The Feed the Future Innovation Lab for

Integrated Pest Management

Semi-Annual Report

2016-2017

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IPM IL | Integrated Pest Management Innovation Lab

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Executive Summary

Over the past six months, the IPM Innovation Lab Management Entity has participated in the annual planning meetings for five of our eight projects: Exportable Fruit Crops IPM in Vietnam, Vegetable IPM for Asia, Rice IPM for Cambodia, Vegetable IPM for Africa, and Climate Change and Biodiversity Assessment in Nepal. In addition, we individually reviewed the Modeling of Invasive Species, Biological Control of *Parthenium*, and Grains IPM for Africa projects.

In October of 2016, the IPM Innovation Lab organized two symposia at the International Congress of Entomology in Orlando, Florida: Integrated Pest Management Components and Packages for Tropical Crops and Spread and Management of the South American Tomato Leafminer, *Tuta absoluta*.

One of our main focuses during the last half year has been the South American tomato leafminer pest, *Tuta absoluta*. The presence of this invasive pest was confirmed in Bangladesh and Nepal last spring. Given how quickly this pest is able to spread, we unfortunately predict it will get as far as Myanmar and Thailand by the end of 2017, and will move into Cambodia, one of our project countries, thereafter.

In order to prepare Cambodian farmers, the IPM Innovation Lab conducted two awareness workshops in Phnom Penh and Siem Reap in November. Each of these workshops had over 60 participants including government officials, NGO representatives, and farmers. We then led two more *Tuta absoluta* workshops in December, this time in Dhaka and Jessore, Bangladesh to aid stakeholders already dealing with the pest problem. These workshops were co-organized by USAID's Value Chain project managed by DAI.

We also prepared a PERSUAP to address *Tuta absoluta* in Nepal, which was accepted by USAID in April 2017.

The IPM Innovation Lab led a symposium on the pest at the International Conference on Biodiversity, Climate Change Assessment, and Impacts on Livelihood in Kathmandu, Nepal. The conference took place from January 10-12, and besides organizing a symposium on *Tuta absoluta,* we participated in symposia on IPM and on biological control of invasive species. The conference was inaugurated by Nepal's president Bidya Devi Bhandari and over 300 participants from the region and around the world attended this conference.

In December of 2016, the IPM Innovation Lab edited a book entitled; "Integrated Pest Management of Tropical Vegetable Crops," which covered our activities doing integrated pest management work in the developing world during the last two decades. It was published by Springer Publishing and edited by IPM Innovation Lab Director Muni Muniappan and Asia Program Manager E.A. "Short" Heinrichs.

The Management Entity compiled IPM IL publications from 1993 to 2016 and printed them as a book. It is available for distribution upon request. We also published a package on IPM technologies for eggplant to accompany the tomato package we have already released. We are currently working on packages for onion and pepper.

From March 29-31, 2017, Muniappan was invited by FAO to participate in the Scientific and High Level Meeting on the Red Palm Weevil in Rome, Italy.

Looking ahead, a proposal to conduct a symposium on "Integrated Pest Management of Tropical Crops" at the Annual Meeting of the Entomological Society of America, Denver, Colorado was accepted. Our request to conduct two sessions each at the International IPM Symposium, Baltimore, Maryland and the International Congress of Plant Pathology, Boston, Massachusetts are pending approval.

In addition, we are currently working on a PERSUAP for the Fall Armyworm in East Africa. This invasive pest arrived recently in Africa but has spread quickly from southern Africa up to our project countries Ethiopia, Kenya, and Tanzania in the east. In addition, the Armyworm is also active in West Africa. The pest moves very quickly and is extremely destructive to maize. Muniappan attended a meeting on the pest in Nairobi on April 27-28 and we will be holding a workshop in Addis Ababa in July 2017.

The following news releases were published by and about our project activities during this semi-annual reporting period:

1. "Virginia Tech researchers spoke at the International Congress of Entomology." *Virginia Tech News* (USA). October 2016.
2. "EPIC: A new partnership in rice pest management in Cambodia." *Rice Today* (Philippines). November 2016.
3. IPM Innovation Lab Fall Newsletter, November 2016.
4. "Virginia Tech scientist works to control insects that attack Niger's most important food crop." *Virginia Tech News* (USA). December 2016.
5. "Early measures to save tomato harvest." *The Daily Star* (Bangladesh). December 2016.
6. "Virginia Tech program leads international workshops on destructive tomato pest." *Virginia Tech News* (USA). January 2017.
7. "Talking Climate Change." *New Spotlight* (Nepal). January 2017.
8. "Scientific Modeling Helps Defend Tomatoes Against Flying Foe." *Feed the Future Newsletter* (USA). January 2017.
9. "Virginia Tech scientist edits new integrated pest management book." *Virginia Tech News* (USA). February 2017.
10. "Alien Invasion." *New Spotlight* (Nepal). February 2017.
11. "Virginia Tech helps Nepal mobilize against devastating pest" (article and video). *Virginia Tech News* (USA). March 2017.
12. IPM Innovation Lab Winter Newsletter, February 2017.

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.

This project addresses four major crops in Vietnam: dragon fruit (*Hylocereus* spp.), mango (*Mangifera indica*), longan (*Dimocarpus longan)* and lychee (*Lychee chinensis*). These four crops collectively represent the major portion of Vietnamese fruit export to the United States markets. Pests and diseases are the major constraints. Managing key pests and diseases is pivotal to decrease losses as well as to increase productivity for export that benefit small scale farmers.

Implementation of IPM packages

The IPM packages were implemented in eleven orchards (0.5-2 ha) Vinh Long, Tien Giang, Ba Ria-Vung Tau for longan, Long An, Tien Giang and Binh Thuan for dragon fruit, and Dong Nai and Dong Thap for mango in the South; and Hung Yen for longan, Hai Duong and Bac Giang for lychee in the North of Vietnam. In these trials, the target pests addressed were: longan – witches' broom syndrome, mite *Eriophyes dimocarpi,* stink bug *Tessaratoma* sp., fruit borer *Conogethes punctiferalis* and *Conopomorpha sinensis*; dragon fruit - canker *Neoscytalidium dimidiatum,* anthracnose *Colletorichum gloeosporioides,* fruit fly *Bactrocera dorsalis* and thrips; mango - Bacterial black spot *Xanthomonas campestris* pv *mangiferae*, anthracnose *Colletotrichum* spp., fruit fly *Bactrocera dorsalis,* fruit borer *Deanolis albizonalis,* leaf hopper *Idioscopus niveosparsus* and thrips *Scirtothrips dorsalis*; and lychee - Powdery mildew *Peronophthora lichii,* anthracnose *Colletotrichum* spp., stem end borer *Conopomorpha sinensis* and stink bug *Tessaratoma papillosa*. Disease and pest incidence, damage, pesticide residues of fruit, population of beneficial organism have been recorded in each treatment.

a. **Dragon fruit:**
   We developed an IPM package of dragon fruit and proposed to apply to the cluster/cooperative in each zone (target provinces) with incorporating with GAP procedures to link the full supply chain from farm to markets.

b. **Mango**
   We are continuing to monitor and collect data in two IPM demonstration sites at Dong Thap and Dong Nai.

c. **Longan**
   Two IPM demonstration at Tien Giang, Ba Ria-Vung Tau have been completed and at one demonstration at Hung Yen data collection is continued. Another from IPM demonstration site at Vinh Long data collection has been completed.

Witches' broom is a major constraint to longan production in Vietnam. In addition, Witches' broom is emerging as a serious problem in rambutan. During the past few years, SOFRI scientists have generated valuable data on Witches' broom in longan. Based on their findings it has been concluded that Witches' broom is a consequence of mites feeding damage to growing buds of young shoots. We hypothesize that specific 'compound(s) in mite's saliva released at the feeding sites triggers metabolic changes leading to phenotypic expression of Witches' broom symptoms. This conclusion is further supported by the absence of phytoplasma and viral sequences from high-throughput sequence analysis of longan samples showing Witches' broom symptoms.

There is likelihood pf presence of more than one species of mite of the genus *Eriophyes* associated with longan. One group seems to cause Witches' broom and the other is not. A combination of studies involving morphological characteristics of mites and DNA Barcoding of mite's genome is being pursued to resolve whether there are two distinct species of eriophyid mites on longan. Data generated on Witches' broom will be published in a peer-reviewed scientific journal.

Field studies will be continued to validate IPM tactics (cultural methods, mites control by chemical and biological means, use of tolerant/resistant varieties, etc.) for mitigating crop losses in farmers' fields due to Witches' broom.

An IPM package of longan has been developed and will be implemented on a large scale.

d. Lychee

We are continuing IPM implementation at Bac Giang and Hai Duong.
Identification of the causal agent of Longan Witches' Broom and strategy for management is ongoing.

Applications of entomopathogenic nematodes (EPN), plant extracts and other beneficial organism to control plant pests

a. Dragon fruit

The effect of beneficial nematodes on control of fruit fly on dragon fruit in the laboratory conditions was tested. The isolation of EPNs from peppermint (*Mentha piperita*) plants in the field had the highest population of *Heterorhabditis* spp. *Steinernema carpocapsae* was mass reared on *Galleria mellonella* larvae. *Steinernema carpocapsae* was effective in killing maggots of *Bactrocera correcta* at 250-300 IJs/maggot in the laboratory conditions. The effectiveness of isolated antagonists of *Streptomyces* sp. and *Bacillus* spp. against *Colletotrichum truncatum*, and *C. gloeosporioides*, causative organisms of anthracnose of dragon fruit were evaluated in laboratory conditions.

b. Mango

The toxicity of four kinds of plant methanol and aqueous extracts and eight insecticides were investigated against scale *Aspidiotus destructor* (Hemiptera: Diaspididae) on mango in laboratory conditions. In bioassay, Spirotetramat (Movento 150 OD) was the most toxic (81.52%), followed by Abamectin (Brightin 1.8 EC) (64.42%), Etofenprox (Trebon 20 WP) (59.62%), Petroleum Spray Oil (SK Enspray 99 EC) (58.63%) and tobacco methanol leaf extract (63.33%) at 2% concentration at five days after application. In bioassay, Spirotetramat (Movento 150 OD), Abamectin (Brightin 1.8 EC), Etofenprox (Trebon 20 WP) and tobacco methanol leaf extract (at 2% concentration) were the most toxic at 3 days application (62.91,49.43, 45.90 and 58.89 per cent, respectively).

c. Longan

Extracts of *Derris elliptica* root and *Bougainvillea glabra* leaf concentrations at 5% were effective in controlling the mite, *Eriophyes dimocarpi.*

Design and selection of for fruit bags for dragon fruit and 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.

Lessons learned

Fruit production investigation and social impact study should be conducted separately in order to shorten each individual interview. The interviewed farmers felt overloaded with questions sometimes.

Technologies Transferred

Four IPM packages for longan, dragon fruit, mango and lychee were developed and transferred to farmers in the selected demonstration sites.

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

The Vegetable Crops and Mango IPM in Asia project implements ecologically-based, participatory IPM in Cambodia, Nepal, and Bangladesh, with a focus on pests of tomato, eggplant, cabbage, cauliflower, Chili peppers, beans, cucurbits, Chinese cabbage, onion, and mango (the latter in Bangladesh).

Research Progress:

Cambodia

1. Baseline surveys in Siem Reap and Battambang provinces were completed. Following a pilot test of the questionnaire, a 400 farm households were selected randomly from vegetable growers in 20 villages in Siem Reap and 20 villages in Battambang. Following completion of the survey, data were entered into Excel by Virginia Tech student intern Millie Smith with assistance of a Cambodian student for translation. The data are now ready for summary and analysis.

2. Field trials were conducted on Chinese Kale and cucumber with 12 cooperating farmers, two of whom are members of the Beung Mealea Woman's Group of Conservation Agriculture in Soutr Nikum, Pouk, and Siem Reap districts. There were six trials on cucumber from August to October 2016 and six Chinese Kale trials from October 2016 to January 2017. The trials have been completed and data are being analyzed and discussed. A second season cucumber IPM package trial began in February/March 2017 with 12 cooperating farmers and the plants are currently in the vegetative stage.

3. Three experiments, including the effects of *Trichoderma* and pesticides on Chinese kale and cucumber and a *Ralstonia solanacearum* rootstock-tolerance trial, were completed by the RUA team (five students and 2 lecturers) from August to October 2016. The cucumber and Chinese kale experiments were destroyed by heavy rainfall that flooded all RUA test fields from mid-October. In the last week of December 2016, water was pumped out of the fields and the students re-established the cucumber and Chinese kale trials, which were completed in March. The *Ralstonia* rootstock experiment survived as it was done in the glasshouse and laboratory, safe from flood water. The results of *Ralstonia* rootstock experiment were used by a student for her thesis and were presented to the visiting team of US scientists in January 2017. Two new trials have been initiated at RUA: 1) Bio-efficacy evaluation of *Trichoderma harzianum*, *Trichoderma viride* and *Trichoderma koningii* for controlling damping off on tomato, and 2) Evaluation of rootstocks for controlling of bacterial wilt (*R. solanacearum*) on grafted tomato, eggplant, and chili under field conditions.

Bangladesh

Field trials and other research activities were undertaken that included: a) assessment of the performance of Bt and non-Bt eggplant under an IPM package, b) a survey on incidence of and pest damage due to South American tomato leafminer, *Tuta absoluta*, c) development of management approach for mango hopper, d) development of a management approach for Oriental fruit fly, *Bactrocera dorsalis*, e) study of the biology, yield loss, and integrated management of white mold of country bean, and f) assessment of economic impacts of vegetable IPM in Bangladesh by one PhD student in agricultural economics at Virginia Tech and a second PhD student from Bangladesh Agricultural University.

1. Performance of Bt and non-Bt eggplant under IPM – An experiment was set up in January with Bt and non-Bt eggplant seedlings in farmer's fields at two locations in Bogra and Jessore. It follows an RCB design with two treatments and three replications: Treatment 1 = Bt eggplant with IPM package and Treatment 2 = Non-Bt isoline with IPM package. IPM package includes, raising of seedlings in mixture of cocodust, tricho-compost, loamy soil and decomposed cowdung, removal of infested shoot and fruit, application of Azadirachtin and Imidacloprid to control sucking pests such as whitefly and jassids, and use of yellow and white sticky traps. Thus far, in the Bt plots no infestation of eggplant shoot and fruit borer (ESFB) has occurred, but ESFB infestation has occurred in the non-Bt plots. Infested shoots and fruits are being removed from non-Bt plots. Crop growth has been satisfactory. The crop is now (early April) at bearing stage and data recording is ongoing. Mortality of plants due to wilting has not been more than five percent.

2. Monitoring of South American tomato leaf miner – Building on the extensive survey completed in farmers' fields in Jessore, Comilla, and Panchagarh earlier in 2016, a survey was conducted at farmers' fields of Panchagarh region and Gazipur beginning in December 2016. Data recording is on-going for the percent damage of tomato plant/ leaf/fruit, including the larval mines per leaf and fruit damaged. Up through March 2017, Tuta has been found at Panchagarh, Rangpur, Gaibandha, Bogra, Sylhet, Moulvibazar, Gazipur, Comilla and Jessore, as indicated in Figure 1. We can assume that Tuta has dispersed in all tomato growing areas of Bangladesh by now. Infestation and intensity was found to be highest at Panchagarh and Sylhet regions.

Figure 1. Monitored locations where *Tuta absoluta* has been found in Bangladesh

3. Development of Management Approach for Mango Hopper -- An experiment based on bio-rational pest management on mango hopper has been on-going since December 2016

in three locations: Gazipur, Rajshahi and Chapai Nawabganj. It follows an RCB design with eight treatments with three replications: Treatment 1 = Pruning of overcrowded and overlapping branches before flowering in December, Treatment 2 = foliar spray of Azadirachtin (Bio-Neem plus 1EC @ 1ml/L of water) thrice at 10 day intervals at flowering, Treatment 3 = Foliar spray of *Metarrhizium anisopliae*/*Beauveria bassiana* twice at seven day intervals at flowering; Treatment 4 = installation of Yellow sticky traps, Treatment 5 = installation of grey sticky traps, Treatment 6 = installation of Bbue sticky trap, Treatment 7 = two sprays with Confidor (Imidachlorpid) 70 WG insecticide @ 0.2g/L of water, and Treatment 8 = Control. Data are being recorded on the number of adults and nymphs on the trunk, leaves, and inflorescences starting from flower initiation to harvesting of mango fruit, number of fruit retained, and fruit dropped, mango yield, and costs. First and second sprays have been done in three locations at flowering and pea stage of mango, with a one month interval. Data recording is on-going for parameters such as fruit retention per panicle, number of trapped hoppers per trap per week, etc.

4. Development of Management Approach for Oriental fruit fly – An experiment based on bio-rational pest Management has been proposed against mango fruit fly and was begun in 2016 and continued in 2017 for a second season in three locations: Gazipur, Rajshahi and Chapai Nawabganj. The experiment follows an RCB design with seven treatments and three replications. These seven treatments include: Treatment 1 = setting of methyl eugenol pheromone traps at six weeks before mango harvest, Treatment 2 = Protein hydrolysate bait trap at six weeks before mango harvest, Treatment 3 = bagging by cloth bag at six weeks before mango harvest, Treatment 4 = bagging by Polythene bag at six weeks before mango harvest, Treatment 5 = Foliar spray of Shobicron 425EC @ 1.5ml/L of water, Treatment 6 = bagging by china brown paper bag at six weeks before mango harvest, and Treatment 7 = Control. Data are being recorded on the number of fruitflies caught in traps per week, number of infested fruit, number of healthy fruit, marketable yield per plant, and costs. Three farmers' trainings will be conducted at three locations in April 2017.

5. Biology, yield loss and integrated management of white mold of country bean – Major objectives of this study are to identify physico-chemical and soil ecological factors that influence white mold disease development (in-vivo) and select effective biocontrol agents against the pathogen. White mold disease incidence was recorded in country bean during the November to March growing season. Ten Upazilas under eight districts (Jessore, Jhenidah, Pabna, Hobiganj, Sylhet, Gazipur, Bogra and Rangpur) were surveyed and monitored for the occurrence of white mold infection in country bean fields. During the survey, some isolates from other plants such as mustard, sunflower, eggplant, flower (marigold) and weeds were also collected. Compatibility among the isolates was studied and in the case of eggplant, white mold is a first record. The pathogen was isolated from infected parts and re-inoculated in eggplant for confirmation. Disease severity of country bean was highest in Bogra followed by Sylhet. The lowest was at Jessore followed by Gazipur. Apothecia formation was the highest from February 15 to March 15 (when temperature fluctuation was the greatest). *Trichoderma harzianum, T. viride*, two isolate

of *Pseudomonas fluorescens*, and three isolates of *Bacillus subtilis*, were found effective in controlling the pathogen under laboratory conditions.

6. Impact assessment – Both economics PhD students are still in the process of analyzing their survey data to assess impacts of vegetable packages on income and pesticide use and are completing the write-ups of their dissertations.

Nepal

Several experiments, capacity building through graduate student research, and *Tuta absoluta* management occurred during the period. During this reporting period, specific activities included a) Surveillance of pest and disease in okra and beans, b) Monitoring of *Tuta* incidence and outbreak in the IDE project implementing districts, c) Survey of economic loss and management practices adopted by commercial tomato growers of Kathmandu, Lalitpur, Bhaktapur and Kavre districts, d) survey of insect pests and diseases of onion, chili, French bean and okra crops and management practices adopted by the farmers in Banke and Surkhet districts, e) ongoing research trial in French bean in Banke district, f) ongoing research trials on onion and chili and of management of fruit fly in bitter gourd and cucumber, g) regular monitoring of pest populations using lures for *Helicoverpa*, *Spodoptera* and *Tuta*, in Banke and Surket, h) efficiency evaluation of pest exclusion net (PEN) for the management of insects in tomatoes, i) efficacy evaluation of *Trichoderma* products available in the market, j) graduate student training in economic impact assessment, plant pathology, and gender analysis, and k) presentations on *Tuta* problem and management.

1. Insect pest and disease surveillance in okra and beans -- Insects and diseases recorded for Okra include fruit borer, whitefly, aphids, red cotton bug, *Yellow vein mosaic virus*, and root knot nematode. For French beans they were cutworms, aphids, rust, Mosaic, and Anthracnose.

2. Monitoring of *Tuta* incidence, research, and training --AVMIPM-IL has been regularly monitoring the presence of *Tuta absoluta* in tomatoes in Nepal. The pest invaded Nepal on 2016 and was identified for the first time in Tarakeshwor Municipality by NARC. The appearance of the pest in the TLM lure began in October 2016 in both project districts. *Tuta absoluta* adults are being monitored on a weekly basis using pheromone lures in Banke and Surket. AVM IPM-IL has set up a PEN trial in Kamdi-9, Paschim Tilakpur to screen the efficacy of Pest Exclusion Nets for the management of the pest. The seedlings used in the trial were raised in plastic trays using coco peat and were seeded on November 1, 2016 and was transplanted on December 4, 2016. Tricho compost was applied during the transplanting, which was prepared three weeks prior to transplanting in both the PEN and open field. The TLM lure, heli lure, Spodo lure and yellow sticky trap were placed inside PEN and in the open field and data recording of the pest is being done on a weekly basis using pre structured format. The difference in the number of insects recorded in the respective traps between PEN plot and open plots will determine the efficacy of pest exclusion to prevent entry of the pest. Currently the crop is at the fruit harvesting stage. In addition, training on identification of *Tuta* and IPM recommendations

for its management were conducted in Nepalgunj for concerned stakeholders. Nine IPM demonstrations were conducted for farmers' groups and 13 training events were organized on *Tuta absoluta* identification and its management for different stakeholders and GoN (with 111 participants).

3. The research trials in onion, chili, cucumber, bitter gourd, and French beans are ongoing with the crops currently in the field and data being collected. For onion, the objective is to test an IPM package. The treatments were segregated into IPM practice and farmers' practice using the variety Nasik red-53. The seedlings were grown in a raised nursery bed. In the IPM plot, Tricho-compost was applied during transplanting. Data are being recoded for major insects pest such as thrips, cutworms, purple blotch, bulb rot, and yield difference will be noted on a pre structured data recording format. Presently the crop is at the bulb formation stage. For chili, the objective is to test an IPM package. The crop is now at the seedling stage for variety NS-1791. Data are being recorded for thrips, aphids, Leaf curl virus, and wilt, and yield difference will be recorded as well. For bitter gourd and cucumber, the objective is to evaluate the efficacy of various lures for management of fruit fly. The seedlings were raised in plastic trays using coco-peat and transplanted into the field. Different lures are being tested: cuelure, protein based lure, and ripe pumpkin with Malathion with one treatment as a control. The number of fruit flies in each trap will be recorded weekly. The crop is at the vegetative growth phase. For French beans, the experiments were conducted in farmers' field at 4 research sites in Banke to test an IPM package. The trial was set up in 6 farmer's field in each of 4 sites for a total of 24 farmers. The treatments were segregated into IPM practice and farmer practice. Tricho-compost along with Poshan Plus (bio fertilizers) were used during transplanting of the seedlings in the IPM plots.

4. Gender Analysis – A literature review was completed on gender, agricultural labor, and empowerment in Nepal by the MS gender graduate student on the Nepal project. Methods were developed for field work to collect a) qualitative data through household interviews, focus group discussions, key informant interviews, and participant observation and b) at quantitative demographic survey.

5. Plant pathology PhD student research progress -- Research has begun on a) identification of *Fusarium* species associated with rhizome rot disease of ginger in Nepal, b) examining the influence of different temperatures, Ph, and water activities on *Trichoderma* isolates from Nepal, c) studying the effects of carbon sources on anaerobic soil disinfestation to reduce soilborne pests in okra and eggplant in Nepal, and d) identifying effective bio-control strains from the Nepalese *Trichoderma* collection.

6. Entomology PhD student research progress—Work has begun to assess climate and altitudinal changes to plant defensive systems. In the laboratory phase, tomatoes are grown under varying temperature, humidity and CO_2 regimes. Plant are infested with H. zea and insect growth as well as plant defensive chemistry is assessed.

Lessons Learned

- The quality and availability of bio-pesticides such as *Trichoderma* and *Bt* are questionable in Cambodia and lab testing is needed as well as field testing for the effectiveness against particular crop pests.
- In Nepal, pest monitoring data generated with pheromone traps were helpful, but need to be correlated with weather and cropping season.
- After the invasion of Tuta in tomato in Nepal, efficacy evaluation of pest exclusion nets for management of the insect pest of Tomato crop is ongoing, but it needs to be carried out on a large scale.

Presentations and Publications

Presentations

- Colavito, L. and L. Sah. (2017). "Developing IPM Packages for Vegetable Crops and its Dissemination in FtF Disticts of Nepal" and "IPM Learning Center: Knowledge Depository for Visitors" Paper and Poster presentations at Asia Pacific workshop on Empowering Farmers through Integrated Pest Management organized in Kathmandu from February 27, 2017 to March 2, 2017.
- Colavito, L. and L. Sah. (2017). "Tuta absoluta Orientation Workshop" was conducted on March 9 at Entrance Café Lalitpur, Nepal. Thirty seven representatives from MoAD, MoLD, NARC, PPD, iDE Nepal, various USAID funded projects and private sector participated in this workshop.
- Koy, C. (2017). "Varietal screening of tomato in bacteria wilt (*Ralstonia solanacearum*) disease," presentation at RUA, January.
- L.P. Sah, Ajay Pratap Giri, Luke A Colavito, Shiva yendyo, Yubraj Dhakal, Dilli R Sharma, George Norton, Edwin G Rajotte, R Muniappan, and Sulav Paudel (2017). Occurrence, Distribution and Management Practices of South American Leaf miner (Tuta absoluta) in Nepal. Oral Presentation at the International Conference on Biodiversity, Climate change Assessment and Impact on Livelihood, Kathmandu Nepal , January 10-12, 2017.(Abstract: ICBCL 52, pp22-23).
- "Pest Management Technology and Tuta absoluta in Nepal" at 10th National Organic Fair organized in Kanchanpur District from February 3 to 6, 2017
- Video documentary: AVIPM-IL Nepal with the help of Bimala Rai Colavito (iDE Volunteer) had released a video on outbreak of Tuta absoluta in Nepal, its damage and way forwards. (https://www.youtube.com/watch?v=kJpwP4e2HBA&spfreload=10)
- Tuta Materials Webpage: http://www.idenepal.org/what/tuta.html.
- IPM Vegetable Package Materials Webpage: http://www.idenepal.org/what/ipm.html.

Publications

- Hossain, M.S., M.Y. Mian, GMA Halim and R. Muniappan. 2016. Bangladeshe Tuta leafminer er abirvab ebong amader karaniya (Bengali booklet) pp.1-14.

- Hossain, MS., M.Y. Mian and R. Muniappan. 2016. First record of Tuta absoluta (Lepidoptera: Gelechiidae) from Bangladesh. Journal of Agriculture and Urban Entomology. South Carolina Entomology Society, USA. 32(1).101-105. DOI: http://dx.doi.org/10.3954/1523-5475-32.1.101
- Mian, Md.Y, Md. S. Hossain, and A.N.M.R. Karim. 2016. Integrated Pest Management of Vegetable Crops in Bangladesh. Chapter 11 in R. Muniappan and E.A. Heinrichs (eds.). Integrated Pest Management of Tropical Vegetable Crops. Springer, 235-250.
- Norton, G.W., J. Alwang and M.S. Issa. 2016. Impacts of IPM on vegetable production in the tropics. Chapter 14 in R. Muniappan and E.A. Heinrichs (eds.). Integrated Pest Management of Tropical Vegetable Crops. Springer, 289-304
- Paudel. S, L.P. Sah, K Pradhan, LA Colavito, BP Upadhyay, EG Rajotte, R Muniappan, 2016. Development and dissemination of Vegetable IPM Practices and Packages in Nepal. Chapter 12 in R. Muniappan and E.A. Heinrichs (eds.). Integrated Pest Management of Tropical Vegetable Crops. Springer, 251-269.
- Sah, L. and others. 2017. Tuta and IPM protocols for tomato were developed utilizing the latest international research and preliminary research conducted in Nepal since the outbreak. The protocols were developed in coordination with Department of Agriculture, Plant Protection Directorate, and NARC in both English and Nepali script.

Technology Transfer and Scaling Partnerships

- Technologies Transferred -- *Trichoderma* use in Bangladesh and Cambodia. Factsheets on *Tuta absoluta* circulated among the USAID's sister projects and DADO staffs to raise awareness on *Tuta* outbreak and its management in Nepal.
- 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, several IPM packages in Bangladesh.

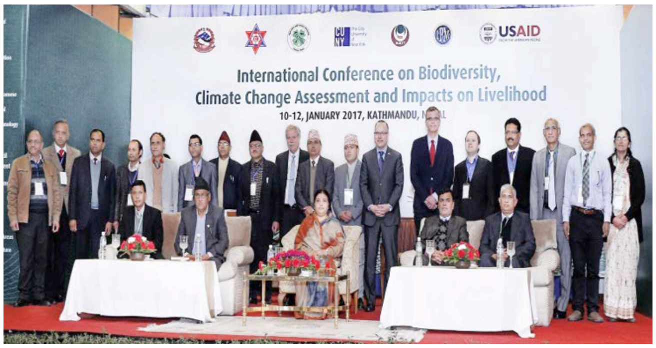
3. Participatory Biodiversity and Climate Change Assessment for Integrated Pest Management in the Annapurna-Chitwan Landscape, Nepal

Principal Investigator: Nir Krakauer, CUNY City College

International conference

The International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood (ICBCL, icbcl17.org) was held on January 10-12, 2017.

The President of Nepal, Hon. Bidhya Devi Bhandari, inaugurated the conference and said Nepal wanted to play a proactive role in protecting biodiversity, reducing the negative impact of climate change and building sustainable livelihood for communities around the country. The broad premise of the conference was that approaches from the natural and social sciences to support economic development particularly in developing countries, which face serious climate hazards, biological invasion, biodiversity loss, agriculture, and water stress. The conference also served more narrowly to introduce the project goals and initial work to a broad national and international audience.



Tribhuvan University Vice-chancellor Tirtha Khaniya, Director General of the International Centre for Integrated Mountain Development (ICIMOD) Dr David Molden, and USAID Nepal Director Peter Malnak spoke at the inauguration on the significance of the conference in providing a platform for exchange of ideas and experiences in biodiversity conservation and combating climate change throughout the world. Director Malnak stressed USAID's interest on adapting to climate change and restricting the impact of invasive plants and pests on Nepal agro-ecosystems. He also stressed the importance of managing the South American tomato leafminer, *Tuta absoluta.*

Around 400 scientists, researchers, professors, environmentalists and conservationists from more than 20 countries, including Nepal, India, China, Pakistan, Bangladesh among others, have been participating the conference in Crowne Plaza Hotel Soaltee, Kathmandu. Over 100 papers and posters were presented during the three-day conference. Special sessions on "*Tuta absoluta*", "Biological Invasion" and "Incentivizing Mountain Communities for Ecosystem Services at the time of Changing Climate" were held. Nepali young scientists, students and experts benefitted from sharing scientific views.

Interaction with farmers

The research team visited research field sites in Chitwan Annapurna Landscape (Puranachaur, Kaski and Chyangchyangdi, Syangja). IPM IL researchers and the CUNY/TU/AFU/IGATT research team interacted with the farmers regarding the implementation of project activities and observed weather stations and student research field sites for two days (January 13-14, 2017).

Research and student progress

N. Krakauer is leading work by the CUNY team to use remote sensing to quantify and attribute changes in vegetation primary productivity and phenology due to contemporary climate change (i.e. that which occurred over the last few decades). The goal of this work is to quantify the rate of biome shifts and changes in plant productivity in Nepal as a result of warming over recent decades, which can be used to estimate the climate impact on biodiversity associated with different biomes, elevations and on invasive species expansion and growth regime. With the help of T> Lakhankar (CUNY) and other team members, including a graduate student, an initial analysis framework has been established and datasets of remotely-sensed vegetation index, high-resolution topography and land use, and climate records have been assembled and fed into machine learning (random forest of regression trees and hierarchical Bayesian linear model) toolkits. First results are now being analyzed.

J. Anadón (CUNY) and his graduate student have focused their efforts on modeling the ecological impacts of climate change on biodiversity in the CHAL. An integrated approach has been taken to use both empirical and theoretical tools, including literature reviews, field biodiversity sampling and spatial modeling, to study the impact of changing climatic conditions on crops, invasive species and Nepal's significant biodiversity.

Anadón's group created technical documents for the project team and relevant researchers to use in biodiversity sampling and for the analysis of spatial data. This includes detailed protocols for the biodiversity sampling and species distribution modeling, which is being used in implementing data collection and analysis for the PhD students' projects. The poster *Modeling of Climate Change Impacts the Chitwan-Annapurna Landscape* presented at the International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood (ICBCL) in Kathmandu, Nepal this year collated the technical steps to collecting and analyzing spatial data from the field, as used in this project and applicable to many of the researchers from the region that were present at the conference.

J. Anadón and his student are also working on distribution models of three invasive plant species (*Lantana camara, Parthenium hysterophorus* and *Ageratina adenophora)* that are particularly relevant to the ChAL. These models depict their potential distribution given their native range and project their distribution in future climate scenarios.

D. Lohman's lab at CUNY is carrying out refinement of Sequence Capture of molecular markers using PCR-generated Probes (SCPP). They will use this novel and complex lab protocol to amplify genetic markers from interacting species across multiple trophic levels. They are currently finishing lab trials of this method prior to sequencing samples on the Illumina Mi-Seq platform. If successful, the method will be implemented in Lohman's graduate student's (T Doleck) doctoral research to elucidate ecological interactions across an elevation gradient in Nepal using caterpillar samples.

Doleck's project hinges on successful capture of markers across flowering plants (angiosperm) and butterfly/moth (Lepidoptera) families using targeted capture with genetic probes generated via PCR. The Lohman lab is currently conducting tests to verify viability of the method, adequacy of selected genetic markers, and optimal markers to capture loci across all angiosperm families. Fifty species of angiosperms have been sampled for this test, and 7 markers have so far been amplified for each using PCR.

Three TU students prepared their theses based on their project-related research. Ganga Shah and Vishubha Thapa have submitted their theses in Central Department of Zoology, TU and have been awarded MSc degrees. In addition, Sagar Khadka has submitted his thesis draft to Central Department of Botany, TU.

Farmer-level training

In addition, in order to promote IPM in the field, two farmer field schools were organized, in Kaski and Syangja. The FFS philosophy is to identify problems, test possible solutions, and eventually encourage the participants to adopt the practices most suitable to their farming systems and make them aware about adapting to climate change and how to restrict invasive plant spread in productive agriculture systems and protect biodiversity. The FFS can also provide an opportunity for farmers for hands-on practice and testing/evaluation of sustainable land use technologies, and introduce new technologies through comparing with conventional technologies in the field. The FFS in Kaski and Syangja emphasize climate adaptive organic cucumber and tomato variety trails. The total duration of the FFS will be 18 - 22 weeks. The following provides an overview of the field plot design being implemented in the locations:

Publications

Project team members presented at the ICBCL17 conference we convened on different aspects of the project and the initial results. Extended abstracts were published in the conference proceedings book. These included the following:

- Aditya, Bhusan, M., and Jha, A.K. 2017. Climate change awareness and action plans: a comparison of graduate students and entry-level teachers. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 124.
- Basnet, S., Puri, C., Jha, A.K., Sharma, M.P., and Tiwari, S. 2017. Insect diversity survey in drip irrigated kitchen garden for healthy vegetable production through IPM methods in drought prone area of Kapilvastu district, Nepal. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 228.
- Bhandari, G., Anadon, J.D., Thapa, R., Giri, Y.P., Manandhar, H.K., Lohman, D., Krakauer, N., Jha, A.K., M., Jha, P.K., Devkota, N.R., Thapa, P., Mandal, R. A., Sharma. 2017. Maize stem borer *chilo partellus* (Swinhoe) distribution along elevational variation and climatic variability. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 220.

- Bhandari, S., Siwakoti, M., Anadon, J.D., Lohman, D., Jha, P.K., Mandal, R. A., Jha, A.K., and Krakauer, N. 2017. Fodder grass for livestock production to enhance people's income and enriching biodiversity at Puranchor village, Kaski district, Nepal. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 322.
- Bhattacharjee, A., Anadon, J.D., Lohman, D., Lakhankar T., Krakauer, N., Jha, A.K., Tiwari, S., Thapa, S., Devkota, D., Devkota, N.R., Doleck, T., Pokharel, M.R., Luitel, D.R., Mandal, R. A., Sharma, M.P., Siwakoti, M., Jha, P.K. 2017. A review of impacts of climate change on biodiversity in Nepal. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 80.
- Dangol, P., Shrestha, B.B., Lakhankar T., Siwakoti, M., Jha, P.K., Mandal, R. A., Jha, A.K., and Krakauer, N.2017. Changes in Life history traits of invasive Alien Weed *Lantana camara L.* along elevation gradient in Nepal. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 34.
- Deitz, M., and Jha, A.K. 2017. Climate-Smart technology transfer for smallholder farmers: A participatory approach. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 95.
- Devkota, D., Devkota, N.R., Sharma, M.P., Jha, P.K., Krakauer, N., and Jha, A.K. 2017. Gender roles and needs of women's enterprise promotion. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 334.
- Ghimire, M.S., Khanal, P., Krakauer, N., Jha, A.K., M., Jha, P.K., Devkota, N.R., Thapa, P. 2017. A review on management options for *Stemphylium* Blight of Lentil. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 222.
- Giri, H.N., Sharma, M.D., Thapa, R.B., Thapa, S., Devkota, N.R., Jha, P.K., Mandal, R. A., Krakauer, N., Jha, A.K.2017. Effect of organic and non-organic fertilizers as climate smart practices on growth and yield of cauliflower (*Brassica oleracea* L. var. botrytis). International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 94.
- Khadka, S., Jha, S.K., Jha, P.K., Anadon, J.D., Mandal, R. A., Jha, A.K., and Krakauer, N.2017. Management of water hyacinth (*Eichhornia crassipes*) in Chitwan-Annapurna Landscape, Nepal. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 33.
- Lakhankar T., Krakauer, N., Jha, A.K., and Khanbilvardi, R. 2017. Review on satellite remote sensing application for biodiversity and agricultural management. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 80.
- Luitel, D.R., Siwakoti, M., Jha, P.K., Krakauer, N., Jha, A.K. 2017. Distribution, production and cropping pattern of finger millet in Nepal. Proceedings of ICBCL 2017. International

Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 187.

- Mahajan, S., Devkota, A., Shrestha., Jha, P.K., Anadon, J.D., Mandal, R. A., and Krakauer, N., Jha, A. K. 2017. Variation in the Life History Traits of an invasive wee *Parthenium hysterophorus* L. along the elevation gradient in central Nepal. Page.32.
- Mandal, A. R., Jha, P.K., Lakhankar, T., Jha, A.K., and Krakauer, N. 2017. Infestation of *Eichhornia crassipes* in Ramsar sites of Nepal: Searching for management. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Pages 29.
- Panthy, A., Jha, P.K., Shrestha, B.B., Devkota, N.R., Krakauer, N., Jha, A.K. 2017. As assessment on the impact of climate change on cropping system and biodiversity in Chitwan District of Nepal. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 96.
- Poudel, A., Shrestha., Jha, P.K., Lohman, D., Krakauer, N., Jha, A.K. *Ageratina adenophora* (Asteraceace) invasion: current state of knowledge and prospect for future research. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 60.
- Puri, C., and Jha, A.K. 2017. Household nutritional security and women's income generation through drip irrigation for kitchen gardens in Syangja district, Nepal. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 327.
- Sapkota, S., Thapa, R.B., Lohman, D., Regmi, R., Krakauer, N., Jha, A.K., Devkota, N.R., Jha, P.K., Thapa, S. 2017. A review of monitoring of dung beetle's diversity and evaluation of its role in nutrient cycling. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 174.
- Shrestha, B.M., Jha, P.K., Siwakoti, M., Jha, A.K., Mandal, R. A. and Krakauer, N. 2017. Assessing livelihood vulnerability of small holder in Nawalparasi, Lamjung and Kaski districts, Central Nepal. Proceedings of ICBCL 2017. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 319.

Conference brochure: This was to advertise and promote the conference on 10-12, January 2017 in hard-copy and digital format. Separate brochures were prepared to promote the *Tuta absoluta* and biological invasion symposia for the conference.

Four news stories about the project were published in major online newspapers, and a 10-minute documentary on the project's technology dissemination work was prepared and broadcast in January 2017 by Mukundasen TV channel, Nepal.

Technology transfer and scaling partnerships

Weather station installation

The research team identified a suitable location in Puranchaur for the relocation of the weather station from Dhading. The station relocation and upgrading was carried out successfully. Additionally, periodic observation and inspection of the already installed weather stations in Syangja and Kapilvastu were conducted and data loggers and sensors upgraded.

Coordination

In order to have wider coordination with likeminded stakeholders, Prof. Dr. Naba Raj Devkota together with Prof. Dr. Pramod Kumar Jha participated in a meeting organized by the iDE Nepal in Kathmandu. Prof. Devkota presented on the project goals and activities. The participants of this meeting included iDE's country head, project staff, and professors from the different universities of the US.

A new additional synergy opportunity is with the NASA High Mountain Asia Team science project "Assessing Impacts of Climate-Induced Change on River Flow and Associated Economic Output", led by Prof. Kyle McDonald (CUNY) and with Krakauer and Lakhankar as Co-Is and other team members in Argonne National Laboratory and Kathmandu University. The Koshi river basin in Nepal is the main study area for this initiative. Collaborators in this project participated in our ICBCL conference, and it is expected that climate and remote sensing data compiled for the NASA project will be helpful for this project and vice versa.

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

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

EPIC aims to develop a rice IPM package validated for Cambodian biophysical conditions. 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).

Baseline survey

The IRRI baseline household survey was completed in September 2016 in each of the EPIC project villages in Takeo, Battambang, Kampong Thom, and Prey Veng; as well as two control villages in Pursat for a total of 400 farmer respondents (98 female, 302 male). The data was on farm characteristics, knowledge and training on pests and IPM, awareness and management practices of rice pests, and economic input-output for rice production. This baseline survey will be used to measure the change in practice and its economic impacts at the target villages within the duration of the project. Data on knowledge and training on IPM will be used to guide extension efforts. The farmers interviewed were mostly smallholders, with mean production area of 1.5 has for Takeo and Prey Veng and 3 has for Battambang and Kampong Thom. Their identified main pests varied across the provinces; for example, farmers in Takeo reported mostly rodents, while those in Prey Veng reported insects to be the main concern. In Battambang 49% reported stemborers as the main insect pest, while in Prey Veng 46% reported rice leaf folder. Only 13% of farmers said they received IPM training; most of them mentioned the Provincial Department of Agriculture as the source of training and information. Women are mostly involved in the hand weeding part of pest management, although some 11% are reported to be involved in buying pesticides or as joint decision maker on pesticide use. Men however, out of the household members, were the ones who joined the trainings.

G. Norton (Virginia Tech) and H. Reissig (Cornell) conducted pesticide knowledge, attitude and practice survey to identify priority pests, pest management practices, knowledge of IPM, extent of current rice IPM adoption, pesticide use practices, and characteristics of the farmers. The survey includes data from Takeo, Prey Veng, Kampong Thom, and Battambang provinces and a total of 400 farm households.

The respondents in the survey were 52.5% female and 47.5% male with an average age of 51 and 5.7 years of schooling. The average land owned was only 1.3 hectares and the average house size was 1.36 rooms. Ninety five percent of those who apply pesticides are male and 65% have become ill applying pesticides. Their largest source of information is farm input sales people and neighbors. Two thirds of their rice is rainfed and 88% of rice is direct seeded in the wet season and 97 % in the dry season. Seventy 3% of farmers earn more than half of their income from non-rice activities. Farmers sprayed their rice an average of 2.3 times spent 5.6 days weeding. Seventy-five percent have become ill from pesticide exposure. Some 81% of farmers mix different pesticides in one application, and 54% said their household member had experienced becoming ill due to pesticides. About 20% said pesticide sellers influence their decision on pesticide use. Except for hand weeding, few IPM practices are applied despite one-third saying they have been trained in IPM. Eighty nine percent of the farmers are aware that there are beneficial insects and 97% say that pesticides can damage the environment.

Crop health survey

The intensity of diseases, damage caused by insect pests and rat, and weed infestation was assessed at booting and ripening stages in two districts of each of the four target provinces during the wet season of 2016. Ten farmers' fields were surveyed in each district. The incidence of diseases or pest injuries affecting leaves and panicles was computed as the percentage of infected or injured leaves and panicles, respectively, in a hill. The incidence of diseases or pest injuries affecting the leaf sheath or both the leaf sheath and leaves was computed as the percentage of affected tillers in a hill. The major insect pest injuries during the survey period and the respective incidence averaged across provinces were rice hispa (5.35%) and whorl maggot (4.51%). The highest incidence of rice hispa damage was observed in Trana Koul, Battambang (16.41%) and Santouk, Kampong Thom (13.27%). The discrepancy between this objective field sampling and farmers' perception in the baseline survey (above) is noted.

The diseases with highest incidence were narrow brown spot (11.57%), brown spot (6.82%) and bacterial leaf streak (2.79%). The highest incidence of narrow brown spot was observed in Banan, Battambang (26.29%) and Santouk, Kampong Thom (29.11%) and the highest incidence of brown spot was observed in Trang, Takeo (24.48%), Trana Koul, Battambang (9.29%) and Steung Sen, Kampong Thom (9.52%). Steung Sten, Kampong Thom had the highest incidence of bacterial leaf streak (6.29%) and Prah Sdach, Prey Veng the highest incidence of neck blast (4.91%).

Weed infestation was severe in most districts. The average weed cover below and above the rice canopy was 34.10% and 29.86%, respectively. Weed cover above the rice canopy was highest in Paem Ror, Prey Veng (52.24%), Trana Koul, Battambang (46.74%) and Steung Sen, Kampong Thom (34.22%). The dominant weed types in most districts were grass and sedge. Weedy rice was observed in Battambang.

The incidence of rat damage was highest in Takeo province, with 11.57% and 5.19% damaged tillers in Trang and Bati districts, respectively. Average yield across sites was 4.34 t per ha.

Virologists of IRRI detected *Rice tungro bacilliform virus* and *Rice tungro spherical virus* from Bayar and Peam Ror, Prey Veng and Svay Chhroum, Svey Rieng. These viruses cause tungro and are transmitted by green leafhoppers. *Rice grassy stunt virus*, which is transmitted by brown planthopper, was detected from Peam Ror, Prey Veng. Rice orange leaf phytoplasma (ROLP) was detected using polymerase chain reaction in infected leaf samples from Svay Chhroum, Svay Rieng. ROLP, which causes rice orange leaf disease, is transmitted by *Inazuma dorsalis* (previously known as *Recilia dorsalis*) and, based on a recent study, by *Nephotettix cincticeps*.

Adaptive Research Platform

Between October 2016 and April 2017, EPIC project has completed the crop health survey in Cambodia. The results were used to pinpoint locations of adaptive research platforms. The proposed interventions (e.g. *Trichoderm*a, resistant varieties, Integrated weed management, Community/Linear Trap barrier system for rodent management, entomopathogenic fungi for insect management) were discussed with collaborating farmers at each intervention village (October 2016). Most of the adaptive experiments started in farmers' fields and GDA/PDAFF's stations in December 2016/January 2017. Some of the experiments will start in April 2017. The experiments were designed as replicated experiments with 3-5 treatments and 4-5 replicates per village involving 2-4 collaborating farmers per village. The summary of the experiments included in the adaptive research platform and the schedule for the current season is given in Table 1.

Table 1. Adaptive Research Platforms through EPIC Project in Cambodia (2016/2017).

Province	Site	Target biotic stress	Experiment	Planting Date	Harvest Date
Prey Veng	Por Las Experimental Station	Diseases (leaf blast, neck blast)	Trichoderma X Resistant variety	02-Jan-17	23-Mar-17
	Thom village	Weeds	Integrated Weed Mgt	30-Dec-17	23-Mar-17
	Sdao Village	Insects (Stemborers, leaffolders, bph)	Entomopathogenic fungi	April-17	
Takeo	Tonlebatie Experimental Station	Diseases (leaf blast, neck blast)	Trichoderma X Resistant Variety	April-17	
	Kandaul village	Rodent	CTBS, rodenticide	05-Jan-17	05-Apr-17
	Ro Veang village	Rodent	CBTS, rodenticide	April-17	
Battambang	Boeug Pring Experimental Station	Diseases (brown spot, narrow brown spot)	Trichoderma	April-17	
	Boeug Pring village	Weeds	Integrated Weed Mgt	April-17	
	Ota Gnea village	Weeds	Integrated Weed Mgt	31-Jan-17	25-May-17
Kampong Thom	Experimental Station	Diseases (brown spot, narrow brown spot)	Trichoderma X Fungicide	April-17	
	O Kunthor Tbong village	Weeds	Integrated Weed Mgt	April-17	
	Panna Chhi village	Insects (rice hispa, whorl maggot)	Entomopathogenic fungi	28-Mar-17	

Lessons Leanred

We had a problem in sourcing entomopathogenic fungi (EPF) for our experiments. There was a concern, shared by our GIZ collaborators on the quality of EPF sources available in Cambodia. Several requests to bring external source of EPF were not granted. During a formal visit to IRRI in February 2017, the DG of GDA, H.E. Hean Vanhan and the head of rice department, Mr. Ngin Chhay commented on the sensitivity of bringing external sources of EPF to the country. They encouraged us to use locally available sources. For 2017 experiments, we are going to use EPF available in Cambodia.

Political/ policy support is needed in Cambodia regarding legislation and use of biocontrol agents (BCA). We need to work on this by expanding the partnerships we have in the government, not only with DAL (Department of Agricultural Legislation) but also within the GDA. We have started a conversation with the Department of Crop Protection and Phytosanitary which has the mandate to approve use of BCA for experimental purposes.

Presentations and Publications

- Buyung Hadi, EPIC Adaptive research platform, presentation at EPIC annual meeting, Phenom Penh, December 2016.
- Buyung Hadi, EPIC: A new partnership on participatory development of rice IPM in Cambodia, presentation in front of H.E. Ty Sokhun, Cambodian secretary of state and delegates, IRRI, Los Banos, February 21 2017.
- Chou Cheythirith, Training program and extension materials on rice IPM – GDA perspective, presentation at EPIC annual meeting, Phenom Penh, December 2016.
- Harvey Reissig, Sydni Jackson, Kean Makarady, Alpy Math, and George Norton, Preliminary Summary of Results from Rice Baseline and Pesticide Survey, presentation at EPIC annual meeting, Phenom Penh, December 2016.
- Keam Makarady, Training program and extension materials on rice IPM – NGO perspective, presentation at EPIC annual meeting, Phenom Penh, December 2016.
- Khay Sathya, Nancy Castilla, Rice Crop Health Survey: Preliminary Results, presentation at EPIC annual meeting, Phenom Penh, December 2016.
- Rica Flor, Baseline survey for impact assessment, presentation at EPIC annual meeting, Phenom Penh, December 2016.
- Rica Flor, Developing an Ecologically based Participatory (IPM) Package for Rice in Cambodia (EPIC) Project and partnership with GIZ, presentation at GIZ operational meeting, February 28 2017
- Rica Flor, Developing Ecologically-based Participatory IPM package for rice in Cambodia: Participatory approaches, presentation at ALISEA general meeting, March 21 2017
- Rica Flor, EPIC learning alliances, presentation at EPIC annual meeting, Phenom Penh, December 2016.

Institutional development

- EPIC project has actively supported the efforts to have clear procedure for BCA registration in Cambodia. GIZ-Cambodia, a partner in EPIC project, has been spearheading the effort using BCA in vegetable production as their focal system.
- Facilitated site visit of staff from General Directorate of Agriculture, and Department of Agricultural Legislation and private company staff on 17 March 2017 to share about the experiments on *Trichoderma*, pest-resistant varieties and integrated weed management.
- Participated in Consultative Meeting on the registration of BCA, 27 March 2017.

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

Principal Investigator: Abhijin Adiga, Biocomplexity Institute, Virginia Tech

This project addresses: modeling the spread of *Tuta absoluta* in Nepal; monitoring pests in an interconnected world; and studying pathways of entry into US and commodity flow.

Modeling the spread of *T. absoluta* in Nepal:

We developed a robust network-based approach to model seasonal flow of agricultural produce and examine its role in pest spread. We applied it to study the spread of *Tuta absoluta*– a devastating pest of tomato– in Nepal where it is an emerging epidemic. Our analysis indicates that *T. absoluta* will invade all major vegetable production pockets in a short period of time. We augment this work by assessing the long-term establishment potential of *T. absoluta* and its economic impact on the country. Our approach is generic and particularly suited for data-poor regions.

In Nepal, *T. absoluta* was first officially reported in 2016 in Kathmandu district. Since then, it has continued to spread to several districts. Tomato is among the major cash crops that Nepalese farmers depend on for their livelihood. It is strongly suspected that trade is an important factor for *T. absoluta*'s rapid spread. It has moved at the rate of more than 800km per year both eastward towards the Indian subcontinent as well as southward in Africa.

This is the first work that analyses human-mediated pathways in the context of *T. absoluta*. Previous modeling efforts have only focused on establishment potential and spatial dispersion.

Modeling commodity flow

We modeled the flow of agricultural produce from one market to another based on the following premise: The total outflow from a market depends on the amount of produce that enters market, and the total inflow depends on the population it caters to. The flows are estimated using a doubly constrained gravity model.
We adapt the approach of the flow Fij from location i to j is given by Fij = aibjOiIjf(dij), where, Oi is the total outflow of the commodity from i, Ij is the total inflow to j, dij is the distance to travel from i to j, f(dij) is a function of dij, called the distance deterrence function. The coefficients ai and bj are computed through an iterative process such that the total outflow and total inflow at each vertex agree with the input values.

Based on the altitude induced agricultural cycle, we have divided the entire year into two seasons–S1 and S2–and as a result we have two flow networks, one for each season. The total outflow from each market i, Oi is determined by the amount of produce that arrives to the market in the specified season. The total inflow Ii is determined by the size of the population catered to by the market. Since production and population data is available only at district level, we implicitly assumed a uniform spatial distribution of these values for each district.

We used a general deterrence function: $f(dij,\beta,\kappa) = dij^{-\beta} \exp(-dij/\kappa)$, where dij is the time taken to travel between markets i and j. Owing to the diverse landscape of Nepal and varying road conditions we used travel time instead of distance between markets. The function f(dij) combines power-law and exponential decay with dij which can be controlled by parameters β, the power-law exponent, and κ, the cutoff time. Our choice of β and κ ranges were informed by the fact that Nepal's vegetable collection and distribution infrastructure is not well-developed (Figure 1).

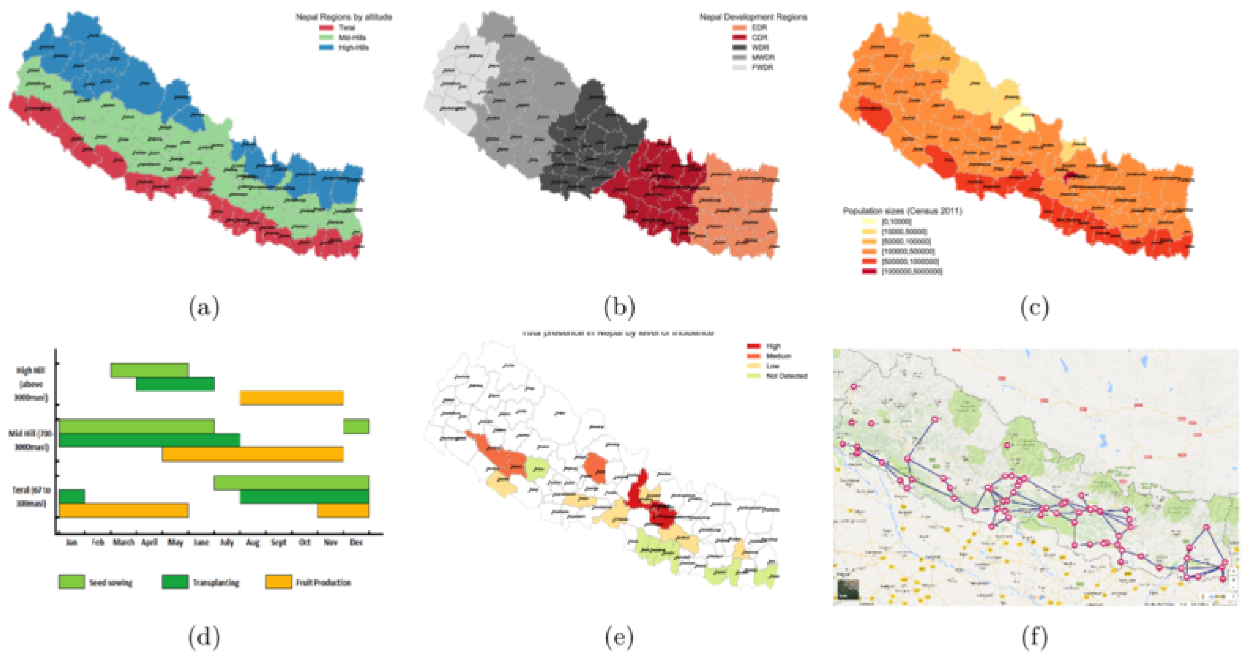


Figure 1. Nepal: geography, population, tomato production, trade and *T. absoluta* incidence. (a) Physiographic division of Nepal. Within a distance of 180km from south to north, the altitudes range from 67 meters above sea level (masl) corresponding to tropical Terai region bordering India to the mountain region exceeding 3000 masl [1]. (b) Division based on development regions from east to west. There is significant variation in the revenue generated by and expenditures dedicated to these regions. For example, the Central Development Region which includes Kathmandu generates 80% of the country's revenue, and 60% of government expenditures is allotted to it [54]. (c) Population distribution: The Terai is the most densely populated region [1] (more than 400 people per square km) with the Mountain region the least populated. One exception to this is the region in and around Kathmandu, which has the highest population. (d) Altitude induced agricultural cycle: Tomato production in different parts of Nepal happen at different times of the year. This is due to the high variation in altitude and therefore, climate conditions between the Terai, Mid Hills and High Hills. During the monsoon season (May-August), as the Terai plains are flooded with water, it is difficult to grow tomato as well as other crops, while in winter (December-February), tomato planted in hills are affected by frost, which leads to a lean supply of tomatoes to the market in hills. We divide the year into two seasons: S1 is the season from June to November when Mid Hills and High Hills produce most of the tomatoes, and S2 when Terai dominates production. (e) District-level report of *T. Absoluta* intensity. The details on monitoring are in the Supplementary Material. (f) Major domestic markets [39]. Some of the major highways are also indicated.

Structure of the flow network

The general trends of tomato trade between markets is depicted in Figure 2. Recalling that our model accounts for the fact that the Mid Hills and the Terai are the primary source of tomato during S1 and S2 respectively, we see that this is reflected in the net flow diagram between geographic regions: north to south in S1 and south to north in S2. An interesting pattern to be noted is the significant flow from east to west during S1 as observed in the net flow diagram between the development regions.

This can be partially explained by the fact that there is a lot of variability in vegetable production among the different development regions. The Central and Eastern Development regions are the primary vegetable producers during this season. In FN1, Dhankuta (district Dhankuta, EDR) and Banepa (Kavrepalanchok, CDR) having by far the highest share of production. In FN2, production is more evenly distributed among several markets in Terai.

The other factor that could be contributing to this flow is the arterial East West Highway which covers almost the entire breadth of the country. Markets with high assigned population are mainly in the CDR and EDR regions of Terai and Mid Hills.

Identifying nodes and edges that could play a crucial role in diffusion over the trade network is valuable in preparing for or stiffling an epidemic. Since production and imports are season dependent, so is a market's role. In essence, we characterize a market which has high outflow (inflow resp.) and negligible inflow (outflow) as a source (sink). However, we also take into account network effects. For example, any node with high production and low population is a good candidate for being a source. We refer to a market as a hub if it has high inflow and outflow of the traded commodity in the projected flow network. Due to high connectivity, such markets are not only vulnerable to infection, but can also play a critical role in spreading the infection. The major sources, sinks and hubs for each season are shown in Figure 2.

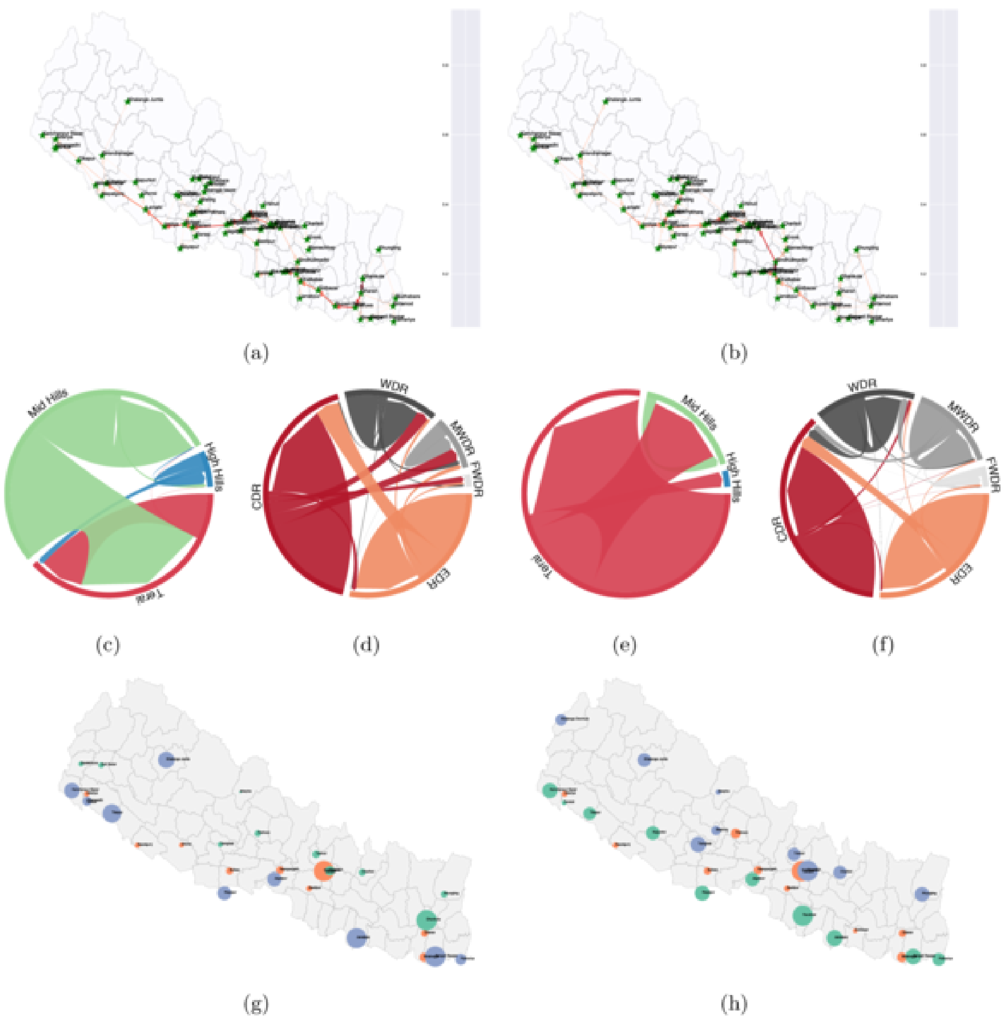


Figure 2. Structural properties of the domestic tomato trade network. The left part corresponds to season S1 and right to S2. (a) and (b) Projected flow networks PFNs. The market to market seasonal flow by the gravity model projected on to the road network generated for $\beta = 2$ and $\kappa = 500$. (c) and (e) Net flow between physiographic regions. (d) and (f) Net flow between development regions. (g) and (h) Sources, sinks and hubs. In the plot, the sizes are all relative. The size of a source (sink) is a function of production (population), while that of a hub is a function of the product of the town's population and $h(\cdot)$ value.

Monitoring pests in an interconnected world

PREMpT is a web-based application (http://ndssl.vbi.vt.edu/gis/prempt/), and requires no setup for a typical user. The user interface is built on top of the ArcGIS API for JavaScript and jQuery.

We use a multi-layered network model to represent the various pathways through which the pest can spread. The movement and establishment of the pest is captured using agent-based models over these networks. Broadly, the pathways considered can be classified as natural dispersal, trade and travel. There are well established ecological models that capture the biology of the pest and its response to climate. We use CLIMEX and extend a cellular automaton based model. International trade data from FAOSTAT provides the commodity flow across countries. To

derive city-level commodity flow estimates, we use disaggregation models from freight analysis research [Viswanathan et al., Transportation Research, 2008]. For constructing a city to city travel network, we used a passenger flow matrix model. To incorporate border interception, we used the analysis to determine whether a country has a reactive or proactive policy to prevent pest entry.
PREMpT is a prototype web app that demonstrates some of the key capabilities of the envisioned system. Some of the individual components of the system are derived from published literature and hence validated. However, validation of the overall system is a big challenge, and is part of the ongoing effort.

Studying pathways of entry into US and commodity flow
Tuta absoluta is one among the top 50 pests identified as a threat to agriculture and biodiversity in the United States. Within the last 10 years, after its accidental introduction to the Mediterranean basin, this devastating tomato pest has spread throughout Europe, Western Asia, Indian subcontinent, and most of Africa. We study the possibility of *T. absoluta*'s invasion of North America, and the dynamics of its spread within the region in the event of entry. We analyze trade and tomato production data, historical pest interception records and current monitoring efforts. We have started analyzing seasonal dependencies and greenhouse production, and have started collecting data in this regard.

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 costal part of Senegal, including the main tomato-producing area (Niayes). Field monitoring showed severe outbreaks during the late dry season.

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* (Mame Diarra Bousso, Master student). 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. First results indicate that *T. Absoluta* can survive at very high temperature (>35-40°C). This work will be completed by June 2017.

Host plants and seasonal population dynamics
Monitoring of *T. absoluta* in tomato crops during the rainy season (from June 2016 to November 2017) has been completed. Results showed that the area of solanaceous host crops, particularly tomato, is the main driver of the decrease of *T. absoluta* abundance during the rainy season.

Tomato crops are very few during the rainy season, due to multiple agronomical constraints including development of fungal diseases. Our study also showed predators, particularly *Nesidiocoris tenuis* can significantly contribute to the reduction of *T. absoluta* populations, but that biocontrol by parasitoids is still very low (2%). Eggplant (*Solanum melongena*) and Ethiopian eggplant (*S. aethiopicum*) residual crops can serve as refuges that allow residual populations to persist during the rainy season.

Crop management and landscape context
Monitoring of a network of 25 tomato fields in a highly-infested area (Niayes) on 2 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 (Serigne Sylla, PhD student). 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. One peer-reviewed scientific paper is expected from this research activity.

France

Physiologically based demographic models
Physiologically based demographic models (PBDMs) are models that capture the weather-driven biology of the species and of relevant interacting species in its food chain or web. The PBDM can streamline pest risk assessment by providing a process-based guide to identify knowledge gaps, and guide the collection of the data required to develop the PBDM determining whether a species should or should not be considered a current or potential pest in a region.

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

Lessons Learned

Our field monitoring and interviews of tomato growers showed that the tomato leaf miner, *T. Absoluta*, is a real concern for tomato production in Senegal, particularly in the late dry season, both in open fields and greenhouses. Research efforts need to be deployed to better predict and manage invasion processes, and to find ecologically-based methods to control damage to crops.

Presentations and Publications:

- Diatte M, Brévault T, Sylla S, Tendeng E, Sall-Sy D & Diarra K (2017) Arthropod pest complex and associated damage in field-grown tomato in Senegal. International Journal of Tropical Insect Science (in press).
- Mateus R Campos, Antonio Biondi, Abhijin Adiga, Raul N.C. Guedes, Nicolas Desneux. 2017. From the Western Paleartic Region to Beyond: *Tuta Absoluta* ten years after its Europe invasion, under review.
- Mateus R Campos, Antonio Biondi, Abhijin Adiga, Raul N.C. Guedes, Nicolas Desneux. 2017. From the Western Palaearctic region to beyond: *Tuta Absoluta* ten years after invading area. Accepted pending revisions in Journal of Pest Science
- Sichao Wu, Henning Mortveit and Sandeep Gupta.2017. A Framework for Validation of Network-based Simulation Models: an Application to Modeling Interventions of Pandemics. Accepted by SIGSIM-PADS '17, May 24–26, 2017. doi: http://dx.doi.org/10.1145/3064911.3064922.
- Sichao Wu, Henning Mortveit, Abhijin Adiga and Srinivasan Venkatramanan. 2017. A Framework for Validation of Network-based Simulation Models: An Application to Modeling Interventions of Pandemics. GENEUS & Application in Pest Diffusion. Poster session presented at the Workshop on Uncertainty Quantification and Data-Driven Modeling, Austin, March 23-24, 2017.
- Srinivasan Venkatramanan, Sichao Wu, Bowen Shi, Abhijin Adiga, Madhav Marathe, Stephen Eubank, Achla Marathe. 2017. Hybrid Models for Ecological and Anthropogenic Drivers of Pest Invasion: Case Study of *Tuta absoluta* in Nepal, International conference on biodiversity, climate change assessment and impacts on livelihood (ICBCL), Kathmandu, 2017.
- Sylla S, Brévault T, Bal AB, Chailleux A, Diatte M & Desneux N. 2017. Rapid spread of the tomato leafminer, *Tuta Absoluta* (Lepidoptera, Gelechiidae), an invasive pest in sub-Saharan Africa. Entomologia Generalis (accepted with minor revisions).
- Sylla S, Brévault T, Diarra K, Bearez P & Desneux N (2016) Life-history traits of *Macrolophus pygmaeus* with different prey foods. Plos One 11:e0166610.
- Sylla S, Brévault T, Streito J-C & Diarra K (2016) First Record of *Nesidiocoris tenuis* (Reuter) (Heteroptera: Miridae), as a predator of the tomato leaf miner, *Tuta Absoluta* (Meyrick) (Lepidoptera: Gelechiidae), in Senegal. Egyptian Journal of Biological Pest Control 26:851-853.
- Sylla S, Diarra K, Desneux N, Brévault T (2016) Invasion of the tomato leafminer, *Tuta Absoluta,* in West Africa: Spatial dynamics, ecological niche, and potential for biological control. International Congress of Entomology (ICE), Orlando, USA, 25-30 September 2016. doi: 10.1603/ICE.2016.108757
- V. Sridhar, K. S. Nitin, R.Asokan and A. Adiga. 2017. Use of CLIMEX to identify the potential areas for spread of *Tuta Absoluta* under climate change, International conference on biodiversity, climate change assessment and impacts on livelihood (ICBCL), Kathmandu, 2017.

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

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

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. This project addresses suppression of this weed through biological control.

Ethiopia

Rearing Bioagents for the Control Parthenium

Parthenium Project staff have continued to rear *Zygogramma bicolorata* and *Listronotus sitocipennis* at Wollenchiti site. This site has also been used to train staff from Ambo and Haramaya Universities on the proper techniques of raising parthenium and rearing the bioagents. Growing parthenium in pots in large numbers with the desired quality and on a regular bases has been a challenge at Wollenchiti and at all the other rearing sites. Currently, there are 1,200 adult *Zygogramma* and 870 adults as well as 448 larvae of *Listronotus* at Wollenchiti.

In October 2016, *Zygogramma* adults produced at the Guder (Ambo University sub-station) and Wollenchiti sites were released in the Southern Region of Ethiopia. A total of 4,500 adults were released at Ziway and Hawassa sites. At the Hawassa University campus, 2,200 adult of *Zygogramma* were released while at Ziway (Hawassa University Research Center) 2300 adults of the beetle were released. Staffs from Hawassa University will monitor the release sites for the emergence of *Zygogramma* after the onset of the rains.

Eight hundred adults of *Zygogramma* were also released on February 17, 2017 at Koaka in eastern Oromia Region. The release site had parthenium growing along the banks of a small stream. The establishment of the bioagent will be monitored after the onset of the rains and the emergence of parthenium.

Z. bicolorata and *L. sitocipennis* are reared at Ambo University – Guder Campus, Amhara Regional Agricultural Research Institute, and Haramaya University.

Ms. Belaynesh Assema, an M.Sc student from Haramaya University, has been investigating the factors that may influence the interest and ability of women farmers to participate in the adoption of biocontrol agents. She has interviewed a total of 130 women farmers (111 M&F households and 19 FNM households) at Tullo district.

Tanzania and Uganda

TPRI has set-up a mass rearing Centre in Arusha. A number of tunnels and rearing cages have been constructed and parthenium was grown in pots. An application for the renewal of an existing import permit was granted and *Z. bicolorata* adults were imported into Tanzania from quarantine facilities at ARC-PPRI, South Africa in March 2017. Due to unfortunate delays at the airport in Dar es Salaam, Tanzania many of the adult beetles perished. However, it is hoped that the surviving adults will breed and lead to the establishment of the first mass rearing Centre for this beetle in East Africa (excluding Ethiopia). A Risk Assessment for the importation of *Z. bicolorata* into Uganda was completed and submitted to the relevant authorities. We are still awaiting feedback from them. In the interim there have been a number of workshops and awareness raising events in Uganda to increase awareness on parthenium and its impacts. CABI in collaboration with ECHO East Africa also hosted a workshop on IAS, with a focus on parthenium in Arusha, Tanzania.

Three MSc students from Sokoine University have initiated their studies on various aspects related to parthenium. Hamis Wambura's thesis is entitled "Impact of carrot grass (*Parthenium hysterophorus* L.) on the production of selected crops grown in Arusha, Tanzania". Leticia Musese thesis title is "Effects of the invasive weed *Parthenium hysterophorus* L. on rangelands in Simanjiro, Masailand, northern Tanzania" while Joyce Christopher is assessing the biocontrol agent *Z. bicolorata* and her study title is "Effectiveness of *Zygogramma bicolorata* L. as a bioagent for the control of *Parthenium hysterophorus* in Arusha, Tanzania. Staff at TPRI (Tanzania) continue to receive training on mass rearing of *Z. bicolorata*.

South Africa

Technical advice on rearing environment and techniques for the leaf-feeding beetle *Zygogramma bicolorata* and the stem-boring weevil *Listronotus setosipennis* was provided by ARC-PPRI to the Project Leader and Project Partners in Ethiopia, Kenya and Tanzania.

During March 2017, a starter culture of 500 adults of was supplied to Tanzania for mass-rearing purposes, at the request of A. Witt of CABI Africa, under the IPM Innovation Lab project. The consignment was hand-carried by P. Goodman, an ecologist from South Africa. Unusually, the air carrier insisted that the consignment of insects be flown as cargo instead of being checked in with luggage as usually occurs, which resulted in a delay of 6 days from packing date before the beetles reached their final destination and were set up on plants for rearing in Tanzania. As a result, considerable mortality of the adult beetles occurred en route. It is hoped that a culture will be able to be formed from the surviving individuals.

Lessons Learned

Availability of high quality parthenium stock is critical for mass rearing of *Z. bicolorata* and *L. setosipennis*. Therefore, there is a focus on improving plant growth conditions (light, temperature, nutrients, moisture) at all bioagent-rearing facilities. Maintaining a healthy and stress-free bioagent culture is also critical for mass rearing. Predation of the bioagents at both the larva and adult stage also remains a challenge. The predators include ants, lizards and spiders that feed on the larva and adults of *Z. bicolorata*. Pests such as spider mites and aphids are also a constant menace to the bioagents. To address these difficulties, staff need to be trained on how to trouble shoot the problems and be proactive to avoid them.

Severe climatic conditions may restrict establishment of some agents in particular, but the return of favorable climatic conditions enables improved field performance of agents. Release sites should be selected bearing in mind the constraints of agents, where known. Timely delivery of starter cultures of agents to their final destination following export is critical to maximize the survival of insect agents, impacting on the success of the mass-rearing program.

Presentations and Publications

Presentations

- Mersie, W. The invasive plant parthenium (*Parthenium hysterophorus* L.) is adversely affecting the biodiversity of the above ground vegetation and soil seed bank of rangelands in Ethiopia. Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood at Kathmandu, Nepal on January 11, 2017.
- CABI, TPRI staff and others gave a number of presentations at the workshop hosted by CABI and ECHO East Africa in Arusha entitled "Management of *Parthenium hysterophorus* in Tanzania." The workshop was attended by 80 people from various research organisations, CBO's, farmers, conservationists, journalists and concerned community members.

Publications

- Chidawanyika, F., Nyamukondiwa, C., Strathie, L., Fischer, K. 2017. Effects of Thermal Regimes, Starvation and Age on Heat Tolerance of the Parthenium beetle *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) following Dynamic and Static Protocols. PLoS ONE12(1): e0169371.doi:10.1371/journal.pone.0169371

- Dhileepan, K., McFadyen, R., Strathie, L. and Khan, N. Chapter 7. Biological Control of pathenium weed. In: (Eds) Adkins, S., Dhileepan, K. and Shabbir, A. Parthenium weed: biology, ecology and management. CABI Publishing. *Edited draft revised.*
- Strathie, L.W. and McConnachie, A.J. Chapter 14. History and Management – Southern Africa and Western Indian Ocean Islands. In: (Eds) Adkins, S., Dhileepan, K. and Shabbir, A. Parthenium weed: biology, ecology and management. CABI Publishing. *Edited draft under revision.*

Technologies Transferred

Ethiopian staff from the rearing sites were shown the latest techniques in nurturing the two bioagents. The trainers are expected to share their knowledge of bioagent rearing to their colleagues when they return back to their institutions. In addition, they will train future staff who will be working at these sites. In Tanzania, staff at the mass rearing Centre at TPRI continue to receive informal training on mass rearing of agents

Technologies scaled

Mass rearing of *Z. bicolorata* has been undertaken at Ambo University's station at Guder, at Haramaya University campus and at Wollenchiti rearing station. Technologies ready to scale
A mass-rearing effort for *L. setosipennis* is also underway in Ethiopia.

7. Rice, Maize, and chickpea IPM for East Africa

Principal Invetigator: Tefera Tadele, *icipe,* Ethiopia

Ethiopia: Maize and chickpea IPM in Ethiopia.
Kenya: Maize IPM in Kenya.
Tanzania: Maize and rice IPM in Tanzania.

Rice, maize and chickpea are staple food crops in Ethiopia, Kenya and Tanzania. Among the biotic factors, insects, diseases, weeds and rodents play a major role in reducing yield. In Africa, farmers generally rely on cultural practices or insecticides to minimize crop losses. Sustainable IPM packages for grain crops need to be developed to reduce the use of pesticides, improve human and environmental health, enhance biodiversity, and increase the productivity of soil and crops. The aim of the project is to reduce crop loss and reduce the use of pesticides through demonstrating already proven technologies while at the same time conducting research to develop new technologies and disseminating information to the stakeholders.

Ethiopia

Chickpea IPM

Integrated management of chickpea wilts using two improved varieties: Habru and Arerti combined with seed dressing using Lamdex; the two varieties planted on raised bed and furrow (farmers' practices). Habru variety seed dressed and planted on raised bed had shown considerable level of resistance to the wilt diseases and high acceptance by farmers.

Nutritional indices of the pod borer, *Helicoverpa armigera*, on chickpea, tomato and faba bean

Significant differences were found within the nutritional indices, especially ECI (efficiency of conversion of ingested food) and ECD (efficiency of conversion of digested food) of *H. armigera* reared on different chickpea, Faba bean varieties and tomato, suggesting that the crops have different nutritional value. For the three larval instars (i. e. third to fifth larval instars) the highest ECI and ECD value of *H. armigera* was high on chickpea varieties and followed by faba bean varieties, indicating that they were more efficient at the conversion of ingested food to biomass. The ECI and ECD values of the whole larval instars were the highest on chickpea varieties and lowest on tomato.

Termite IPM

Integrated termite management trials were conducted in maize by using cropping system as a major component. The components were maize intercropped with *Desmodium*, or soybean or maize mulched with stover and manure. Total number of damaged plants, number of harvested plants, root and stem damages were less in maize intercropped with *Desmodium*, or soybean or maize mulched with stover and manure compared to maize planted alone.

Farmers' Perception of Push-pull Technology for Stem borer Control in Hawassa

Push-pull technology targeting management of maize stem borers was implemented in Hawassa area district of Ethiopia with an ultimate goal of increased food security among the smallholder farmers. This study evaluated farmers' perception of push-pull technology based on their experiences and observation of demonstration plots established at farmers' field in two villages of the district in 2016. The study examined farmers' perception on importance of a push-pull technology in controlling stem borers, improving soil fertility and access to livestock feed. Majority (89%) practicing farmers have rated the technology significantly ($P<0.05$) better than their own maize production practices on major attributes such as access to new livestock feed and control of maize stem borer damage. As a result, about 96% of interviewed farmers were interested to adopt the technology starting the upcoming crop season. For sustainable use and scaling-up of the technology, awareness creation through trainings and using effective dissemination strategies should be strengthen among the stakeholders and policy makers.

Kenya

Baseline survey results

The Kenya baseline survey report was produced and shared with partners. The major pests reported by farmers include stem bore, cutworm and Aphids and termites. About 81%, and 39% and 27% of respondents in Bomet and Nakuru counties indicate stem borer and Cutworm and Aphids and termites are major pests affecting their maize production. Major diseases in the counties include maize ear rot, maize lethal necrosis, streak virus and rust. The most important pest control measures being exercised by farmers include removing and burring infected crops (71%), crop rotations (66%) and maize-legume intercropping (59%). About 26%, 5% and 3% of farmers were also used pest resistant varieties, bio-pesticides and push-pull technology respectively. Framers were also asked about their perceptions toward maize IPM practices (non-pesticide pest control practices). About 62% of the farmers mentioned that IPM was more affordable compared to the conventional pesticides application. Notably, about 45% and 48% of farmers in both counties perceived maize IPM to be safer to human health and the environment respectively. Interestingly, about 21% of the farmers were already aware that IPM is good for beneficial insects which check the population of the pests in the farm.

Stem borer IPM in Nakuru and Naivasha

The push-pull was planted in Nakuru and Naivasha in 2016 to control stem borers in maize; the number of exit holes and tunnel length in the push-pull demos showed reduction in tunnel length and exit holes which most probably contributed to the yield increases observed. The push-pull fields gave an average yield of 24.9kg of grain which was more than the 20.1kg for the control. The average yield increase of push-pull fields over the control was 13.8%. Maize yields in the demos were increased as a result of the use of the technology. Based on the results obtained, a yield increase of 13.8% can be expected over a wide variety of conditions such as different varieties and locations. As such, the push-pull technology has proven to be effective despite the variation in conditions. The yield increase was obtained under conditions very much representative of Kenyan smallholder maize farming. Most importantly, the yield increases were the result of one season, by farmers with no prior skills in practicing this technology. It may be expected that yield differences could increase if the technology was practiced over several seasons. There was a large variation in the yield increase obtained through the push-pull technology. This could be ascribed to the differences in motivation of the farmer groups involved, different disease incidence and maize varieties planted

Farmers' selection: A total of 40 farmers were selected including 20 in Nakuru, 10 in Gilgil and 10 in Kericho areas in order to demonstrate the push-pull technologies against the maize stem borers in March 2017.

Tanzania

Farmers' perceptions on rice stem borers

Farmers' perceptions on rice stem borers and farm management practices in irrigated lowland rice ecosystem in Morogoro was conducted. A total number of 60 farmers were interviewed. About 96.7% of the farmers reported insect pests such as stem borers, white flies, leaf rollers and grasshoppers as major constraints of rice production. Other constraints reported were such as diseases (63.3%), damage by birds (98.3%), drought (33%), weeds (78%) and lack of access to loan for purchasing inputs such as improved seeds, fertilizers, insecticides and herbicides (61.7%). Among the insect pests mentioned by respondents infesting rice in the study area, 56.7% of respondents reported stem borers as worst insects whereas 40% farmers reported white flies as worst insect. About 78% of the farmers use chemical pesticides for pest management, 13% burn crop residue and 3.3% remove and burry infested plants and 1.7% use balanced Nitrogen fertilizers. About 65%, 20% and 6.7% of the farmers, respectively, reported the use of insecticides, uprooting and burning of infested plants and split application of nitrogen fertilizer as common practices they use to reduce stem borers infestation in rice, but most farmers had little knowledge of the best recommended stem borer management practices. Presently an experiment is ongoing in evaluating biopesticides, *Beauveria* and *Metarhizium* against rice stem borers and *Trichoderma* and *Bacillus subtilis* against rice blast.

Lessons Learned

Ethiopia and Kenya baseline survey

- An average farmer in both counties owned 3 cows is likely to enhance farmers' willingness to adopt the push-pull technology since the benefits of the technology includes enhanced milk production since *Desmodium* component of push-pull technology is a nutritious leguminous fodder.
- Agricultural extension service providers are popular source of agricultural information and thus promotional campaigns on push-pull should be channeled through formal extension services.
- There is low social capital stock since group membership stands at slightly less than 50%. This might hinder IPM dissemination and thus farmers need to be encouraged to participate in groups to enhance IPM information flows.
- Farmers perceive non-pesticide maize pest control methods to be effective and cheaper but they also believe that pesticides are effective. Other benefits of IPM such as health, environmental safety and effect on beneficial insects should be emphasized to enhance IPM adoption.
- Women and men seemed to have equal decision making roles in determining utilization of incomes form sale of maize. However, women have little decision making role on matters involving maize production such as pest control.
- Women should be empowered through trainings to participate in all activities of maze production especially on maize pest and disease control decision making.

Lessons learnt from Tanzania rice survey

- Social network such as a farmer to farmer and famer to agricultural extension officer interactions can contribute to awareness and dissemination of a new blast disease management technology.
- Fellow farmer/neighbor/ friend and agriculture extension officers were reported by most farmers as their main sources of information.
- Lack of awareness of the importance of infected rice crop residue in the transmission of rice blast disease may contributes to the persistence of rice blast disease inocula in the field.
- Farmers use rice straws as a mulch for horticulture production. This could be contributing to persistence of rice blast disease inocula in the field if infected rice straws are used.

Presentations and Publications

Presentations

- Ballo, S. 2016. Demonstration of the push-pull technology in Hawassa against maize stem borers.
- Chuwa, C. 2016. Screening and verification of rice varieties against blast, yellow mottle rice virus and blight diseases. Progress report presented in annual review and planning meeting. Addis Ababa, Nov 6-7, 2017.
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- January, B. 2016. Integrated management of rice stem borers in Tanzania. Progress report presented in annual review and planning meeting. Addis Ababa, Nov 6-7, 2017.
- Korir, J. 2016. Economics of rice, maize and chickpea IPM in East Africa. Progress report presented in annual review and planning meeting. Addis Ababa, Nov 6-7, 2017.
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- Likhayo, P. 2016. Maize stem borers using the push-pull technology in Kenya. Progress report presented in annual review and planning meeting. Addis Ababa, Nov 6-7, 2017.
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- Tefera, T. 2017. Rice, maize and chickpea project highlights to icipe management, Feb 8, 2017, Nairobi, Kenya.
- Zewdie, A. 2016. Chickpea wilts, blight and pod borer IPM in East Shoa. Progress report presented in annual review and planning meeting. Addis Ababa, Nov 6-7, 2017.

Publications

- Baseline survey Report on Maize Production and Perceptions about Integrated Pest Management in Nakuru and Bomet Counties, Kenya.
- Farmers' Perception of Push-pull Technology for Stem borer Control in Hawassa District, Ethiopia. Submitted to Crop Protection.
- Pest Diagnostics Services Provision Capacity of Plant Health Clinics, Quarantine Posts, Research Centers, and Universities in Ethiopia
- Pest Diagnostics Services Provision Capacity of Plant Health Clinics, Quarantine Posts, Research Centers, and Universities in Kenya
- Pest Diagnostics Services Provision Capacity of Plant Health Clinics, Quarantine Posts, Research Centers, and Universities in Tanzania

Technology Transfer and Scaling Partnerships

Ethiopia

- Push-pull demonstration trials in Adami Tulu and Hawassa were established with 20 farmers in Hawassa
- 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

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
- Joint Push-pull demonstration trials site selection with local authorities and extension agents done

Tanzania

- Push-pull on-farm demonstration trials against maize stem borers were conducted in Morogoro region in Motombo village with 10 farmers.
- Two rice diseases tolerant varieties: Komboko, Saro 5 and local varieties trials were conducted in in Mvomero district with ten on-farm trials against major diseases such as blasts, yellow mottle virus and blight.

8. Integrated Pest Management for Vegetables in East Africa

Principal Investigator: John Cardina, The Ohio State University

This project conducts research, training, and outreach to build capacity for IPM development and implementation for priority pests of tomato, onion, cabbage, and other vegetable crops in Tanzania, Ethiopia and Kenya.

Baseline Survery

Kenya: The Kenya Baseline survey included 206 male and 197 female respondents, with a mean of 3.3 acres of land (0.33 acres of tomato, 0.53 of cabbage, 0.51 of beans, 1.11 of chili peppers, and .47 of onions). Most (257) farmers sold their vegetables to traders (25% of them were consumed at home) and most farmers used irrigation. Fifty percent of tomato farmers feel they have a high severity pest insects and diseases, and that diseases/viruses cause the most damage (especially bacterial wilt and bacterial canker). The two most common non-pesticide means they use to manage those problems are staking the plants and removing damaged plants. The main reason they use a non-pesticide practice is to save costs. They apply pesticides an average of 7.9 times and spend 7.9 days spraying and 5.6 days weeding.

Roughly half of cabbage producers feel the severity of insects and diseases is low with 45% saying that insects/worms were their major type of pest and 51.6 % saying that diseases were their main pest problem. Black rot was their worst disease. Removing damaged plants was their main non-pesticide practice used to manage insect and disease problems. Cost considerations is the main reason they use non-pesticide practices rather than pesticides. They applied pesticides 4.5 times, spent 1 day spraying and ten days weeding.

Similar numbers of French bean producers felt that their insect/worm severity was low (27.7%), medium (31.9), or high (36.2), and 44.7% felt that their disease pressure was medium (a fourth low and a fourth high). Rust and blight were their worst diseases and white flies their worst insect pest. They applied pesticides an average of 7.1 times and spent 13 person days weeding. Removing damages plants was their most utilized non-pesticide pest management practice. Cost compared to pesticides was the reason the most important reason for using a non-pesticide practice.

Eighty-one out of 403 had received IPM training (an average of 2.6 times), and from a variety of sources. Mostly the respondent to the questionnaire (the farmer), whether male or female, decides what to do for pests and is the person who purchases the pesticides. Most decisions involving money from vegetables sold are made jointly between spouses. Forty-two percent had become ill from applying pesticides, but most felt that pesticides were effective, and if not they spray more. Visible damage is the greatest determinant of when to spray, followed by the label and growth stage of the plant. More than 80% say these spray wearing long pants, long sleeve shirt, and boots. Fifty-six percent had heard of insects that help their crops and 69.3% thought that pesticides could have an adverse effect on the environment (19.7 % no and 11% don't know).

Ethiopia: The baseline survey was designed and implemented in Ethiopia for tomatoes and cabbage, jointly with the Grains IPM IL project. The data are ready to be cleaned, summarized, and analyzed.

Tanzania: Baseline survey was conducted in two regions, several districts within each. Several villages were selected from each village. From the total population of 53,000 we chose 400 growers, 200 from Morogoro, 200 from Iringa regions. Gender and age distributions reflected that of the farming population: 73% of respondents were male, 27 female. The mean age was 40 years. Seventy-nine percent had attended primary school, 16% secondary school; 6% lower than primary. The average land ownership was 4 acres; mean acreage last season was 3.4; 2% did not own land. Dominant crops were tomato, onion, cabbage, some cucumber and watermelon. Most sell at farm gate; traders come around to buy the crop. Farmer groups included TAHA, MVIWATA, and SEVIA. Specific IPM practices included tomato grafting, hybrid varieties for pest resistance, use of biopesticides, botanical pesticides against thrips, parasitoids against stem maggot, overhead irrigation against Diamondback moth. There is a need to assess cucurbit pests and to evaluate potential management practices for *Tuta absoluta*. Information mostly comes from other farmers, also from ag extension. Knowledge of IPM is marginal. Men like going to town to buy pesticides, taking money from their wives.

Diagnostic Workshop

We initiated a network among project participants using the digital app "WhatsApp". The objective of this network is to develop a hub site that allows those who have participated in project related training to communicate with each other about all aspects of vegetable IPM. Ultimately, we expect to spawn spoke networks among farmer groups and/or villages to connect to this network. The network will allow for assistance in such issues as pest diagnosis, pest management decision-making, rapid sharing of research results, assistance on all manner of technical issues related to IPM technology from clean seed production through to post-harvest management. So far, participants are mostly female (64%). As of April 2017, 88% of messages have been from Tanzania, 7% from Kenya, 5% from USA. The main subject so far has been about bacteria, symptoms, and seeds.

Vegetable Seedling Production Workshop

The Workshop on Vegetable Seedling Health was conducted at Sokoine University of Agriculture. The objective was to provide training in practical methods to produce healthy seedlings, free of insects, viruses, and root pathogens, as a first step in IPM. This workshop combined theory with hands-on training. Participants learned how to begin the season with healthy seedlings. We covered critical IPM issues including seed quality, seedling quality, media sterilization, irrigation and nutrition management, grafting seedlings, netting, and use of biocontrol products. Trainees were from SUA, KALRO, MARI, IITA, farmers, SEVIA, MVIWATA, TAHA, and other.

Technology Transfer and Scaling Partnerships

- A WhatsApp network developed.
- Technologies Transferred: Healthy Seedlings as a package technology, which includes clean seeds, selection of resistant varieties, grafting on MT-16 and other resistant rootstock, netting, biocontrol products, soil sterilization, solarization, media preparation etc.
- Technologies scaled: Healthy Seedling production.

Lessons Learned

- Use of digital technology, i.e. “tablets” facilitated data collection and allowed for relatively rapid data cleaning and analysis.
- Proper education of enumerators who can speak the native language is key for getting data believed to be accurate.
- Changes in pest management practices will require attitudinal changes as much as technology development due to pervasive dependence on pesticides.
- Most of the WhatsApp traffic occurred following workshops where new participants were added to the network. More effort is needed to connect with farmer groups to form their own network, and to be connected to the Expert Network.

Human and Institutional Capacity Development

a. Long-Term Training

Strengthening production and export of Vietnamese fruit crops through innovative and market-orientated IPM								
Country	**Name**	**Gender**	**Degree**	**Discipline**	**Home institution**	**Training Institution**	**Start Date**	**End Date**
Vietnam	Dang Thi Kim Uyen	F	PhD		Southern Horticultural Research Institute	Can Tho University	Nov-15	Nov-20

Innovative Scientific Research and Technology Transfer to Develop and Implement Integrated Pest Management Strategies for Vegetable and Mango Pests in Asia								
Country	**Name**	**Gender**	**Degree**	**Discipline**	**Home Institution**	**Training Institution**	**Start Date**	**End Date**
Nepal	Sulav Paudel	M	PhD	Entomology	IDE Nepal	Penn State University	Aug-16	May-20
Bangladesh	Farhanaz Sharma	F	PhD	Economics		Virginia Tech	January 1, 2016 (on this project)	Jul-17
USA	Kaitlyn Spangler	F	MS	Geography (Gender Studies)	Virginia Tech	Virginia Tech	Aug-16	Expected: June 2018
Nepal	Arjun Khanel	M	PhD	Economics	Tribbuvan University	Tribbuvan University and Virginia Tech	January 1, 2016 (on this project)	Jul-18
Bangladesh	Sadique Rahman	M	PhD	Economics	Bangladesh Agricultural University	Bangladesh Agricultural University and Virginia Tech	January 1, 2016 (on this project)	Dec-17
Cambodia	Koy Chakrya	F	BS	Plant Pathology	Royal University of Agriculture	Royal University of Agriculture	Feb-16	Dec-16
Bangladesh	Mafruha Afroz	F	PhD	Plant Pathology	Bangladesh Agricultural Research Institute (BARI)	Bangabandhu Sheikh Mujibur Rahman Agricultural University	Mar-13	Sep-17
Nepal	Ram Khadka	M	PhD	Plant Pathology	Nepal National Agricultural Research Council	Ohio State University	Aug-16	May-20

Participatory Biodiversity and Climate Change Assessment for Integrated Pest Management in the Annapurna-Chitwan Landscape, Nepal							
Country	**Name**	**Degree**	**Gender**	**Discipline**	**Home/Training Institution**	**Start Date**	**End Date**
Nepal	Mr. Dol Raj Luitel	M	PhD	Botany	Tribhuvan University	2016	2019
Nepal	Ms Seerjana Maharjan	F	PhD	Botany	Tribhuvan University	2016	2019
Nepal	Ms Anju Sharma	F	PhD	Botany	Tribhuvan University	2016	2019
Nepal	Pristi Dangol	F	MSc	Botany	Tribhuvan University	2016	2018
Nepal	Sanjeeb Bhandari	M	MSc	Botany	Tribhuvan University	2016	2018
Nepal	Bidya Maya Shrestha	F	MSc	Environmental Science	Tribhuvan University	2016	2018
Nepal	Vishubha Thapa	F	MSc	Zoology	Tribhuvan University	2016	2017
Nepal	Ganga Shah	M	MSc	Zoology	Tribhuvan University	2016	2017
Nepal	Sagar Khadka	M	MSc	Botany	Tribhuvan University	2016	2017
Nepal	Bivekananda Mahat	M	MSc	Entomology	Agriculture and Forestry University	2016	2018
Nepal	Madhu Sudhan Ghimire	M	MSc	Entomology	Agriculture and Forestry University	2016	2018
Nepal	Ramesh Upreti	M	MSc	Agronomy	Agriculture and Forestry University	2016	2018
Nepal	Hom Nath Giri	M	PhD	Agronomy	Agriculture and Forestry University	2016	2019
Nepal	Ghanashyam Bhandari	M	PhD	Entomology	Agriculture and Forestry University	2016	2019
Nepal	Sarita Sapkota	F	MSc	Entomology	Agriculture and Forestry University	2016	2018
Nepal	Pratiksha Sharma	F	MSc	Agronomy	Agriculture and Forestry University	2016	2018
Nepal	Yashoda Panthy	F	MSc	Agronomy	Agriculture and Forestry University	2016	2018
USA	Alexis Brewer	F	PhD	Biology (ecology)	City Unversity of New York	2016	2020
USA	Tenzing Doleck	F	PhD	Biology (ecology)	City Unversity of New York	2011	2018

USA	Arun Ravindranath	M	PhD	Civil Engineering (climate change impacts)	City Unversity of New York	2014	2018

Development of Ecologically based Participatory Integrated Pest Management (IPM) Package for Rice in Cambodia (EPIC)								
Country	**Name**	**Gender**	**Degree**	**Discipline**	**Home Institution**	**Training Institution**	**Start Date**	**End Date**
Cambodia	Chou Cheythyrith	M	PhD	Crop Protection	General Directorate of Agriculture	Royal University of Agriculture/ Nagoya University	Aug-16	Jul-19
Cambodia	Chhun Sokunroth	M	MSc	Weed Management	Provincial Directorate of Agriculture	Battambang University	Jan-17	Dec-18
USA	Cprey Riedel	M	MSc		Virginia Tech	Virginia Tech	Aug-16	Dec-18
Cambodia	Sek Pisey	M	MSc (only funding for research)	Rodent ecology	Royal University of Phnom Penh	Royal University of Phnom Penh	Jan-17	Dec-17
Cambodia	Ong Socheath	F	PhD (provisional acceptance)	Plant pathology	Royal University of Agriculture	Royal University of Agriculture/Nagoya University	Aug-17	Jul-20
USA	Sydni Jackson	F	MS	Agricultural Economics	Virginia Tech	Virginia Tech	August 2015 (May 2016 on IPM IL)	Jun-17

A High-resolution Interaction Based Approach to Modeling the Spread of Agricultural Invasive Species								
Country	**Name**	**Gender**	**Degree**	**Discipline**	**Home Institution**	**Training Institution**	**Start Date**	**End Date**
US	Bryan Kaperick	M	BS	Computation Modeling & Data Analytics	Virginia Tech	Virginia Tech	Aug-14	May-18
India	Amleshwar Kumar	M	BS	Mathematics	Indian Institute of Science	Virginia Tech	Aug-13	May-17
China	Sichao Wu	M	PhD	Computer Science	Virginia Tech	Virginia Tech	Aug-13	May-17
Senegal	Serigne Sylla	M	PhD	Horticultural crops	Université Cheikh Anta Diop de Dakar	CIRAD-BIOPASS	Feb-14	Feb-17
Senegal	Oumar Seydi	M	MS	Horticultural crops	Université Cheikh Anta Diop de Dakar	CIRAD-BIOPASS	Jun-16	Dec-16

Senegal	Mame Diarra Bousso	M	MS	Entomology	Université Cheikh Anta Diop de Dakar	CIRAD-BIOPASS	Jun-16	Dec-16
Senegal	Ahmadou Sow	M	PhD	Entomology	Université Cheikh Anta Diop de Dakar	CIRAD-BIOPASS	Apr-15	Apr-18
Senegal	Arame Ndiaye	F	Postdoc	Molecular biologist	Université Cheikh Anta Diop de Dakar	CIRAD-BIOPASS	Apr-17	NA
Niger	Issa Awal		MS	Statistics	Ecole Nationale de Statistiques Appliquées et d'Economie	CIRAD-BIOPASS	Mar-17	Jul-17
France	Mateus Ribeiro de Campos	M	Postdoc	Research Engineer level 1	Institut National de la Recherche Agronomique INRA	Institut National de la Recherche Agronomique INRA	Jul-17	Feb-17

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

Country	Name	Gender	Degree	Discipline	Home Institution	Training Institution	Start Date	End Date
Ethiopia	Belaynesh Assema	F	M.S.	Rural Development	Wollo University	Haramaya University	Oct-17	Apr-17
Ethiopia	Gizachew Girma	M	M.S.	Crop Protection	Ambo University	Ambo University	Jun-17	Jun-17
Tanzania	Leticia Musese	F	M.S.	Ecosystem Sciences and Management	Sokoine University	Sokoine Univeristy	Sep-17	Jun-17
Tanzania	Joyce Christopher	F	MSc	Ecosystem Sciences and Management	Sokoine University	Sokoine University	Sep-16	
Tanzania	Hamis Wambura	M	MSc	Ecosystem Sciences and Management	Sokoine University	Sokoine University	Sep-16	
South Africa	Ethel Xolile Magoso	F	B Tech	Agriculture (Crop Production)	ARC-Plant Protection Research Institute, South Africa	Tshwane University of Technology	Jan-17	Apr-18

Rice, Maize and Chickpea IPM for East Africa

Country	Name	Degree	Gender	Discipline	Home Institution	Training Institution	Start Date	End Date
Tanzania	Bonaventure January	M	PhD	Agricultural entomology	AfricaRice Centre	Sokoine University of Agriculture	Jul-16	Jun-19
Tanzania	Ibrahim Hashim	M	PhD	Plant Pathology	Dakawa Agricultural	Sokoine University of Agriculture	Jul-16	Jun-19

					Research Institute			
Kenya	Josphat Korir	M		Agricultural Economics	University of Nairobi	University of Nairobi	Sep-16	Jun-19
Ethiopia	Tarekegn Fite	M	PhD	Agricultural entomology	Ministry of Agriculture	Ambo University	Jul-16	Jun-19
Ethiopia	Gezahegn Getaneh	M	PhD	Plant Pathology	EIAR (Ethiopian Institute of Agricultural Research)	Jimma University	Jul-16	Jun-19
Ethiopia	Denberu Kebede	M	MSc	Applied Microbiology	M EIAR (Ethiopian Institute of Agricultural Research)	Addis Ababa University	Jan-17	Dec-18
Ethiopia	Birhanu Sisay	M	MSc	Crop Protection	M EIAR (Ethiopian Institute of Agricultural Research)	Haramaya University	Jan-17	Dec-18
Ethiopia	Nana Ameri	F	MSc	Applied Microbiology	University of Dar Es Salam	University of Dar Es Salam	Jan-17	Dec-18

Integrated Pest Management for Vegetables in East Africa								
Country	**Name**	**Gender**	**Degree**	**Discipline**	**Home Institution**	**Training Institution**	**Start Date**	**End Date**
Kenya	Celia Ngugi	F	PhD	Entomology	Kenya Agricultural & Livestock Research Organization	University of Nairobi	Aug-16	Jun-19
Kenya	Charity Gahambini	F	PhD	Plant Pathology	Kenya Agricultural & Livestock Research Organization	University of Nairobi	Aug-16	Jun-19
Kenya	Joshua Kinere	M	MS	Entomology	Kenya Agricultural & Livestock Research Organization	Chuka University	Jan-17	Dec-18
Kenya	Dennis Nyamu	M	MA	Entomology		Ohio State	Aug-17	Dec-19
Ethiopia	Kumsa Dida	F	MS	Entomology	Hawassa University	Hawassa University	Jul-16	Sep-18
Ethiopia	Feyissa Bekele	M	MS	Weed Science	Hawassa University	Hawassa University	Jul-16	Sep-18
Ethiopia	Habtom Hagos	M	MS	Horticulture	Hawassa University	Ohio State	Aug-17	Jan-19
Tanzania	Hellen Kawyaga	F	PhD	Plant Pathology	Sokoine University	Ohio State	Jan-17	Jun-19
Bangladesh	Muntasir Hasan	M	MS	Agricultural Economics	North South University	Virginia Tech	August 2015 (May 2016 on IPM IL)	Jun-17

b. Short-Term Training

Strengthening production and export of Vietnamese fruit crops through innovative and market-orientated IPM							
Type	**Location**	**Date**	**Female participants**	**Male Participants**	**Total**	**Home institution (if applicable)**	**Training Institution**
Biotechnology	Can Tho University, Vietnam	Sept. 3-Oct. 3	4	1	5		Can Tho University
Seminar: An overview of trapping crop	SOFRI-Vietnam	22-Mar	7	6	13		University of Florida - IFAS
Seminar: An Overview of Virus Diseases	SOFRI-Vietnam	9-Mar-17	13	9	22		Washington State University

Innovative Scientific Research and Technology Transfer to Develop and Implement Integrated Pest Management Strategies for Vegetable and Mango Pests in Asia							
Type	**Location**	**Date**	**Female Participants**	**Male Participants**	**Total**	**Home Institution (if applicable)**	**Training Institution**
IPM package trials undergraduate theses	Phnom Penh, Cambodia	Oct-16 – Mar-17	4	3	7	Royal University of Agriculture (RUA)	RUA & VT
Participate in climate change conference	Nepal	10-12 Jan		1		Bangladesh Agricultural Research Institute (BARI)	IPM IL Climate Change project
Tuta absoluta Orientation Workshop (national level)	Lalitpur	9-Mar-17	9	28	37	iDE Nepal	AVIPM-IL
Tuta absoluta: Identification and Management Training (Regional level)	Nepalgunj	20-Mar-17	9	29	38	iDE Nepal	AVIPM-IL

Participatory Biodiversity and Climate Change Assessment for Integrated Pest Management in the Annapurna-Chitwan Landscape, Nepal							
Type	**Location**	**Date**	**Female Participants**	**Male Participants**	**Total**	**Home Institution (if applicable)**	**Training Institution**
Training on MaxEnt		19-Nov-16	6	6	12		TU
Research team presentations and discussion		7-Jan-17	7	12	19		CUNY, TU
Research team presentations and discussion		8-Jan-17	13	24	37		CUNY, TU, IGATT
Press meet for international conference		8-Jan-17	10	20	30		CUNY, TU
International Conference		10-12 Jan	124	231	355		CUNY, IGATT, TU, AGU, IPM IL, Govt. of Nepal and other partners
Interaction with farmers		13-Jan-17	12	27	39		CUNY, IGATT, TU, AFU, IPM IL
Interaction with farmers		14-Jan-17	12	28	40		CUNY, IGATT, TU, AFU, IPM IL
Ecological modeling training		15-Jan-17	11	7	18		CUNY

Development of Ecologically based Participatory Integrated Pest Management (IPM) Package for Rice in Cambodia (EPIC)							
Type	**Location**	**Date**	**Female Participants**	**Male Participants**	**Total**	**Home Institution (if applicable)**	**Training Institution**
Adaptive research planning meeting – discussing and adapting intervention options	Battambang	11-Oct-16	4	16	20		IRRI
Adaptive research planning meeting - discussing and adapting intervention options	Kampong Thom	12-Oct-16	5	17	22		IRRI
Adaptive research planning meeting - discussing and adapting intervention options	Prey Veng	13-Oct-16	3	19	22		IRRI
Adaptive research planning meeting - discussing and adapting intervention options	Takeo	13-Oct-16	3	16	19		IRRI
Rodent management	Takeo	30-Nov-16			28		IRRI

Training on insect identification	Phnom Penh	18-20-Jan-17	3	11	14		IRRI
Farmer reflection meeting – Rodent management	Takeo	20-Jan-17	3	10	13		IRRI
Training on BEDDA	Los Banos (Philippines)		0	3	3		IRRI

Biological Control of the Invasive Weed *Parthenium hysterophorus* in East Africa							
Type	**Location**	**Date**	**Female Participants**	**Male Participants**	**Total**	**Home Institution (if applicable)**	**Training Institution**
Practical training	Wollenchiti Bioagent Mass Rearing Site Ethiopia	16-Dec-17	2	3	5		Virginia State University
Workshop	Arusha, Tanzania	15-16 Nov. 16	46	34	80	ECHO East Africa and CABI	CABI

Rice, Maize and Chickpea IPM for East Africa							
Type	**Location**	**Date**	**Female Participants**	**Male Participants**	**Total**	**Home Institution (if applicable)**	**Training Institution**
Training of Researchers and extension agents	Bako	10-11 Dec-16	1	34	35	Ministry of Agriculture and EIAR	icipe
Training of Researchers and extension agents	Debrezeit	30-31 Mar-17	6	21	27	Ministry of Agriculture and EIAR	icipe

Integrated Pest Management for Vegetables in East Africa							
Type	**Location**	**Date**	**Female Participants**	**Male Participants**	**Total**	**Home Institution (if applicable)**	**Training Institution**
Seedling Health Workshop	Tanzania		15	40	55		SUA, KALRO, MARI

Collaborators by Project

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

Innovative Scientific Research and Technology Transfer to Develop and Implement Integrated Pest Management Strategies for Vegetable and Mango Pests 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 University
Sally A. Miller	Professor	Ohio State University
Yousuf Mian	Coordinator	IPM Innovation Lab, Bangladesh

Participatory Biodiversity and Climate Change Assessment for Integrated Pest Management in the Annapurna-Chitwan Landscape, Nepal		
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
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Sanjay Kumar Jha		Department of Botany, Tribhuvan University, Nepal
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Development of Ecologically based Participatory Integrated Pest Management (IPM) Package for Rice in Cambodia (EPIC)		
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Collaborators	**Title**	**Organization**
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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
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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
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Invasive Species Modeling for South American Tomato Leafminer and Groundnut Leafminer		
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Arame Ndiaye	Molecular Biologist	Biopass, Senegal
Madhav Marathe	Professor	Biocomplexity Institute, Virginia Tech
Nicolas Desneux	Research Scientist	French Nation Institute for Agricultural Research
Ousmane Ndoye	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

Biological Control of the Invasive Weed *Parthenium hysterophorus* in East Africa		
Principal Investigator	**Title**	**Organization**
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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 Inernationale Zusammenarbeit (GIZ), Ethiopia
Sintu (Lydia) Alemayehu	Project Coordinator in Ethiopia	Virginia State University
Tesfay Amare	Weed Scientist	Ambo University, Ethiopia

Rice, Maize and Chickpea IPM for East Africa		
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Ferdu Azerefegne	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

Integrated Pest Management for Vegetables in East Africa		
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Danny Coyne	Soil Health Scientist	International Institute of Tropical Agriculture (ITTA), Kenya
Ferdu Azerefegne	Associate Professor	Hawassa University, Ethiopia
George Norton	Professor	Virginia Tech
Henry Wainwright	Joint Managing Director	Real IPM, Kenya
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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