr. Jon Eisenback conducting a nematode survey on vegetables in Cambodia

3. Participatory Biodiversity and Climate Change Assessment for Integrated Pest Management in the Annapurna-Chitwan Landscape, Nepal

Principal Investigator: Nir Krakauer, CUNY City College

Collaborating Institutions: Tribhuvan University, Agriculture and Forestry University, City College and Queens College—CUNY, Institute of Global Agriculture and Technology Transfer (IGATT)

Collaborating Scientists: Ajay Jha, Pramod Kumar Jha, Mohan Siwakoti, Bharat Baby Shrestha, Anjana Devkota, Sanjay Kumar Jha, Sundar Tiwari, Min Raj Pojhrel, Naba Raj Devkota, Mohan Sharma, BR Ranabhat, Tarendra Lakhankar, José Daniel Anadón, David Lohman

Description

Nepal now ranks second in Asia and one of the top 20 countries in the world for the percentage of its surface area that is protected for biodiversity conservation. It holds around 3% and 1% of the world's flora and fauna species respectively. There are 118 ecosystems and 75 vegetation types in Nepal. Many species are under threat due to increasing population (with 1.35% per year), climate change, and biological invasion.

GPS and GIS Training

Training on GPS handling and map preparation using GIS was organized for MSc and PhD students between July 19-20, 2016 by Dr. Ram Asheshwar Mandal at Central Department of Botany, Tribhuvan University, Kirtipur, Nepal. The main objective of the training was to transfer knowledge and skills about the handling GPS and GIS so that students would be able to collect and generate research data efficiently and effectively and map the research sites. The training had two sections. The first was focused on the handling of GPS and collecting the coordinates of the field sites. The second part was focused on the preparation of maps applying ArcGIS software. Students learned to use GPS to capture the data in the field and prepare maps.

SPSS training:

The training started on August 20, 2016 and lasted for two days with an introduction from Professor Pramod Kumar Jha and technical input from Dr. R. A. Mandal. This training helped students apply statistics in their research work. Discussion and interaction allowed students to learn more about the application of Statistical Package for Social Science (SPSS), along with hands-on practice. The training was divided into two parts. The first part emphasized discussion on application of statistics, while the second part of the training was for the use of SPSS. Students raised several inquiries during the training, like the use of parametric and non-parametric tests and regression.

The field visit took place from April 7 to 10, 2016 at Gaidakot – 8, Fulbari, Mangalpur, Jaynagar and Kawasoti in Nawalparashi, Chitwan, Kapilwastu, and Nawalparashi districts. In total 25, 19, 15 and 11 participants attended at Fulbari, Mangalpur, Jaynagar and Kawasoti respectively. The main objective of this visit was to familiarize farmers and district stakeholders with the project

activities. The field coordinators Dr. Ram Asheshwar Mandal and Mr. Praseed Thapa both visited these sites and shared the project activities.

Field level training for farmers at Gaidakot and Fulbari

Two training events were conducted for farmers specifically focusing on orientation about the project. The first training was done on April 7 at Gaidakot, Nawalparasi and the second at Fulbari, Chitwan on April 8. There were 20 participants in each training. The training was coordinated by Mr. Basant Rana Bhat and facilitated by Professor Mohan Sharma, Dr. Ram Asheshwar Mandal, and Mr. Praseed Thapa. The training curriculum included climate change and its impacts, and damage due to crop insects and pests and their management. These same participants also attended a training on “climate change and biological invasion.” The resource people were Professor Mohan Sharma, Dr. Ram Asheshwar Mandal and Mr. Praseed Thapa (see annex 6.a and 6.b).

Orientation training at Kawasoti, Chitraban and Gorusinghe

Three trainings were organized for farmers from May 18-20, 2016 at Kawasoti, Bhimnagar Chitraban and Gorusinghe in Nawalparashi, Chitwan and Kapilwastu districts, respectively. Eighty-three participants participated in the training in these sites; 58 female and 25 male. The purpose of the training was to familiarize the farmers with the impacts of climate change and biological invasion. Professor P.K. Jha, Prof. Mohan Sharma, Prof. Nabraj Devkota, Dr. Ram Asheshwar Mandal, Mr. Basant Ranabhat and Mr. Praseed Thapa were the resource people in the training.

Training for famers at Chyang Chyangdi and Puranchaur

Two orientation trainings were organized at two different places between June 17-18, 2016. These trainings were organized at Chyang Chyangdi and Puranchaur in the Syangja and Kaski districts respectively. The focus of this training was to transfer knowledge about climate change impacts and the effects of insects and pests in daily life. This training also served as a preparation for the household survey. It also included a session about the scope of the USAID project. The resource people were Dr. Ram Asheshwar Mandal, Mr. Basant Rana Bhat, and Mr. Praseed Thapa. There were 60 participants in this orientation training program, thirty at each site (Chyang Chyangdi and Puranchaur).

Baseline survey

The baseline survey is an important part of the project activities and this work was completed in three phases. The first phase was focused on the preparation of the questionnaire and orientation on the survey. The second phase was focused on household survey and third phase includes data entry and processing.

Dr. Durga Devkota prepared the questionnaire with other research team members. A one-day orientation workshop for the students was conducted on June 7, 2016 about surveys. Baseline surveys were done at all project locations: Kawasoti and Gaidakot of Nawalparasi district,

Bhimnagar and Fulbari of Chitwan district, Gorusinghe of Kapilbastu district, Changchangdi of Syanja district and Puranchaur of Kaski district. After the completion of the survey, the data were entered and submitted to Dr. Nir Krakauer, Dr. Ajay Jha, and Dr. P. K. Jha on September 30, 2016.

Report submission about women and enterprise

Ms. Anuskha Bansal, a student from the Jabaharlal Neharu University in New Delhi, India, did her research work in Nepal between June 27 to July 9, 2016 as an internship. Her research topic was “Women empowerment through enterprises in Nepal.” She worked and interacted with personnel from the WWF, Hariyoban, iDE, CARE Nepal, and NEDC. She visited women-owned enterprises in the Lalitpur and Nawalparashi districts of Nepal. Her field visits were at i. Chisapani, Nawalparasi, where women are involved in growing lemongrass, cetrenerala, and plamarosa to produce oil and sell; ii. Lele, Lalitpur, where women were involved in organic vegetable farming businesses; and iii. Dumkibas, Nawalparasi, where women are generating income from milk production and dairy.



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

PI: Buyung Hadi, International Rice Research Institute (IRRI), The Philippines

Description: EPIC aims to develop a rice IPM package validated for Cambodian biophysical conditions and co-designed with Cambodian rice value-chain actors. The validated rice IPM package will reduce pre-harvest loss due to pests, weeds, and diseases, and the levels of pesticide use in rice production by using cultural methods, host-plant resistance, and biological control tactics (both conservation and augmentative biological control). Pesticide use will strictly be limited to areas where no other options are effective. Area-wide implementation of the tactics will be achieved through community organization (e.g., for a trap barrier system) or by involving market actors (e.g., agricultural input providers, policymakers) to promote the availability of IPM products.

Between April and September 2016, the EPIC project trained public researchers in Cambodia on identifying rice pests, weeds, and diseases in the field and in the laboratory. The training activities took place as a four-day course at the Cambodian Agriculture Research and Development Institute (CARDI) as well as on-the-job training in Cambodia and at IRRI. The knowledge gained through these training activities was promptly utilized to conduct an in-depth rice health survey in the four target provinces in Cambodia. The survey was enriched by viral and nematological sampling facilitated by the IRRI virology group and Virginia Tech, respectively. The results of the survey are currently being compiled and analyzed.

EPIC, in collaboration with GIZ, has successfully conducted a two-day biocontrol agent forum in Cambodia. Attended by more than 140 participants, the forum raised awareness of biocontrol options in rice and vegetable production in the country and served as a discussion platform for registration and regulation of biocontrol products in Cambodia.

Baseline survey

Impact baseline and pesticide knowledge, attitude, and practice (KAP) surveys were completed in collaboration with CEDAC (Centre d'Etude et de Développement Agricole Cambodgien), Virginia Tech, and Cornell University. A baseline survey was conducted to identify the farmers' report on priority pests, pest management practices, knowledge of IPM, extent of current rice IPM adoption, pesticide use practices, and characteristics of the farmers. The survey was conducted in intervention villages (implemented by Rica Flor, IRRI postdoc) as well as the surrounding villages (implemented by Sidney Jackson, student at Virginia Tech) in the provinces of Takeo, Prey Veng, Kampong Thom, and Battambang. A total of 800 farmers were surveyed, more than one-third of whom are female.

Pests identification Training

Hands-on courses on field identification of pests, weeds, and diseases, and on impact assessment was conducted. Course participants included not only the project's government but also representatives from the national university (Royal University of Agriculture) and CABI. A total of 35 participants were trained on critical rice pest research and management. In addition, the hands-on courses and on-the-job training also improved the institutional capacities of the main government partners (CARDI, GDA, PDA).

Biocontrol forum

More than 140 participants attended the two-day public forum and demonstration on biocontrol agents in Cambodian crop production. The forum raised awareness on the use of biocontrol agents as an alternative method for crop protection in Cambodia. A focus group discussion was also conducted to map out the potential beneficiaries and stakeholder impact of the introduction of biocontrol agents in the market.

Lessons learned

1. Data from the baseline survey from intervention villages have been digitized and are currently being analyzed. The following are some preliminary findings from the survey at the intervention villages:

- Farmers reported that weeds and diseases are the main problems in the intervention villages in Battambang, insects and diseases in Kampong Thom and Prey veang, and snails and rodents in Takeo.
- In the wet season, fungicides are the most frequently used pesticide (a maximum of 16 applications per season), whereas insecticides are the most frequently used in the dry season (a maximum of 24 applications per season).

The data other villages (those surrounding the intervention villages) will be summarized and analyzed. The data will be used in an MS thesis to assess factors influencing IPM adoption and pesticide use.

2. Field experiments on *Trichoderma* in irrigated rice against pests, weeds, and diseases

The field experiments started in August 2016 and are designed to investigate the effects of *Trichoderma* and blast tolerance on disease symptoms as well as on insect populations and associated pest injuries across the season. The data from these experiments will be used by Chou Cheythirith, GDA national IPM program coordinator, to satisfy the dissertation requirement for a PhD degree at Nagoya University.



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

PI: Abhijin Adiga, Biocomplexity Institute, Virginia Tech

Description: The long-term goal of this project is to develop an integrated modeling framework representing the spread of invasive pests, and apply it to study the spread of the two leafminers: the South American tomato leafminer, *Tuta absoluta*, and the groundnut leafminer, *Aproaerema modicella*.

FAO has released tomato trade data detailing the volume of tomatoes traded between different countries (<http://faostat.fao.org/>). However, each data point is reported by both the exporting country as well as the importing country. This creates a conflict in the construction of a network to model this trade. We have produced tables and plots comparing the characteristics of the network generated by import data to the characteristics of the network generated by the export data. To circumvent this issue, we decided to combine these two datasets and created a maximal graph which, upon conflicting trade information, uses the largest volume of tomatoes traded. Similarly, we created a minimal network. Under the hypothesis that trade is an important pathway for the spread of the pest, these two networks represent the worst-case and best-case scenarios respectively. Also, it is to be noted this analysis was conducted for other vegetables as well (peppers, eggplants, and potatoes).

We studied several properties of all these networks constructed. We studied in-degree (a country's imports), out-degree (country's exports), betweenness centrality (a measure of vulnerability or how well a country is connected), etc. For each node trait we studied, for a given network, the countries were ranked based on their importance with respect to the trait. In this manner, networks were compared by comparing the Jaccard Index between the top ranked countries in each trait for two different networks. A similar measure was calculated by comparing the absolute difference in values for each country node's ranking from one network to another.

In addition to trade networks, we have also constructed networks representing connectivity of seaports, airports and migration flows. Compared to the international trade matrix construction, these are hard to construct. These require integration of data from multiple sources. For example, working under the hypothesis that the length of the journey of tomatoes over the sea affects the ability of the virus to spread, it became necessary to construct a network with approximations for the length in terms of both distance and speed for crops to travel from water-separated countries. We created a program which scraped this information from an online website (<http://ports.com>) which stores this information. Similarly, for air travel, we used data from (<http://openflights.org/data.html>) to construct airline network. There have been several works which estimate passenger travel from one country to another, and this is a very non-trivial task. In our case, it is harder considering that we are interested in the population which is closely associated with vegetable production and transport.

Another important consideration has been incorporating domestic production volume for each country into the analysis of community and trade structure. We constructed scatter plots of different node traits against that country's production data to visualize and detect any trends or correlations between a country's node trait and the amount it produces. This is guided by the

hypothesis that a country's domestic tomato production is in some way related to its international trade presence. The figure below provides an indication of countries that are at the highest risk from *Tuta absoluta* based on their economic and societal dependency on tomato production and vulnerability in the network.

Understanding community structure of trade networks is one of the most important motivations for this project. Previously, from the perspective of network structure, we explored two extremes: on one hand we looked at the global properties of the network and on the other, the focus was on the individual nodes and edges, their local interactions as well as role in the network. Here, we dig deeper into its structure to see if there are any interesting patterns in the way groups (clusters or communities) of countries trade with each other, and with the rest of the world. How do we define a community? What is its role in the market and the spread of the pest? How independent are they from external trade influence? As a community, how vulnerable is it to invasion? Is there a correlation between geography and community membership? How does community structure vary across vegetables? We applied several clustering algorithms to mine communities in the trade network. Below is a picture of communities unraveled by one of our community detection algorithms for the tomato network. Note the high geographic correlation in the community structure.

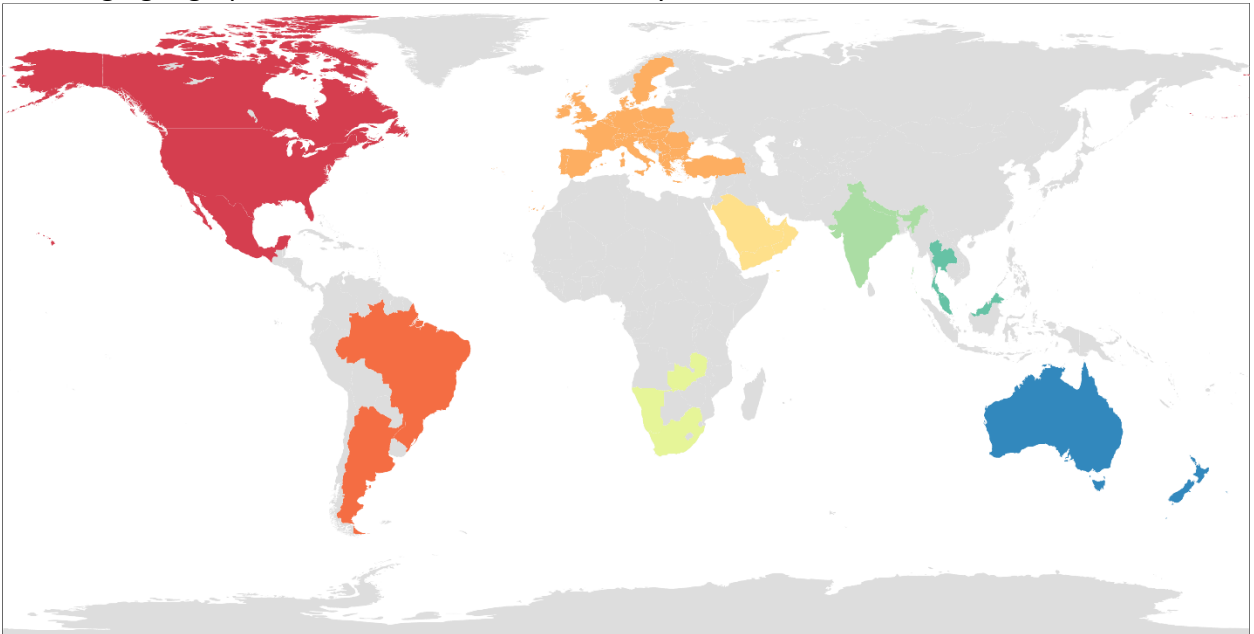


Figure 1: Communities in the tomato trade network. Each community has little trade interaction with the rest of the world, but considerable interaction within.

We studied the hypothesis that trade unions and agreements such as NAFTA are correlated to community structure. That is, that the existence of a trade agreement between a set of countries suggests that set is more likely to be a community in a tomato trade network.

In addition, we have developed several visualization programs to aid in the analysis of the data. These include heatmaps, network visualization, etc.

Dynamical analysis of the international trade network (experimental design on Netlogo Pest Spread Model)

To investigate the critical role played by human activities in *Tuta absoluta* spread, we created an international tomato trade network diffusion model using Netlogo. Netlogo is an agent-based programmable modeling environment that supports applications across domains. The model uses two major data inputs: FAO tomato export matrix and latitude and longitude values for points representing each country. A snapshot of the resulting framework is shown in Fig. 6. The framework allows the user to set the rate of invasion, delay in becoming infectious, and time it takes for a node to recover (if at all). It also provides flexibility use various versions of the network. The user has the option to set infection rate to be directly proportional to the trade volume, a logarithmic function of trade volume or even completely disregard it and use an unweighted network. It also has the ability to discard edges below a particular volume. Using this framework, we ran experiments for various combinations of the above mentioned parameters using a factorial design. Then, we employed a more rigorous approach for validation of the simulation model. Validation involves exploring the model parameter space and therefore requires systematic experimental design. However, since Netlogo environment only provides full factorial design, this is not feasible when the parameter space is large. FUSE is a general computational framework developed in our lab for supporting uncertainty quantification, sensitivity analysis and experimental design, it can accommodate a multitude of simulation models seamlessly and handle the experimental design, model execution, and data management automatically. We coupled FUSE with the simulation model develop in Netlogo and such integration enables advanced sparse experimental design techniques such as Latin Hypercube Sampling and sensitivity analysis of the model parameters. This extension of experimental design module can also be a potential contribution to the Netlogo open source community.

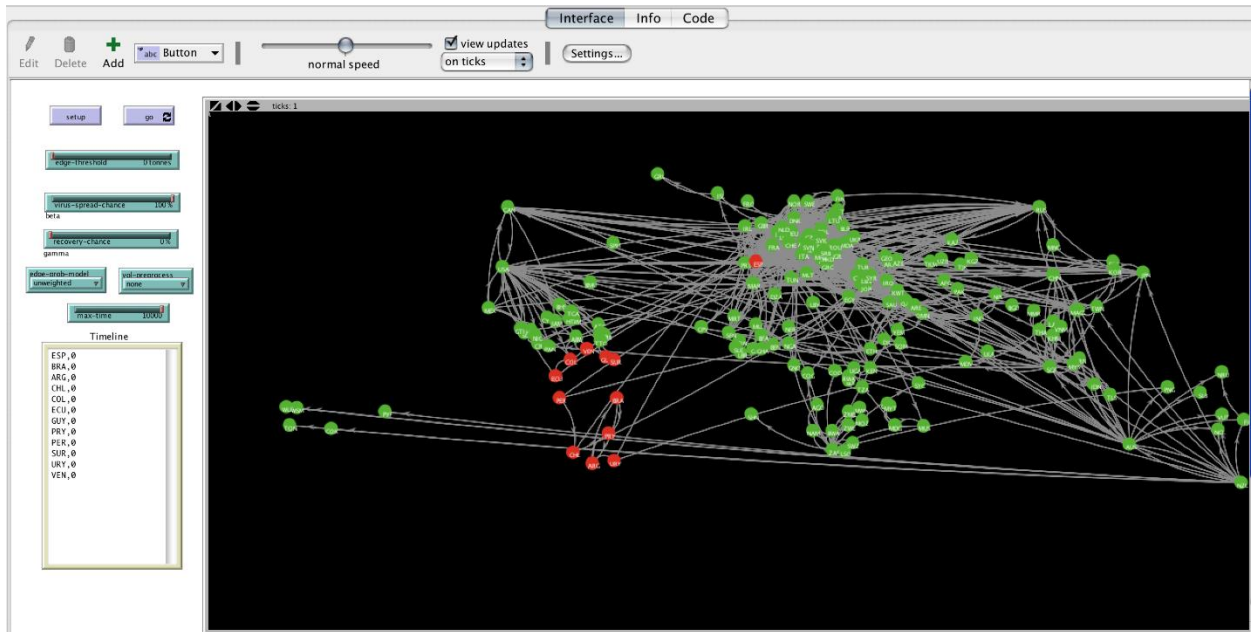


Figure 2: Netlogo implementation of SEIR diffusion models for international trade network. Each node in the network corresponds to a country and edges represent exports from one country to another.

Economic impact modeling

We are developing a framework for assessing the economic impact of *Tuta absoluta*. There are various components that are needed for conducting this analysis:

- a. map of the host presence,
- b. a pest risk map which itself depends upon the climate, pests' current locations, and a pest diffusion model,
- c. current production and yield by region/county/district
- d. market price of tomatoes,
- e. price elasticity of demand,
- f. price elasticity of supply,
- g. loss in production due to the pest and
- h. the cost of intervention if any.

The current area of focus is Nepal where *Tuta* invasion has recently been confirmed. We are collecting data from a variety of sources in Nepal to instantiate the parameters in our modeling framework. For calculating the direct economic impact, we use the partial budgeting approach and apply it at a district level. For a more comprehensive impact analysis we apply the partial equilibrium approach, which calculates the change in social welfare due to *Tuta* infestation. The partial equilibrium approach measures the shift in tomato supply curve for each district and calculates the new aggregated supply curve. The new aggregated supply curve changes the equilibrium, clearing price and impacts the producer surplus and the consumer surplus. The consumers' surplus is measured by the difference in the willingness to pay by the consumers, as reflected in the demand function, and the market clearing equilibrium price. Similarly, producers' surplus is measured by the difference in the equilibrium price and the cost of

production, i.e. profits. We assume non-linear demand and supply curves with constant price elasticities of demand and supply respectively.

We also consider two host models, one where host is assumed to be uniformly present in a district and the other where the host is present according to the tomato crop data. This assumption affects the diffusion model for the pest and hence the pest risk probabilities in each district. These pest risk probabilities along with the crop distribution in each district determine the area affected by the pest. The models are adapted from (Soliman et al., 2012).

Pest Spread Modeling in Nepal

We surveyed existing literature for short distance spread of pests. Several candidate modeling methods were explored. Finally, we chose (Guimapi et al., 2016), a very recent paper on modeling the spread of *T. absoluta*. In this, the authors developed a cellular automata-based model for the spreading behavior of *Tuta absoluta* in several African countries. We plan to create a similar model for Nepal. The model construction procedure is described as follows. First, the area under study is divided into square regular lattice of 25x25sqkms to characterize each individual cell of the cellular automata. Each cell can be in one of the three states: susceptible, exposed, and invaded. During the simulation, the susceptible state can become either exposed or invaded. Exposed state means the corresponding region has been passed by *Tuta absoluta* but has not been invaded. The invaded state denotes the region has a high risk of permanent establishment of the pest. We consider factors including land vegetation cover, temperature, relative humidity and yield of tomato production. Cell state transition happens when predetermined threshold values of the factors are reached. Currently, we have collected the necessary data for the model construction. The normalized difference vegetation index (NDVI) is a widely used metric of land vegetation cover rate. NDVI for the study area was downloaded from NASA Earth Observations (NEO) website (<http://neo.sci.gsfc.nasa.gov/>). Temperature values were obtained from the WorldClim Relative humidity data was retrieved from the NASA Atmospheric Science Data Center website (<https://eosweb.larc.nasa.gov/>). And the tomato production information was from the website of Ministry of Agricultural Development of Nepal (Nepal, 2009). Eventually, this model will be used to predict year-to-year risk of the invasion and spread of *Tuta absoluta* across Nepal, and also applied to other regions such as Bangladesh and the United States.

Domestic commodity flow

In order to study the flow of tomato or any fresh vegetable on an interstate/county level, we need to construct a commodity flow network which has shipment values for that commodity for origin destination pairs in respective geographical scale. One such example of a commodity flow network is the Commodity Flow Survey (CFS 2007) which is part of the economic census conducted by U.S. Census Bureau and U.S. Department of Commerce (DOC), partnered with the Bureau of Transportation Statistics(BTS) and the U.S. Department of Transportation. The CFS data contains shipment weight, tonnage, value across origins destination pairs of FAF zones. The Federal Highway Administration Freight Analysis Framework, Version 3 (FAF3) is a database

available publicly providing shipment estimates both in terms of weight and value (in million dollars) for 131 geographical regions (FAZs) and 43 commodities as classified by SCTG (Standard Classification of Transported Goods) and seven to eight modes of transportation. Our focus is on creating a similar commodity flow network which is generic enough (in terms of data requirement) so that it can be produced for any country where we wish to study the spread of *Tuta Absoluta* through interregional trade.

Experiments: The datasets at our disposal consists of CFS (2012), AgCensus, NASS, Vegesumm and AMS datasets. The AgCensus consists of statewide and countywide tomato planted and harvested. The Vegesumm dataset consists of statewide data for acreage, production, yield per acre, price per cwt, area planted. The AMS dataset consists of origin destination shipment values of tomato by months. In the AMS dataset, the origin destinations are major state markets. The problem with Vegesumm and AMS both is that they are very incomplete and do not cover all the states or markets. In the preliminary analysis we used three datasets AgCensus, Vegesumm, and AMS. The main motive of the preliminary analysis was to study the interaction between the variables stated above, especially the interaction between the outbound shipment and the inbound shipments with the production, acreage, yield per acre, area planted and area harvested. The correlation plot between all the variables showed that the shipment variable is very highly correlated with the production, area planted, and area harvested variables. The price per cwt was negatively correlated with those variables. Since the production variable was highly correlated with the area planted and harvested variables, a linear regression model was run using AgCensus data which has the area harvested and planted data for all the states to learn the production values for all the states. Then with area planted and production data for all the states and using shipment data from the AMS dataset shipment for all the states were produced, in a semi supervised way using a linear regression model. Next we plotted some heat maps to show the distribution of tomatoes in United states, along with the heat maps of other commodities in SCTG 03, which includes potatoes, onions, lettuce, leguminous plants and other fresh vegetables to see how they are distributed through the states. This will help us to decide whether the distribution of crops across the states are uniform and whether proportional weighting for commodity specific disaggregation is feasible.

Future Direction: Next we will model the production and attraction factors specific to the commodity of our interest, tomato. Disaggregating the FAF data countywide for tomato would be a good motivation for proceeding ahead. Moreover, understanding the dynamics and the supply and demand of tomato will also help us generate such commodity flow networks for other countries for which such rich commodity flow surveys are not available. Most of the papers while using regression models, Direct Regression and Optimal Regression, for estimating the flows tend to avoid the autocorrelation effect. Including the autocorrelation model in our network would make it more realistic. Moreover, we tend to make as less assumptions on the availability of datasets as we can make, so that our model is generic enough to create commodity networks for as many countries as we want with minimalistic data requirements. For validating a model, we can use commercially available TRANSEARCH and TransCAD databases. Once we have such interregional commodity flow networks, we can perform our analyses of spread of *tuta absoluta* on them. Running diffusion models on top of these

networks would simulate the spread of pests in real world if they enter the regions on which these networks are built upon.

Groundnut leafminer

Meetings were held with the IPM Innovation Lab and Troy Anderson of the University of Nebraska, Lincoln, for possibility of conducting gene sequence analysis, gene annotation, gene prediction, and phylogenetic tree building and viewing of groundnut leafminer samples to be collected by this project. This task addresses topic T5. We have received quotes from NSF CIPM and UNL in this regard.

Biopass, Senegal

Since its first detection in Senegal in 2012, the invasive tomato leaf miner has become a real threat for the continued production of tomatoes in the whole West Africa. A nationwide trapping network showed that *T. absoluta* populations were present throughout Senegal in 2015. Abundance of trapped moths was greatest on the coastal part of Senegal, including the main tomato-producing area (Niayes). Field monitoring showed severe outbreaks during the late dry season.

Routes of introduction

In collaboration with some other African countries (Mali, Burkina Faso, Niger, etc.) and research teams (UGB, UMR CBGP), we will collect samples of *T. absoluta* moths from the whole of West Africa. Samples will be genotyped using molecular markers including microsatellites and compared with existing database from North Africa and Europe. Expected outcomes include the identification of routes of introduction of the invasive pest and potential genetic structuring among populations in West Africa. Research on the genetic diversity of populations of *T. absoluta* in West Africa is necessary to identify pathways of invasion, and particularly for predicting the potential for future expansion of the range of the pest.

Demographic parameters

Classical bioassays in temperature-controlled chambers are being carried out to evaluate the impact of high temperatures on *T. absoluta* population growth, and its probable major natural enemy in Senegal, *Nesidiocoris tenuis*. The objectives are to (i) establish life tables of *T. absoluta* and *N. tenuis*, and to (ii) assess predation under high temperatures and low relative humidity as experienced in Senegal during dry season. Demographic parameters of will feed the population dynamics model.

Alternative host plants

Prospection of *T. absoluta* in various agricultural and semi-natural landscapes has been completed in 2015-2016. Main host of *T. absoluta* is tomato, but other species of Solanaceae

crops such as potato, eggplant, Ethiopian eggplant, and sweet pepper can provide alternative resources. Greenhouse experiments (mesocosm) with tomato plants and other cultivated host plants in Senegal showed a strong correlation between oviposition preference of females and larval performance. This suggests strong specialization on tomato and lower chance of major switch to other crops. Another field study is being conducted to identify drivers of the observed decrease of *T. absoluta* incidence during the rainy season (climate, resources, natural enemies, etc.). Results will give us insights on factors shaping *T. absoluta* invasion and persistence in unstable tropical agro-ecosystems.

Natural enemies

Prospection of *T. absoluta* larvae in solanaceous crops been completed in 2015-2016. Very low larval parasitism (0.4 %) was observed whereas predators such as *Nesidiocoris tenuis* (Hemiptera, Miridae) and *Orius* sp. (Hemiptera, Anthocoridae) might be good candidates for biocontrol. Samples of those natural enemies have been conserved (in vials containing ethanol 90 °) for further morphological and molecular identification (barcoding at UMR CBGP). Gut content of potential predators will be analyzed for prey detection using qPCR methods. 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.

Crop management and landscape context

Monitoring of a network of 25 tomato fields in a highly-infested area (Niayes) on two crop cycles (2015-2016 seasons) has been carried out to assess the effect of crop management (particularly insecticide use) and landscape context on *T. absoluta* incidence and biocontrol. Landscape composition and configuration has been mapped using GIS. Land cover includes other crops (particularly alternative host crops belonging to the family Solanaceae), orchards, and semi-natural vegetation. Statistical analyses are in progress. They will mainly use generalized linear mixed models (GLMM) to evaluate the effect of landscape context and cultural practices on the abundance of the targeted pest and predators.



Trap for monitoring *Tuta absoluta* moths in tomato fields.



Training of smallholder farmers on *Tuta absoluta* identification and integrated pest management (Kolda, Senegal).

6. Project Title- Biological Control of the Invasive Weed *Parthenium hysterophorus* in East Africa

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

Description: *Parthenium* (*Parthenium hysterophorus* L.), a native plant of tropical and sub-tropical South and North America, adversely affects food security, biodiversity, and the health of both humans and livestock in eastern Africa. In eastern Africa, *Parthenium* reduces the yield of many major crops such as sorghum and corn, competes with preferred pasture species, and, when consumed by domestic animals, taints their milk and meat, thereby reducing their value. It also causes human health problems such as severe contact dermatitis and respiratory problems. In addition, because of its ability to release toxic chemicals, *Parthenium* can replace natural vegetation, thus adversely affecting plant biodiversity.

The specific objectives of this project are to: 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; 2) evaluate the establishment and impact of these released agents on *Parthenium*, crops, and biodiversity; 3) evaluate new *Parthenium* bio-control agents for their safety to non-target plant species under quarantine and, if specific to the weed, seek a permit for their release; and 4) scale-up the release and monitoring of *Z. bicolorata* in Tanzania, obtain the necessary permits for field release of *Zygogramma* in Uganda, and release *Listronotus* and other natural enemies (evaluated in Ethiopia) in Tanzania and Uganda.

Ambo University (AU) – Guder Campus

Mr. Tesfaye Amare, a faculty member from AU, and Mr. Fula Galana, a research staff member from AU, were trained in rearing and culturing bioagents at Wollenchiti. After the training, they have started to rear the leaf-feeding beetle, *Zygogramma bicolorata*, and the stem-boring weevil, *Listronotus bicolorata*, at Guder. The *Parthenium* project has provided AU with supplies such as mesh and wooden poles along with the funds to erect three walk-in cages. Additional benches have been installed in the cages along with a nursery to grow *Parthenium* for the bioagents that have been established. Additional small cages to rear *Listronotus* have also been given to AU.

Amhara Regional Agricultural Research Institute (ARARI) at Sirinka/Kobo

A bioagent rearing facility was established at Sirinka/Kobo that has two large breeding cages (5 x 7 m) and three smaller breeding cages (0.5 m x 0.5 m x 1.9 m). A *Zygogramma* culture (200 adults) has been provided to Sirinka/Kobo Center for rearing. The culture has now multiplied to 2000.

Ethiopian Institute of Agricultural Research (EIAR) –Ambo Plant Protection Research Center (APPRC)

Ms. Lorraine Strathie from ARC-PPRI South Africa reared and delivered a starter culture of 1800 *Smicronyx lutulentus* adults to the Ambo quarantine facility on December 13, 2015. Ms Strathie also gave hands-on training on techniques of culturing *Smicronyx* to staff from EIAR and ARARI

on December 13 and 20, 2015. The staff has also received documents that explain the biology and the culturing of this weevil.

Staff at the Ambo quarantine facility have faced several challenges in rearing *Smicronyx* since its introduction. The culturing and handling techniques of this bioagent are very different from that of *Zygogramma* and *Listronotus*, and the staff had to learn many new procedures. In addition, *Smicronyx* requires different set-up and environmental control, and it is prone to escape from cages because of its small size. Larvae have been collected from plants and placed in containers half-filled with soil for pupation. However, no adult has emerged so far from these pupation boxes. The lack of adult emergence from pupae has caused a precipitous decline in its population. This lack of adult emergence from pupation boxes is being investigated.

The quarantine facility at APPRC also houses the two bioagents that are approved for release, *Z. bicolorata*. and *L. setosipennis*. Cultures of *Zygogramma* and *Listronotus* are maintained in separate sections of the quarantine facility.

Haramaya University (HU)

Haramaya University has been rearing and releasing *Zygogramma* for the last several months. To aid this activity, HU has been provided materials to erect two additional walk-in cages as well as small breeding cages. *Zygogramma* has been released at various locations in the campus of HU after the sites were fenced. A second generation of adults are emerging and staff are monitoring the establishment of *Zygogramma* at these release sites.

A starter culture of *Listronotus* was transferred to the HU campus in late July for rearing. Staff have been trained and the necessary materials to rear this bioagent have been provided to HU. It is expected that several hundreds of *Listronotus* adults will be produced and released in the near future.

Tanzania and Uganda: submitted by Arne Witt at CABI-Africa

Agreements between Sokoine University of Agriculture (SUA) and the Tropical Pesticides Research Institute (TPRI) in Tanzania, and National Agricultural Research Organization (NARO) in Uganda, have been signed. Despite these initial delays, activities have progressed considerably in Tanzania and Uganda. Applications for the renewal of import permits for *Z. bicolorata* have been submitted. TPRI has set-up a mass rearing Center in Arusha. In Uganda, additional funds have been acquired to undertake host range testing of *Z. bicolorata*. With the establishment of a National Invasive Species Coordination Unit there is increased impetus to manage invasive species such as *Parthenium*.

South Africa - Agricultural Research Council-Plant Protection Research Institute (ARC-PPRI)

Technical inputs were provided to a report by the Ethiopian Institute of Agricultural Research (Plant Protection Research Centre, Ambo) regarding problems experienced with rearing of the seed-feeding weevil *S. luteiventris*. Problems were experienced by EIAR during attempts to

establish a culture of *S. lutulentus* from an imported starter culture in December 2015. It appeared that plant quality, inexperience with handling and rearing techniques, and possibly environmental conditions could have resulted in failure to establish a culture in quarantine in Ethiopia. Technical requirements in terms of facilities and equipment for rearing of *S. lutulentus*, visual materials (photos of life stages, and of step-by-step rearing techniques) and relevant literature on the weevil had been provided to EIAR researchers by L. Strathie. Researchers involved would benefit from practical training on the agent at ARC-PPRI Cedara in South Africa, prior to the next importation. This would enable exposure to all stages of the rearing process, as well as to other aspects of *Parthenium* biocontrol, including host-specificity testing.



7. Rice, Maize and Chickpea IPM for East Africa

PI: Tefera Tadele, *icipe*, Ethiopia

Ethiopia: Maize and chickpea IPM in Ethiopia.

Kenya: Maize IPM in Kenya.

Tanzania: Maize and rice IPM in Tanzania.

Relevant stakeholder identification was carried out in the three countries including from research system, extension, and private sector. The project launching and planning workshop was held in Addis Ababa, on April 7-8, 2016. About 30 participants from the United States, Ethiopia, Kenya, and Tanzania attended the workshop. The participants were drawn from national agricultural research and extension systems, *icipe*, USAID Ethiopia, Hawassa University, Virginia Tech, and RealIPM (private sector). The workshop was launched with brief remarks by Dr. Rangaswamy Muniappan, Director, IPM Innovation Lab; Dr Tracy Powell, Agricultural Development Officer, USAID Ethiopia; and Dr Christopher Prideaux, Director of Research and Partnership, *icipe*.

Meetings were held in the three countries with stakeholders in order to introduce the project to local partners and authorities and also to select appropriate project piloting areas. While conducting research on testing new IPM technologies, the project also scales up already proven IPM technologies, such as push-pull. The push-pull demonstration trials were done with 20 farmers in Hawassa (Ethiopia) and with 13 farmers in Nakuru (Kenya); training and sensitization were conducted of farmers and extension agents on the push-pull technology in managing maize stem borers; joint demonstration sites selection with local authorities and extension agents was made in the two countries. Field trials on evaluation of termite IPM trials in Bako were established in two sites and data collection is underway. Chickpea IPM trials in East Shoa (Ethiopia) were conducted in five locations. The chickpea trials include seed dressing, resistant varieties, raised bed, and furrow. Training for 68 extension service providers was given in Ethiopia (37 participants) and Kenya (31 participants) on IPM of maize stem borers. A total of 279 participants drawn from local authorities, farmers, researchers, and NGOs attended field days held on the push-pull demonstration trails for stem borer control both in Ethiopia (147 participants) and Kenya (132 participants). Sub-awards were given to the local partners in the three countries in order to conduct specific research needs for each country. Five new PhD students have joined the project to conduct their PhD research in various topics of IPM. Three consultants were identified and are presently assessing local pest diagnostics capacities in the three countries. Survey instruments for maize and vegetable crops are being developed in collaboration with the Vegetable IPM project socio-economic team. These instruments are being implemented in four counties of Kenya (Nakuru, Bomet, Tharak-Nithi and Nyeri) and data collected from 400 maize and vegetable growers. The two counties (Bomet and Tharak-Nithi) are part of Feed the Future (FtF) influence zone. Six trained enumerators and supervisors collected the data using tablets. The baseline data is being analyzed to establish indicators and generate information for researchers and other stakeholders who are part of the project. Draft chickpea and rice survey instruments are being completed based on the Kenya maize survey instrument and baseline surveys in Tanzania and Ethiopia will commence in December 2016 after partners have provided their inputs on the instrument.

Identification and prioritization of rice, maize and chickpea key pests and their management options

The project team, in collaboration with local partners, identified ranges of insect pests, diseases, and weeds for maize (stem borers, striga, leaf blight, leaf spot, and ear-rots), chickpea (pod borer, cutworms, blight, and wilt), and rice (stem borers, gall midges, yellow mosaic virus, and blast). The IPM components available in each country to address the identified challenges were presented and reviewed. These include, pest monitoring and mass trapping using pheromone/sticky traps, use of local/commercial biopesticides (*Metarhizium anisopliae*, *Beauveria bassiana*, *Trichoderma* spp, *Bacillus subtilis*, *B. thuringiensis*), conservation of natural enemies, push-pull technology, resistant varieties, treated seeds, botanical extracts, and planting dates (where applicable). Out of ranges of insect pests and diseases described above, the following priority pests were selected for each crop: pod borer, wilts and blights for chickpea; stem borers and striga for maize, and yellow mottle virus, blast and stem borers for rice.

Chickpea pests and IPM components

Pod borers, cutworms, and aphids were identified as insect pests while fusarium wilt and Aschochyta blight are recognized as major diseases. Various IPM components were also compiled for these pests. These components included pheromones traps, Nuclear polyhedral virus, early planting dates, planting marigold, use of bird perch, Bt formulations, Beauveria, and Metarhizium, sweep net, treated seed, border plant, sticky traps, conserving natural enemies, selective insecticides (see USAID-Ethiopia PERSUAP) for insect pests. For diseases: treated seed, early planting date, raised bed (ridges and furrow), *Trichoderma*, *B. subtilis*, resistant varieties, fungicides (see USAID-Ethiopia PERSUAP) are recognized as IPM components. Cultural practices like deep plough, optimum seed rate (plant density), sanitations, and mustard green manure are applicable to all diseases.

Maize key pests and IPM components

Stem borers and striga are the major maize pests. Various IPM strategies have been prioritized for this management. These include push-pull technology, conservation of parasitoids, using resistant varieties, botanicals, Imazapyr Resistant (IR) Maize (see USAID PERSUAP), *Fusarium nygamai* –RealIPM, and tied ridges. High N. Termites are identified as a pest of maize in Ethiopia. For their management: crop diversity (intercropping vs. sole cropping), plant population density (dense vs. sparse), soil fertility management (use of inorganic fertilizers vs. organic materials such as green manure, animal manure, composting, incorporating crop residues, botanicals, use of lodging, resistant and early maturing maize varieties, and evaluation of less toxic and non-persistent chemicals (see USAID PERSUAP) are recommended IPM strategies.

Rice pests and IPM components

Rice yellow mosaic virus, rice blast, and stemborers are identified as the main pests of rice. The IPM components for their management include: quarantine measures, rouging volunteers, disease free seeds, varietal mixtures and inter-planting, using resistant varieties, biopesticides (*Bacillus* and *Trichoderma*), using recommended spacing (20 x 20cm) at planting to enhance aeration and light penetration, using recommended doses of nitrogen for the respective area, maintaining clean fields, burning or burying infected crop debris, and using selective pesticides (USAID PERSUAP).

Developing and testing IPM packages

The following researches were conducted over the last six months in the three countries:

Integrated management of termites in maize in Bako (two locations) Ethiopia with the objectives to determine the effect of crop diversity, density, soil fertility and botanical plants on termite incidence and crop damage. Evaluation of integrated pest management practices against chickpeas insect pests and diseases is being carried out in East Shoa (Ethiopia) in 5 locations. The

trials include, seed dressing, resistant varieties, raised bed and furrow. Data collection is underway. About 20 native isolates of entomopathogenic fungi (*Beauveria* and *Metarhizium*) have been collected from various sources; this will be screened against larval instars of chickpea pod borer. Ascochyta disease leaf samples were collected from chickpea growing parts of Ethiopia to study the pathogenicity and genetic variation in the pathogen population. Twenty push-pull demonstration trials in Hawassa (Ethiopia) and thirteen demonstration trails in Nakuru (Kenya) were established. Training need assessment for farmers, researchers and extension agents were conducted in the three countries.

Alignment with target countries research priorities and needs

One of the research priorities of the three target countries is increasing productivity of food crops including rice, maize, and chickpea. This project plays a vital role in enhancing crop productivity by reducing crop losses due to pests. This project is in line with Tanzania's Vision 2025, Kenya's Vision 2030, and Ethiopia's Agricultural Transformation Plan, all of which laid emphasis to staple crops including maize and rice productivity, to commercialize the sector to ensure nationwide food security and food self-sufficiency.

Pest diagnostic capacity

An assessments of pest diagnostic services provided by the national plant health related laboratories or departments (agricultural research system, ministry of agriculture, universities) was conducted in the three countries. Special emphasis was given to rice and maize pests in Tanzania; maize and chickpea pests in Ethiopia; and maize pests in Kenya. This identified institutional strengths, weaknesses, gaps, and needs to enhance national pest diagnostic capacity. Strengthening pest diagnostic capacity of national research systems and agricultural service providers would improve production and productivity of rice, maize, and chickpea, while reducing the risk derived from pest threats to plant health and food safety.

Technology Transfer and Scaling Partnerships

Steps Taken

Stakeholder mapping including relevant key partners/institutions, farmers, national researchers, extension service providers, and NGOs was done and the project target areas in the host countries were identified. Identification of key partners and developing a strategy for implementation followed problem identification and prioritization, designing and testing of selected IPM technologies. Alternative IPM technologies were identified, designed, and tested and are being evaluated on-farm with participating farmers and stakeholders.

Technologies Transferred

- In Ethiopia push-pull demonstration trials in Adami Tulu and Hawassa were established with 20 farmers in Hawassa and 12 farmers in Adami Tulu. In Kenya push-pull demonstration trials in Nakuru and Naivasha were established with a total of 13 farmers participated in the demos, of which 8 were female and 5 male
- Training and sensitization of farmers and extension agents on the push-pull technology in managing maize pests
- Joint demonstration site selection with local authorities and extension agents was made
- Field trials on evaluation of termite IPM trials in Bako were established

Technologies ready to scale

The push-pull technology is ready to deploy against maize stem borers and striga in Tanzania, Kenya, and Ethiopia. In addition to year 1, scaling out of push-pull technology is planned in year 2 of the project. Chickpea IPM package: raised bed, resistant varieties and spray with selective pesticides will be considered in Year 2.



8. Integrated Pest Management for Vegetables in East Africa

PI: John Cardina, Ohio State University

KENYA

A baseline survey was conducted in Kenya 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 do or do not adopt. The crops surveyed were tomato, cabbage, and French beans. The survey was conducted jointly with the Grains IPM in East Africa project and therefore included maize as well. It was conducted in Nyeri, Tharaka Nithi, Nakuru, and Bomet counties, and a total of 400 farmers were surveyed, one-third of them female. The data were entered into tablet computers and are currently being summarized and formatted for Stata for statistical analysis.

The survey was done July 26-29, 2016. A structured questionnaire was administered through face to face interviews with farmers to collect data on: current vegetable production and marketing practices; knowledge of pests and current pest management practices and socio-economic background characteristics. A random sample of 108 farmers was selected from a list of 408 farmers involved in vegetable production provided by the Ministry of Agriculture in the county. Of the 108 farmers interviewed, 62 (57.4%) were male and 46 (42.6%) were female. Color photographs were used to help farmers identify pests and diseases. Outputs generated from the activity included farmer perception of pest priorities, factors affecting pest management practices, profitability of current practices and gender issues associated with pest management practices. Outputs to be generated by the activity may include the perceptions of 108 tomato farmers randomly selected from an already available list of farmers belonging to four farming groups. Gender disaggregation of pest management practices was done to inform on gender issues that would influence IPM adoption.

Some of the variables that were considered in identifying the socio-demographic characteristics of the farmers included age, education, family size, occupation, and income since these affect household relations as well as influence farmers' production practices. The mean age of the heads of households was 54 years and the average household size was 5.7. The majority of the interviewed farmers had farming as their main source of income with average land sizes of three acres. The main vegetable crops grown in the four irrigation schemes were tomato, French beans, cabbage, kale, and onions. The main method of pest control reported was chemical pesticides, with more than half of the farmers reporting increased usage due to increased pest infestations and resistance. Pesticide application was an exclusively male domain. Heads of households were the ones who purchased pesticides, made most of the decisions on the amount of money to be spent on pesticides. However, the decisions on how to spend money from the sale of vegetables were made most often by head-of-household along with the spouse with only one-third of the household heads claiming to solely make decision. Very few of the farmers had heard of IPM, biological control, or biopesticides.

Stakeholder research needs

Tomato: Bacterial wilt is the number one problem in tomato and needs better management. We need to screen more rootstocks for tolerance. *Trichoderma spp.* and *Bacillus subtilis* should be tested on the many strains of bacterial wilt pathogens, which are regionally variable. For *Tuta absoluta*, there was discussion about whether populations are declining and the issue of insecticide resistance. Coragen is used frequently. Other options for testing include neem, biopesticides, *Bacillus thuringiensis*, *Artemisia cina* extract, clove oil, and nanosilica, maybe in combination with insecticides.

Cabbage: We need treatments for diamondback moth (DBM) and black rot. We need to test healthy, clean seeds, use of BT, *Trichoderma*, *B. subtilis*. These could be a demo from which data are collected. Neem used as a repellent compared with use of BT. Microbial pesticides to be tested, e.g. *Beauveria*, *Metarhizium anisopliae*, BT, *Paecilomyces*.

French beans: Research needs identified: biology of bean fly. Microbial pesticides for white flies, thrips and black bean aphid. Evaluate resistant varieties for rust. Test biopesticides, neem, other botanicals pheromones for legume pod borer, *Maruca vitrata*

Onion: For Thrips, evaluate *Metarhizium* 69. For Pythium test *Trichoderma*. For downy mildew: test *Trichoderma*. Test time of harvest effect on *Erwinia* soft rot and curing.

Pest and disease diagnostic training in Chuka (September 27-28, 2016)

The facilitators were three plant pathologists (2F: 1M), one entomologist (M), one information technology expert (F), one extension officer (F) and one driver (M). The purpose was to provide training on identification and integrated management of major pests and diseases of French bean, tomato, cabbage and kale in the project area. The training was geared toward growers and area agricultural field extension officers. Pre and post training tests were done to establish the knowledge of participants on pest diagnostics and IPM before and after the training. Farmer knowledge on average improved from 20.2 to 60.8 % while the extension staff scores improved from 60.6 to 83.8 %. Each of the two groups received training on different days. Both were introduced to the smart phone technology for pest diagnostics and sharing of information through WhatsApp. The training consisted of lectures with power point presentations, and hands-on learning in nearby fields. It was anticipated that the content of the training would prepare the participants for effective participation in the EAVC-IPM-IL project. The extension officers in attendance were 24 (11F: 13M). There were 30 farmers trained (11F: 19M). The course content was similar for both groups but more detailed for the extension officers. Topics covered in the training included principles of IPM, integrated management of seed/soil borne diseases, identification and integrated management of tomato, French beans, cabbage and kale diseases, arthropod pests and nematodes, use of smartphone for disease diagnostics, and use of social media for pest diagnosis and information sharing. It was also agreed that the extension officers would be given the pdf copies of the presentations in compact discs and the same would be sent to them via e-mail. However, since farmers had no access to computers, the presentations would be combined and printed and bound for distribution.

Establishment of pathogen free seedlings

Nursery beds for the tomato, cabbage and kale experimental trials were prepared in six of the 12 selected sites. This activity doubled up as a practical training on preparation of raised nursery beds, incorporation of manure and solarization. The polythene sheet (500 gauge, transparent) and watering cans were provided from the project budget, the cow manure and labor were provided by farmers. In total 28 farmers (12F: 16M) were trained. Solarization will be done for four weeks at 26-28°C, after which low tunnels will be constructed and nursery beds covered with insect proof nets to exclude insect pests and disease vectors.

TANZANIA

Develop baseline survey

Baseline survey plans were initiated in Tanzania to identify priority pests, pest management practices, knowledge of IPM, etc. Surveys were planned but not yet implemented in Tanzania, but will start in the new year, jointly with the Grains IPM IL project. The baseline surveys on vegetable viruses and vectors were planned to be conducted in five major vegetable growing regions of Tanzania. The surveys have been completed in at least three of the regions including: Morogoro, Iringa, and Lake Victoria (Bukoba and Mwanza). The survey was completed in two remaining regions in Arusha and the coast (Tanga and Pwani) by the end of October 2016. At least 127 virus and 46 insect samples (whitefly, aphids, leaf hoppers, thrips, beetles and caterpillars) were collected from 40 smallholder vegetable (tomato, cabbage, Chinese cabbage, kale, green pepper, onions, African egg plants, squash/pumpkins) fields. The virus samples were stored at -80°C in the laboratory at MARI. The insect samples were kept in ethanol at room temperature. Virus samples will be analyzed by polymerase chain reaction (PCR) and rolling circle amplification (RCA) followed by sequencing. Insects will be analyzed using PCR and sequencing of the mitochondrial cytochrome oxidase I (mtCOI) DNA. The results will be used to develop pest and disease prevalence and distribution maps, and management strategies. Questionnaires on socio-economics were administered to 24 smallholder vegetable farmers to assess the knowledge of virus diseases and insect vectors.

Stakeholder Meetings/ Training.

April 1-2: Drs. Cardina, Erbaugh, Welty, and Norton met with stakeholders in meetings at Dar es Salaam to identify priority vegetable crops and pests in Tanzania. Background information on Tanzania vegetable production constraints were given by Anthony Chamanga of TAHA, which has several thousand farmer members, most having joined in the past three years. He sees *Tuta absoluta* as a major problem since 2013. There are registration challenges for biologicals. TAHA has its own training manual and extension team. Juma Shekedele of Horticulture Research and Training introduced training and production activities at HORTI Tengeru, a government institution established in 1980 to train extension workers, resulting in Diploma of Horticulture, as well as training for farmers and extensionists. Their Practical Training Center was established in 2014. Major challenges are inadequate technical knowledge in horticulture, and lack of availability of biological agents such as Trichoderma. Amon Maerere gave background on Sokoine University of Agriculture (SUA) activities in IPM. They have good connections with public and private partners, including MARI, TAHA, SEVIA, and work in three target areas: Morogoro region, Iringa region, and Kilimanjaro region. Peter Sseruwagi gave an overview of work at MARI. We tabulated specific IPM practices appropriate for each crop and pest, and indicated which required further research in this project.

Research Needs

Evaluation of the effects of tomato grafting on wild solanum rootstock to prevent bacterial wilt in tomato; development and evaluation recipes for slurry, biogas and microbe bio-pesticides (Trichoderma, Bacillus, etc.) to get a consistent product for control of root diseases as transplant treatment for tomato, cucurbits and brassicas. Initiate trials on onion variety

selection – to evaluate hybrid varieties for pest resistance, yield, quality and other characteristics. Seeds will be provided by SEVIA. Evaluate bio-pesticides *Metarhizium*, *Beauveria* and others for their effectiveness in controlling the white grubs in onion. Conduct literature search on botanical pesticides (including neem) on their effectiveness to repel thrips and other pests of onion, use of parasitoids against the bean stem maggot. Evaluation of the effect of overhead irrigation in the evening to interrupt mating flights of the diamondback moth attacking brassicas. Conduct surveys to determine the importance of water melon and other cucurbits pests in different geographic regions.

Workshop on Diagnosis of Diseases and Identification of Insect Pests and Vectors in Vegetable Crops.

The training was conducted by seven instructors including: Prof. S. Miller (OSU), Prof. Robert Gilbertson (UC Davis) and Dr. L. Cañas. Dr. Gration Rwegasira, Ms. Hellen Kanyaga (SUA), Jesca Mbaka (KALRO), Dr. J. Ndunguru and Dr. P. Sseruwagi (MARI).

The workshop was attended by a total of 30 participants including: extension officers (8), researchers (14), horticulturalists (2), university lecturers (3), seed certification (1), pesticides registration and regulation (2) from Tanzania. There were 16 males and 14 females.

Cañas administered a pre-workshop quiz using clickers to assess general knowledge related to viral and bacterial pathogens of vegetable crops, virus vectors and pests of vegetables. Trainees were provided a sample submission form. Trainees and trainers participated in a field trip to three locations. Trainees use the sample submission form to ask questions of the farmers to assist in developing diagnoses. Samples of diseased plants, vectors, and pests were collected. At the second location, participants observed virus diseases and conducted in-field testing using lateral flow devices/immunostrips. At the third site plants with virus symptoms, vectors and insect pests were collected. The following day, samples were processed and evaluated. Participants attended sessions on bacterial pathogen diagnosis, virus diagnosis, and vector/pest identification. Participants were instructed in the use of smartphone cameras to visualize bacterial streaming from plants, as well as other diagnostic features of bacterial and fungal diseases. Miller also demonstrated the APS Tomato MD App given to each participant as a free download. In the virus session participants used the Agdia general potyvirus immunostrip test. We demonstrated the FTA card technology where samples are squashed onto a filter paper, impregnated with nuclease inhibitors, returned to a laboratory for extraction of nucleic acids and PCR and RT-PCR. Emphasis was placed on distinguishing *Tuta absoluta* from other leafminers. Cañas and Rwegasira used a camera and computer to show samples of leafminers, aphids, whiteflies, scales and mites. The use of social media for communication in diagnostics, and online resources for pest identification was introduced, specifically WhatsApp. A user group was established for all participants. Cañas administered the post-quiz; there was a 17% overall improvement in scores from the pre- to post-quiz. Certificates were distributed to all trainees.

ETHIOPIA

Develop baseline survey

Surveys were planned but not yet implemented in Ethiopia, in part due to travel restrictions, but will start in the new year, jointly with the Grains IPM IL project.

Stakeholder Meetings/ Training.

We met with project stakeholders, Entomologist, co-PI, Yibrah Beyene, Entomologist, Alemayehu Chala, Plant Pathologist, and Ms. Hiline Wolde, a lab assistant; Dr. Gashaw Meteke, Head, Plant and Horticultural Science School. We also met with Ato Germane Garuma Chagen, Deputy Bureau Head, Teye Mamo, MS in crop protection, Germame Homsebo, M.S. plant pathology, Alawi Shifa, M.S. weed science, and Getenesh Aragaw, Laboratory technician at the Plant Health Clinic; and Dr. Tesfaye Abebe, Vice President for Research and Technology Transfer at Hawassa University. We learned about agriculture in the Rift Valley, which has intensive production of horticultural crops, from small-holders to industrial scale farms. There is significant potential for intensification and expansion due to proximity and access to research and markets. There are significant pest problems and misuse of pesticides. Onion, tomato, cabbage are main crops there. There is a wide range of knowledge and use of pest management.

Farmers recognize pests and diseases and depend mainly on pesticides, few materials at high rates and frequencies. There is little awareness of pesticide safety or regulation in the use of pesticides. The main IPM challenges are: lack of observance of regulations by farmers, lack of a market incentive for IPM, lack of integration of methods for pest management, and the strong attachment farmers now have to pesticides.

Research needs

Tomato: Management of *Tuta absoluta*, African Bollworm; soil-borne diseases, late blight; early blight; viruses, bacterial spot; root rot. Research needed to develop a production package for clean seedlings. Need to evaluate practices for seedling production, including burning beds to “heat treat” the soil, anaerobic disinfestation, steam disinfestation, biofumigation, and flooding.

Identify and evaluate local *Trichoderma* strains for seedlings. Evaluate the effectiveness of *Metarhizium* and *Beauveria* for insect management.

Onion: Research Needs identified: Management for thrips, purple blotch, downy mildew. Investigate rotation of ‘soft’ insecticides and mixtures. Research is needed to determine when to start applications and when to stop. Evaluate *Metarhizium* for trips management.

Cabbage and other brassicas: Management for DBM; aphids; black rot; root rots; thrips. Need to develop and evaluate methods for clean seedling production, e.g. anaerobic disinfestation, steam disinfestation, biofumigation, and flooding for soil pathogens; use of netting for insect exclusion. Identify local strains of *Trichoderma* for seedling treatments. Evaluate effectiveness of *Beauveria* and Bt for control of DBM.



Long Term Training by Country

Country	Strengthening production and export of Vietnamese fruit crops through innovative and market-orientated IPM						
	Name	Degree	Gen	Home institution	Training Institution	Start Date	End Date
Vietnam	Ms. Dang Thi Kim Uyen	PhD	F	Southern Horticultural Research Institute	Can Tho University	11/2015	11/2020
Innovative Scientific Research and Technology Transfer to Develop and Implement Integrated Pest Management Strategies for Vegetable and Mango Pests in Asia							
Bangladesh	Farhanaz Sharma	PhD	F		Virginia Tech	1/2016	12/2017
Bangladesh	Sadique Rahman	PhD	M	Bangladesh Agricultural University	Bangladesh Agricultural University and Virginia Tech	1/2016	6/2017
Nepal	Sulav Paudel	PhD	M	iDE Nepal	Penn State	8/2016	5/2020
Nepal	Arjun Khanel	PhD	M	Tribhuvan University	Tribhuvan University and Virginia Tech	1/2016	7/2018
Participatory Biodiversity and Climate Change Assessment for Integrated Pest Management in the Annapurna-Chitwan Landscape, Nepal							
Nepal	Seerjana Maharjan	Ph D	F	CDB, TU		1/2016	1/2019
Nepal	Dol Raj Luitel	Ph D	M	CDB, TU		1/2016	1/2019
Nepal	Anju Sharma Poudel	Ph D	F	CDB, TU		1/2016	1/2019
Nepal	Ghanshyam Bhandari	Ph D	M	AFU		1/2016	1/2019
Nepal	Homnath Giri	Ph D	M	AFU		1/2016	1/2019
Nepal	Bidhya Maya Shrestha	M S	F	CDB, TU		1/2016	2017
Nepal	Pristi Dangol	M S	F	CDB, TU		1/2016	2017
Nepal	Sagar Khadaka	M S	M	CDB, TU		1/2016	2017
Nepal	Sanjeeb Bhandari	M S	M	CDB, TU		1/2016	2017
Nepal	Vishubha Thapa	M S	F	CDZ, TU		1/2016	2017
Nepal	Ganga Sah	M S	M	CDZ, TU		1/2016	2017

Nepal	Sarita Sapkota	M S	F	AFU		8/2016	2017
Nepal	Pratiksha Sharma	M S	F	AFU		8/2016	2017
Nepal	Ramesh Upreti	M S	M	AFU		8/2016	2017
Nepal	Bivekananda Mahat	M S	M	AFU		8/2016	2017
Nepal	Madhu Sudhan Ghimire	M S	M	AFU		8/2016	2017
Nepal	Yashodha Panthy	M S	F	CDB, TU		8/2016	2017
Rice IPM Cambodia							
Cambodia	Chou Cheythirith	PhD	M	GDA	Nagoya University and IRRI	8/2016	
U.S.	Sydni Jackson	M.S.	F	Virginia Tech	Virginia Tech	8/2015 (5/2016 on IPM IL)	6/2017
A High-resolution Interaction Based Approach to Modeling the Spread of Agricultural Invasive Species							
China	Sichao Wu	PhD	M	Virginia Tech	Virginia Tech	8/2013	5/2017
India	Amleshwar	BS	M	IISC	Virginia Tech	8/2013	5/2017
Senegal	Serigne Sylla	PhD	M	Biopass	Biopass	2/2014	2/2017
Senegal	Oumar Seydi	MS	M	Biopass	Biopass	6/2016	12/2016
Senegal	Mame Diarra Bousso	MS	M	Biopass	Biopass	6/2016	6/2016
Senegal	Ahmadou Sow	PhD	M	Biopass	Biopass	4/2015	4/2018
U.S.	Bryan Kaperick	BS	M	Virginia Tech	Virginia Tech	8/2014	5/2018
Biological Control of the Invasive Weed <i>Parthenium hysterophorus</i> in East Africa							
Ethiopia	Belaynesh Assema	M.S	F	Wollo University	Haramaya University	10/2016	6/2017
Ethiopia	Gizachew Girma	M.S	M	Ambo University	Ambo University	6/2016	6/2017
Tanzania	Leticia Musese	M.S	F	Sokoine University	Sokoine University	9/2016	6/2018
Rice, Maize and Chickpea IPM for East Africa							
Tanzania	Bonaventure January	PhD	M	Africa Rice Centre	Sokoine University	7/2016	6/2019

Tanzania	Ibrahim Hashim	PhD	M	Dakawa Agricultural Research Institute	Sokoine University	7/2016	6/2019
Kenya	Josphat Korir		M	University of Nairobi	University of Nairobi	9/2016	6/2019
East Africa Integrated Pest Management Innovation Lab							
Bangladesh	Muntasir Hasan	M.S.	M	North South University	Virginia Tech	8/2015 (5/2016 on IPM IL)	6/2017
Kenya	Cecilia Ngugi	PhD	F	KALRO	University of Nairobi		10/2016
Kenya	Charity Gathambiri	PhD	F	KALRO	Jomo Kenyatta University of Agriculture and Technology		
Tanzania	Hellen Kanyaga	PHD	F	Sokoine University of Agriculture	The Ohio State University	1/16	6/2020

Short term training by project

Strengthening production and export of Vietnamese fruit crops through innovative and market-orientated IPM							
Project Initiation Meeting	SOFRI	April 25-26 2016					
Workshop: Raise awareness of gender issues in agriculture, human subjects IRB requirements, and introduce Gender Dimensions Framework	SOFRI-Vietnam	June 26-July 9	6	8	14		Dr. Maria Elisa Christie from Virginia Tech
Workshop: Train Vietnam team in implementing gender in value chains participatory methods and in gender analysis	SOFRI-Vietnam	June 26, 27; July 4-9	6	8	14		Dr. Maria Elisa Christie from Virginia Tech
Bio-technology	CTU-Vietnam		4	1	5		Professor: Tran Nhan

							Dung from Can Tho university
Vegetable IPM Asia project							
Farmer Field day	Bogra, Bangladesh	8/17/2016	30	90	120		BARI
Virus Workshop	Cambodia	8/10-12/16	10	6	16	RUA	Washington State
<i>Tuta Absoluta</i> workshops (2)	Cambodia (2 provinces)				85	RUA/GDA/ CARDI/ others	Virginia Tech
<i>Trichoderma</i> workshop	Cambodia	Sept 2016				RUA/GDA/ others	Virginia Tech
Intensive training on IPM and post-harvest technology	Banke, Surket, Nepal	Banke : 8/30,2016 Surkhet7/23-24/2016	Banke (12) Surkhet (21)	Bank e(8) Surkhet (4)	45	iDE	iDE and CEAPRED
Gender workshop	Banke, Nepal	6/10/2016	0	3	3	iDE	INGENAUUS
Climate Change Biodiversity project Nepal							
Effective use of Microsoft word, excel, power point and Remote sensing	CDB, TU Kirtipur Kathmandu	28 - 31March	9	14	23	CDB, TU	Dr. Tarendra Lakhankar CUNY
Field visit & Orientation Training	Gaidakot Nawalparasi	07 April	18	1	19		AFU & ECOSCENTRE
	Fulbari Chitwan	08 April	15	10	25		AFU & ECOSCENTRE,
Field visit	Jaynagar, Goringhe	9 April	8	7	15		AFU & ECOSCENTRE
	Kawasoti, Nawalparashi	10 May	3	8	11		AFU & ECOSCENTRE,
Orientation training	Kawasoti	18 May	23	5	28		AFU & ECOSCENTRE
	Bhimanagar	19May	12	2412			AFU & ECOSCENTRE,

	Jaynagar	20 May	23	8	31		AFU & ECOSCENTR E
	Chyang Chyangdi	16 July	14	14	28		AFU & ECOSCENTR E,
	Puranchaur	17 July	10	22	32		AFU & ECOSCENTR E
GPS GIS training	CDB, TU	19-20, July	5	3	8		CDB, TU
SPSS training	CDB, TU	20-21, August	6	9	15		CDB, TU
Mendely training	AFU, Chitwan	8 August	8	7	15		AFU
MS words trick	AFU Chitwan	17 July	9	11	20		AFU
Rice IPM Cambodia							
Hands-on course – Field identification of rice pests, diseases, and weeds	CARDI, Phnom Penh, Cambodia	4-7 July 2016	7	12	19	CARDI, GDA, RUA, CABI	IRRI
On-the-job training – Rice health survey portfolio	Target villages, Cambodia	18-20 July 2016	2	5	7	CARDI	IRRI
Hands-on course – Conducting an impact baseline survey	GDA, Phnom Penh, Cambodia	25-26 August 2016	5	11	16	GDA	IRRI
On-the-job training	IRRI	26-30 September 2016	1	1	2	CARDI	IRRI
Public forum and field demonstration (2 days) – Use of biocontrol agents as an IPM option in rice and vegetables	Phnom Penh, Cambodia	22-23 September 2016	45	98	143	CARDI, GDA, DAL (Department of Ag Law), farmer groups, private sector	IRRI, GIZ
Biological Control of the Invasive Weed <i>Parthenium hysterophorus</i> in East Africa							
Hands on training- culturing Smicronyx	Ethiopian Institute of Agricultural Research	Dec 13, Dec 20, 2015					
Practical training	Wollenchiti Bioagent	15-17 May 2016	5	11	16		Virginia State University

	Mass Rearing Site Ethiopia						
Short-course	Grahamstown, South Africa	09/16	1			CABI	Rhodes University
Practical training	Grahamstown, South Africa	09/16		1		NARO	Rhodes University
Theory and practical training	Cedara, South Africa	09/16		2	3	CABI Kenya Hebrew Univ	ARC-PPRI

Rice, Maize and Chickpea IPM for East Africa							
Stem borer management using the push pull technology, training for extension service providers	Kenya	Aug 25, 2016	13	18	31	Farmers, Nakuru and Naivasha county Department of Agriculture, KALRO (Kenya Agriculture and Livestock Research Organization)	icipes
Field day in Idabibi, push pull demo trial	Idabibi, Kenya	Aug 23, 2016	30	47	77	Farmers, Nakuru county Department of Agriculture, KALRO (Kenya Agriculture and Livestock Research Organization)	icipes
Field day in Gilgil, push pull demo trial	Gilgil, Kenya	Aug 24, 2016	32	23	55	Farmers, Nakuru county Department	

						t of Agriculture , KALRO (Kenya Agriculture and Livestock Research Organizatio n)	
Training for extension service providers on stem borer management using the push pull technology	Hawassa, Ethiopia	Sept 6-8, 2016	2	35	37	Ministry of Agriculture , Hawassa University, EIAR (Ethiopia Institute of Agricultural Research) and model farmers	icipe
Field day in Hawassa, push pull demo trial	Hawassa, Ethiopia	Sept 9, 2016	8	139	147	Farmers, Ministry of Agriculture , Media, NGOs, EIAR	icipe
East Africa Integrated Pest Management Innovation Lab							
	Location	Date	Participants			Home Institution	Training Institution
Type			Female	Male	Total		
Baseline Socio Economic survey	Kenya	26 th and 29 th July 2016	46	62	108		
Stakeholder Meeting	KALRO Kandara and Thika.	March 30-31					
Progress of project implementation	KALRO Kandara and Thika.	1 August 2016					
Budget Discussion	KALRO Kandara and Thika.	2 August 2016					
Stakeholder engagement and experimental site selection		16 th -19 th Aug 2016	8	4	12		

Pest and disease diagnostic training- Extension staff	Chuka	27 th Sept 2016	11	13	24	Extension offices	KALRO
Pest and disease diagnostic training- Farmer training	Chuka	27 Sept 2016	11	19	30	(farmers)	KALRO
Pest and disease diagnostic training- Farmer training	Chuka	28 Sept 2016	12	16	28	(farmers)	KALRO
Stakeholder Meeting	Tanzania	April 1-2 2016					
Project discussion and inputs on Mission value chain partner collaborators	Dar es Salaam	Aug 3, 2016			4		
Discuss budget and planning a workshop	Dar es Salaam	Aug 4, 2016			4		
Research Discussion with SUA faculty	Morogoro	Aug 5, 2016			7		
Pest and disease diagnostic training - Train-the-trainer	Mikoche ni, Tanzania	20-26 August	14	16	30	ARI, TAHA, Hort-Tenguru, SUA, MARI, Plant Health Services, various municipalities	Ohio State, MARI, UC-Davis, KALRO, SUA
Stakeholder meeting	Hawassa University Ethiopia				11		

Collaborators by Project

Biological control of the invasive weed <i>Parthenium hysterophorus</i> in East Africa		
Principal Investigator	Title	Organization
Wondi Mersie	Associate Dean and Director of Research	Virginia State University
Collaborators	Title	Organization
Arne Witt	Regional Coordinator	Centre for Agriculture and Biosciences International (CABI) Africa, Kenya
Birru Yitaferu Woldetsadik	Director General	Amhara Regional Agricultural Research Institute, Ethiopia
Kassahun Zewdie	Coordinator of Parthenium Weed Management	Ethiopian Institute of Agricultural Research
Lisanework Nigatu Gebreyes	Associate Professor	Haramaya University, Ethiopia
Lorraine Strathie	Researcher	ARC-Plant Protection Research Institute, South Africa
Maria Elisa Christie	Director	Women and Gender in International Development, Virginia Tech
Mulugeta Negeri Tulu	Dean of the College of Agriculture	Ambo University, Ethiopia
Richard Molo	Head, Biological Control Unit	Nation Agricultural Research Organization, Uganda
Samora Macrice	Ecologist	Sokoine University, Tanzania
Samuel Assefa	Project Coordinator	Gesellschaft für Internationale Zusammenarbeit (GIZ), Ethiopia
Sintu (Lydia) Alemayehu	Project Coordinator in Ethiopia	Virginia State University
Tesfay Amare	Weed Scientist	Ambo University, Ethiopia
Vegetable Crops IPM in East Africa		
Principal Investigator	Title	Organization
John Cardina	Associate Professor	Ohio State University
Collaborators	Title	Organization
Amon P. Maerere	Professor of Horticulture	Sokoine University of Agriculture, Tanzania
Cathy Rakowski	Associate Professor	Ohio State University
Danny Coyne	Soil Health Scientist	International Institute of Tropical Agriculture (ITTA), Kenya

Ferdu Azerefege	Associate Professor	Hawassa University, Ethiopia
George Norton	Professor	Virginia Tech
Henry Wainwright	Joint Managing Director	Real IPM, Kenya
J. Mark Erbaugh	Director of International Programs in Agriculture	Ohio State University
Jessica Mbaka		Kenya Agricultural and Livestock Research Organization
Luis Alberto Cañas Castro	Associate Professor of Entomology	Ohio State University
Matthew Kleinhenz	Professor of Horticulture	Ohio State University
Peter Sseruwagi		Mikocheni Agriculture Research Institute, Tanzania
Robert Gilbertson	Professor of Plant Virology	University of California, Davis
Sally A. Miller	Professor of Plant Pathology	Ohio State University
Maize, Rice, and Chickpea IPM for East Africa		
Principal Investigator	Title	Organization
Tadele Tefera	Country Head	International Centre of Insect Physiology and Ecology (<i>icipe</i>), Ethiopia
Collaborators	Title	Organization
Cornelius Fabian	Assistant Director	Plant Health Services, Tanzania
Ferdu Azerefege	Associate Professor	Hawassa University, Ethiopia
Florence Olubayo	Associate Professor	University of Nairobi, Kenya
Henry Wainwright	Joint Managing Director	Real IPM, Kenya
Hugo de Groote	Principal Scientist	International Maize and Wheat Improvement Center, Kenya
Murenga Mwimali	Principal Research Specialist	Kenya Agricultural Livestock Research Organization
Patrick Gicheru	Senior Principal Research Scientist	Kenya Agricultural Livestock Research Organization
Solomon Chanyalaw	Center Director	Ethiopian Institute of Agricultural Research
Stephen Mugo		International Maize and Wheat Improvement Center, Kenya
William Hutchison	Professor and Extension Entomologist	University of Minnesota
Vegetable Crops and Mango IPM in Asia		

Principal Investigator	Title	Organization
George Norton	Professor of Agricultural Economics	Department of Agriculture and Applied Economics, Virginia Tech
Collaborators	Title	Organization
Cristina Rosa	Assistant Professor of Plant Virology	Penn State University
Edwin G. Rajotte	Professor of Entomology	Penn State University
Luke Colavito	Director	International Development Enterprises (iDE), Nepal
Maria Elisa Christie	Director	Women and Gender in International Development, Virginia Tech
Megan O'Rourke	Assistant Professor	Department of Horticulture, Virginia Tech
Mike Roberts	Director	International Development Enterprises (iDE), Cambodia
Naidu Rayapati	Associate Professor of Plant Pathology, Virologist	Washington State Univeristy
Sally A. Miller	Professor	Ohio State University
Yousuf Mian	Coordinator	IPM Innovation Lab, Bangladesh
IPM for Exportable Fruit Crops in Vietnam		
Principal Investigator	Title	Organization
Nguyen Van Hoa	Plant Pathologist	Southern Horticultural Research Institute (SOFRI), Vietnam
Collaborators	Title	Organization
A. Sivapragasam (Siva)	Regional Director	Centre for Agriculture and Biosciences International-Southeast Asia (CABI-SEA), Malaysia
Dang Thi Kim Uyen	Plant Pathologist	Southern Horticultural Research Institute (SOFRI), Vietnam
Dang Thuy Lin	Deputy Head	Science and International Cooperation Department, (SOFRI)
Hunynh Thanh Loc	Researcher	Southern Horticultural Research Institute (SOFRI), Vietnam
Le Cao Luong	Lecturer and Researcher	Plant Protection Department, Nong Lam University (NLU), Vietnam
Le Dinh Don	Lecturer of Agronomy	Nong Lam University (NLU), Vietnam
Le Quoc Dien	Entomologist	Southern Horticultural Research Institute (SOFRI), Vietnam

Le Xuan Vi	Entomologist	Plant Protection Research Institute (PPRI), Vietnam
Mai Van Tri	Tropical Fruit Pest Specialist	Southern Horticultural Research Institute (SOFRI), Vietnam
Maria Elisa Christie	Director	Women and Gender in International Development, Virginia Tech
Naidu Rayapati	Associate Professor of Plant Pathology, Virologist	Department of Plant Pathology, Washington State University
Ngo Thi Thanh Truc		Can Tho University, Vietnam
Nguyen Duy Hung	Researcher	Fruit and Vegetable Research Institute, Vietnam
Nguyen Thanh Hieu	Plant Pathologist	Southern Horticultural Research Institute (SOFRI), Vietnam
Phan Thi Thu Hien	Pathologist	PQIPS, Vietnam
Quyen Dinh Ha	Lecturer and Researcher,	Vietnam National University of Agriculture
Russell Mizell	Professor of Entomology	University of Florida
Tran Thi My Hanh	Entomologist	Southern Horticultural Research Institute (SOFRI), Vietnam
Trinh Xuan Hoat	Deputy Director General	Plant Protection Research Institute (PPRI), Vietnam
Truong thi Ngoc Chi	Sociologist	Cuu Long Delta Rice Research Institute, Vietnam
Rice IPM for Cambodia		
Principal Investigator	Title	Organization
Buyung Hadi	Entomologist	International Rice Research Institute (IRRI), Phillipines
Collaborators	Title	Organization
Alexander McNaughton Stuart	Post-Doctoral Fellow	International Rice Research Institute (IRRI), Phillipines
Casiana M. Vera Cruz	Senior Scientist	International Rice Research Institute (IRRI), Phillipines
Chou Cheythyryth		General Directorate of Agriculture, Cambodia
Claudius Bredehöft	National Project Coordinator	ASEAN Sustainable Agrifood Systems, Gesellschaft für Internationale Zusammenarbeit (GIZ), Cambodia
David Edward Johnson	Senior Scientist	International Rice Research Institute (IRRI), Phillipines

Il-Ryong Choi	Plant Virologist	International Rice Research Institute (IRRI), Phillipines
Jean Claire A. Dy	Communications Specialist	International Rice Research Institute (IRRI), Phillipines
Kazuhito Kawakita	Professor of Plant Pathology	Nagoya University, Japan
Makarady Keam		Research Department Directory, Cambodian Center for Study and Development in Agriculture
Pieter Rutsaert	Agricultural Economist	International Rice Research Institute (IRRI), Phillipines
Ricardo Oliva	Scientist	International Rice Research Institute (IRRI), Phillipines
Sathya Khay		Plant Protection Division, Cambodian Agricultural Research and Development Institute
Virender Kumar	Senior Scientist	International Rice Research Institute (IRRI), Phillipines
W. Harvey Reissig	Professor of Entomology	New York State Agricultural Experiment Station, Cornell University
Modeling for Biodiversity and Climate Change		
Principal Investigator	Title	Organization
Nir Krakauer	Assistant Professor of Civil Engineering	City University of New York (CUNY) - City College
Collaborators	Title	Organization
Ajay Jha	Director	Institute for Global Agriculture and Technology Transfe
Anjana Devkota		Department of Botany, Tribhuvan University, Nepal
Bharat Babu Shrestha		Department of Botany, Tribhuvan University, Nepal
BR Ranabhat		Ecological Services Centre
David Lohman	Assistant Professor of Biology	City University of New York – City College
José Daniel Anadón	Assistant Professor of Biology	City University of New York – Queens College
Madan Lall Shrestha	Academician	Nepal Academy of Science and Technology
Min Raj Pokhrel	Assistant Professor	Agriculture and Forestry University, Nepal
Mohan Sharma	Professor	Agriculture and Forestry University, Nepal

Mohan Siwakoti		Department of Botany, Tribhuvan University, Nepal
Naba Raj Devkota	Professor	Agriculture and Forestry University, Nepal
Pramod Kumar Jha		Ecology and Resource Management, Tribhuvan University, Nepal
Ram Asheshwar Mandal	Project Coordinator and Post Doc	Tribhuvan University, Nepal
Sanjay Kumar Jha		Department of Botany, Tribhuvan University, Nepal
Sundar Tiwari	Assistant Professor	Agriculture and Forestry University, Nepal
Tarendra Lakhankar	Project Scientist	CUNY Crest Institute
Invasive Species Modeling for South American Tomato Leafminer and Groundnut Leafminer		
Principal Investigator	Title	Organization
Abhijin Adiga	Senior Research Associate	Biocomplexity Institute, Virginia Tech
Collaborators	Title	Organization
Achla Marathe	Professor	Biocomplexity Institute, Virginia Tech
Anaïs Chailleux	Research Entomologist	French Agricultural Research Centre for International Development, Senegal
Arame Ndiaye	Molecular Biologist	Biopass, Senegal
Madhav Marathe	Professor	Biocomplexity Institute, Virginia Tech
Nicolas Desneux	Research Scientist	French Nation Institute for Agricultural Research
Ousmane Ndoeye	Technical Assistant	Fédération des Producteurs maraîchers de la zone des Niayes, Senegal
R. Asokan	Principal Scientist, Agricultural Entomology	Indian Institute of Horticultural Research
R. Venugopalan	Senior Scientist, Agricultural Statistics	Indian Institute of Horticultural Research
Srinivasan Venkatramanan	Postdoctoral Associate	Biocomplexity Institute, Virginia Tech
Thierry Brevault	Research Entomologist	French Agricultural Research Centre for International Development, Senegal
Y.G. Prasad	Principal Scientist of Entomology	Institute for Dryland Agriculture, India
V. Sridar	Entomologist	Indian Institute of Horticultural Research