



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative



2019 Integrated Pest Management Innovation Lab Semi-Annual Report (2018-2019)

Center for International Research, Education, and Development

Outreach and International Affairs | Virginia Tech

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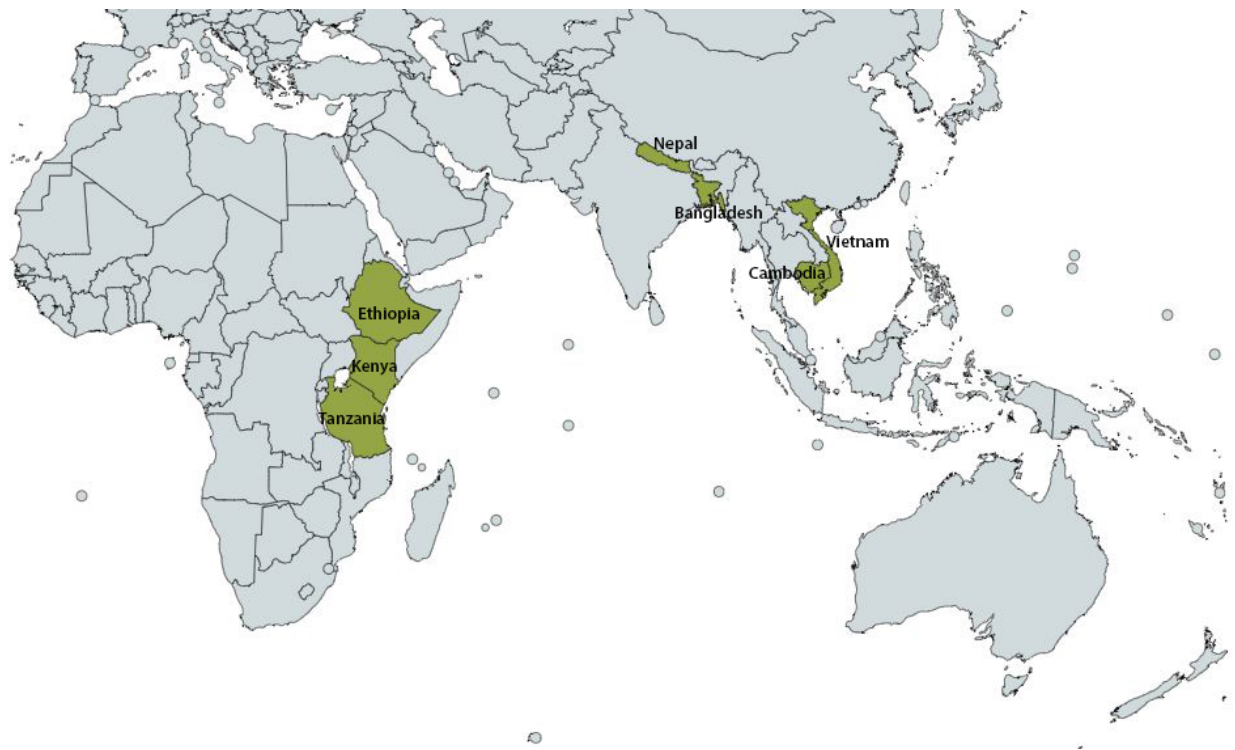
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AVRDC/World Vegetable Center

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icipe

WHERE WE WORK



PROGRAM PARTNERS

U.S. Partners

Cornell University, Louisiana State University, New York State Agricultural Experiment Station, Ohio State University, Pennsylvania State University, University of California – Davis, Virginia State University, Virginia Tech, Washington State University, University of Virginia, North Carolina State University.

U.S. Governmental Agencies

USAID, U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS), Animal and Plant Health Inspection Service (APHIS)

International Agricultural Research Centers

French National Institute for Agricultural Research, French Agricultural Research Centre for International Development (CIRAD), International Centre of Insect Physiology and Ecology (ICIPE), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Institute of Tropical Agriculture (IITA), International Rice Research Institute (IRRI), World Vegetable Center (AVRDC).

ACRONYMS

BARI	Bangladesh Agricultural Research Institute
Bt	<i>Bacillus thuringiensis</i>
CARDI	Cambodian Agricultural Research and Development Institute
CEDAC	Cambodian Center for Study and Development in Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CESAIN	Center of Excellence on Sustainable Agricultural Intensification and Nutrition
CIRAD	Agricultural Research for Development
DAI	DAI Global
FAW	Fall Armyworm
EPIC	Ecologically Based Participatory IPM Package for Rice in Cambodia
GIS	Global Information System
GPS	Global Positioning System
iDE	International Development Enterprises
<i>icipe</i>	International Center for Insect Physiology and Ecology
IITA	International Institute for Tropical Agriculture
INRA	French National Institute for Agricultural Research
IPM IL	Integrated Pest Management Innovation Lab
IRRI	International Rice Research Institute
KAVES	Kenya Agricultural Value Chain Enterprises
KALRO	Kenya Agricultural and Livestock Research Organization
MARI	Mikocheni Agricultural Research Institute, Tanzania
NARC	Nepal Agricultural Research Council
NGO	Non-governmental Organization
PBDM	Physiologically Based Demographic Model
PERSUAP	Pesticide Evaluation Report and Safe Use Action Plan
RUA	Royal University of Agriculture, Cambodia
SOFRI	Southern Horticultural Research Institute, Vietnam
SUA	Sokoine University of Agriculture, Tanzania
TAC	Technical Advisory Committee
USAID	United States Agency for International Development
VT	Virginia Tech

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EXECUTIVE SUMMARY

Key accomplishments this reporting period from the IPM Innovation Lab include, to name a few, continued monitoring and management of invasive species, mitigating pests and diseases on staple crops, and human and institutional capacity development of students, smallholder farmers, the private sector, and others.

The IPM Innovation Lab (IPM IL) operated five months out of six months of this period without receiving FY 2019 funds and no congressional notification funds were received during this time. In the last week of October 2018, the Director attended the Fall Armyworm (FAW) workshop organized by the USAID taskforce in Addis Ababa, Ethiopia. While he was in Ethiopia, he participated in field trips to collect FAW egg masses to examine parasitism. On November 29, 2018, he participated in the FAW awareness workshop in Kathmandu, Nepal. Representatives from the USAID mission, Government of Nepal, Nepal FAW taskforce, iDE, NARC, private companies, CIMMYT, and other organizations attended this workshop.

In December 2018, we organized a team consisting of Dr. S. Shanmugasundaram (Sundar) and Dr. Jacob Ricker-Gilbert to review the IPM Innovation Lab. The Management Entity hosted the team as well as Dr. Dely Gapasin, member of the Technical Advisory Committee (TAC), in Blacksburg to brief the team on IPM IL activities. Dr. George Norton, Dr. Abhijin Adiga, and Dr. Wondi Mersie (skype) presented a brief report of their project activities. Dr. Gapasin (in person) and Dr. Lawrence Datnoff (phone) explained TAC activities to the team. We also arranged for Dr. Sundar to travel to Ethiopia and Tanzania for onsite observations.

In January-February, 2019, the Associate Director traveled to Cambodia, Bangladesh, and Nepal and participated in the annual planning of the Vegetable Crops and Mango IPM in Asia. In March 2019, the Director accompanied Dr. John Bowman, AOR, to review the Rice IPM for Cambodia project. At that time, the Director presented a seminar on FAW at CE-SAIN facilities for the Cambodian Government and Royal University of Agriculture (RUA) participants. He also participated in the roundtable conference for business owners of the IPM products organized by the value chain project Harvest II and iDE Cambodia.

On February 19, 2019, the IPM IL Director attended a half-day meeting in Washington, D.C., organized by USAID, which outlined the reorganization of the Bureau of Food Security to Bureau for Resilience and Food Security. On February 26 and 27, the Director and Associate Director attended the Horticulture Innovation Lab meeting in Washington, D.C.

Activities of sub-award projects are presented in the body of this report.

ARTICLES

Articles:

- Agri-business Blooms out of Integrated Pest Management Innovation Lab Partnership. *Agrilinks*. 5-9-19
- Why IPM Adoption is Lower in Developing Countries. *Entomology Today*. 5-7-19
- Enhancing the Private Sector: Two Teams Collaborate for a Common Goal. *Agrilinks*. 4-11-19
- Virginia Tech taps text message services to assist farmers in developing countries. *VT News*. 4-1-19
- Stakeholders Meet in Nepal to Develop Action Plan Against the Fall Armyworm. *IAPPS*. 3-29-19
- Program prepares farming communities in Nepal for impacts of a changing climate. *VT News*. 3-25-19
- Gender Research in IPM: Women's Empowerment as a Key to Unlocking Food Security. *Agrilinks*. 3-22-19
- Gender Research in IPM: Women's Empowerment as a Key to Unlocking Food Security. *Entomology Today*. 3-15-19
- Be Careful with Invasive Pests. *Nepal*. 3-6-19
- Celebrating Women in Science: Eight Women Breaking Ground in Agriculture. *Food Tank*. 2-11-19
- Knowledge Management: Online and Offline Tools for Global Success. *Agrilinks*. 1-29-19
- A Dangerous Pest is on its way to Nepal. *Spotlight Magazine*. 12-9-18
- Entomologist from Vietnam gains global perspective at Virginia Tech. *VT News*. 11-27-18
- Virginia Tech teams up with researchers in Niger to improve livelihoods. *VT News*. 11-26-18
- Not Just Maize: Africa's Fall Armyworm Crisis Threatens Sorghum, Other Crops, Too. *Prevention Web*. 11-21-18
- Not Just Maize: Africa's Fall Armyworm Crisis Threatens Sorghum, Other Crops, Too. *Entomology Today*. 11-20-18
- Value-Added Food and Processes: Biocontrol Opens New Prospects in the Sahel. *Agrilinks*. 10-24-18
- Agrilinks Young Scholars Blog Contest: We Have a Winner! *Agrilinks*. 10-16-18
- Training on *Trichoderma* and Plant Growth Promoting Rhizobacteria. *IAPPS*. 10-1-18

Success Stories:

- Agri-business Blooms out of IPM Innovation Lab Partnership
- A Partnership Celebrated: Former IPM Innovation Lab Collaborator Continues to make Agricultural Strides across Uganda
- Fighting Fruit Flies: Bangladesh uses Common Materials against a Common Pest

Rice, Maize, and Chickpea for East Africa



Project PI: Tadele Tefera

Collaborators:

Ethiopia Institute of Agricultural Research, Ministry of Agriculture and Natural Resources of Hawassa Regional State Bureau of Agriculture and Natural Resources – Ethiopia, Ambo University – Ethiopia, Haramaya University – Ethiopia, Addis Ababa University – Ethiopia, Jimma University – Ethiopia, Kenya Agricultural and Livestock Research Organization, Kenya Agricultural Value Chain Enterprises, Agricultural Research Institute (Dakawa) – Tanzania, National Biological Control Programme – Tanzania, Sokoine University of Agriculture – Tanzania, Real IPM – Tanzania.

Activities:

Ethiopia

Chickpea IPM

Both botrack and femtrack lures were effective in attracting the adult male moth of *Helicoverpa armigera* under field conditions. Application of 5% aqueous extracts of either *Azadiracta indica*

or *Milletia ferrugipeda* (or in combinations at 2.5%) were effective in reducing the infestation of *H. armigera*.

Maize IPM

Over 700 farmers have demonstrated on-farm the push-pull technology in Hawassa area; farmers have benefited from reduction of stem borer and fall armyworm damage, increased milk yields, and improved soil fertility.

In 2018, five different species of parasitoids were recovered from FAW eggs and larvae. Six commercial pheromone lures were evaluated for trapping FAW male moths in Ethiopia and Kenya.

Termite Management

Intercropping maize with *Desmodium*, mulching + intercropping maize with soybean, and Diazinon 60% E. C. reduced the number of lodged plants per plot compared to sole maize (control).

Kenya

Maize IPM

The push-pull plots recorded 21% maize yield increase compared to the controls. The demo farmers recorded almost no stem borer infestation in the push-pull plots compared to the controls. A total of 629 farmers have sensitized on push-pull technology. One technician and three researchers from KALRO were trained by *icipe* on rearing and release of local bio-control agents against fall armyworm.



The fall armyworm is a pest that thrives in harsh conditions, and has devastated numerous plant species across Asia and Africa, namely, maize.

In the laboratory and greenhouse tests, fall armyworm moths laid more eggs on wheat than on maize. No eggs were laid on beans. The egg parasitoid, *Telenomus remus* (Hymenoptera: Platygasteridae) was the dominant egg parasitoid accounting for 69.3% egg parasitism, followed by *Trichogramma chilonis* (20.9) whereas *Chelonus curvimaculatus* caused low levels of egg

parasitism (4%). The larval parasitoid, *Cotesia icipe* was the main larval parasitoid (42%), whilst *C. ater* caused low level of parasitism (2%).

Tanzania

Rice IPM

The highest incidence of rice blast disease (97%) was in Mvomero district, followed by Korogwe (91%), Morogoro rural (86%) and Muheza (71%) districts. The highest yield loss (50%) was on Supa (local) genotypes and the lowest yield loss (23%) was on NERICA 7 (improved) genotype.

Maize IPM

Telenomus remus was the dominant egg parasitoid causing 58.8% parasitism. *Cotesia icipe* caused 16% parasitism, whereas *C. ater* caused low level of parasitism (5%).

Publications:

Fite, Tarekegn, Tefera, Tadele, Negeri, Mulugeta, Damte, Tebekew, Sori, Waktole, Hutchison, William D. 2019. Comparative Performance of *Helicoverpa armigera* (Lepidoptera: Noctuidae) on chickpea and faba bean. International Journal of Biology; 2019; Vol. 11: 29-45.

Fite, Tarekegn, Tefera, Tadele, Negeri, Mulugeta, Damte, Tebekew, Legesse, Hirpa. 2019. Farmers status, knowledge & management practices on major chickpea insect pests in some selected zones of Ethiopia. Journal of Agricultural Science; Vol. 11: 31-45.

Non-referred publications:

Tadesse, D. 2018. Integrated management methods changing the landscape of chickpea production in Ethiopia

Tadesse, D., Enchalew, Bayu. 2018. Push-Pull Technology demo trials monitoring and Evaluation in Hawassa, November 2018.

2018. One Simple Farming Technique Successfully Battles Africa's Key Agricultural Constraints, (this story was produced by IPM IL).

Presentations:

Hashim, I. 2018. Investigation of smallholder farmers' knowledge and management of rice blast disease in upland rice production in Tanzania. October 2018, Department of Crop science and Horticulture, Sokoine University of Agriculture

Hashim, I. 2018. Evaluation of the effect of microbial agents on management of rice blast disease in Tanzania. November 2018, Department of Crop science and Horticulture, Sokoine University of Agriculture

Tefera, T. Rice, maize and chickpea project an overview of the project in the 3 countries, External Evaluation, 18 December 2018, Dar es Salaam, Tanzania.

Elibariki, S. maize stem borers and striga management in tanzania using push- pull technology, External Evaluation, 18 December 2018, Dar es Salaam, Tanzania.

Bonaventure J. Management options for rice stem borers in irrigated low land rice ecosystem in Tanzania, External Evaluation, 18 December 2018, Dar es Salaam, Tanzania.

Hashim, Ibrahim. Rice blast disease (*Pyricularia oryzae* Cav.) incidence, severity, genotype reaction and management in Tanzania, External Evaluation, 18 December 2018, Dar es Salaam, Tanzania.

Chuwa, C. Screening and Disseminating rice tolerant varieties to blast, rice yellow mottle virus and bacterial leaf blight diseases in Morogoro, Tanzania, External Evaluation, 18 December 2018, Dar es Salaam, Tanzania.

Kassie, Menale 2018. Socioeconomic component: Key achievements, External Evaluation, 21 December 2018, Addis Ababa, Ethiopia.

Zewdie, A. On-farm verification and demonstration of integrated wilt/ root rot and pod borer management method on chickpea in East Shewa Zone, External Evaluation, 21 December 2018, Addis Ababa, Ethiopia.

Kebede, Denberu. evaluation of endophytes associated with maize and entomopathogenic fungi against the spotted stem borer, *chilo partellus*, External Evaluation, 21 December 2018, Addis Ababa, Ethiopia.

Sisay, Birhanu. Evaluation of Different Management Options of Fall armyworm, *Spodoptera frugiperda* (Lepidoptera: *Noctuidae*) and Assessment of Their Parasitoids Enemies in Some Parts of Ethiopia, External Evaluation, 21 December 2018, Addis Ababa, Ethiopia.

Sisay, Birhanu. Management of Maize Stem borers using Push- Pull technology in Hawassa, Ethiopia, External Evaluation, 21 December 2018, Addis Ababa, Ethiopia.

Getaneh, Gezahegn. Integrated Chickpea diseases management for Fusarium wilt and Ascochyta blight, External Evaluation, 21 December 2018, Addis Ababa, Ethiopia.

Fite, Tarekegn. Management of Chickpea Pod Borer in Ethiopia, External Evaluation, 21 December 2018, Addis Ababa, Ethiopia.

Demissie, G. Integrated Management of Termites in East Wollega Zone of Oromia Regional State, Western Ethiopia, External Evaluation, 21 December 2018, Addis Ababa, Ethiopia.

Tadesse, D. IPM project communications and Knowledge Management approaches, External Evaluation, 21 December 2018, Addis Ababa, Ethiopia.

IPM for Vegetable Crops in East Africa



Project PI: Luis Cañas, The Ohio State University (OSU)

Collaborators:

The Ohio State University, University of Hawassa – Ethiopia, University of California – Davis, Sokoine University of Agriculture – Tanzania, Kenya Agricultural and Livestock Research Organization, Virginia Tech, Mikocheni Agriculture Research Institute – Tanzania.

Activities:

Tanzania, Tanzania Agricultural Research Institute (TARI)-Mikocheni

Conducted short-term hands-on training of farmers and stakeholders on healthy seedling production, nursery hygiene and management, pest scouting, good agricultural practices (GAPs) and IPM of vegetable viral diseases and insect vectors.

IPM strategies validated for tomato viral diseases and associated insect vectors. Awareness created on cause, symptoms, scouting and management of tomato viral diseases to farmers and extensions workers. Used the WhatsApp group to enhance communication and knowledge sharing on vegetable crop production with GAPs and IPM among the members.

Tanzania, Sokoine Agricultural University (SUA)

The IPM package for tomato field trial was conducted at Msufini village. This included the use of healthy seedlings, recommended seedbed preparation practices, mulching and staking, appropriate use of pesticides (only PERSUAP-approved chemicals used), *Trichoderma*, recommended fertilizer applications, and high yielding resistant varieties. Studies on temporal distribution and management of *Tuta absoluta* and grafting of tomato to control bacterial, fungal and nematode problems were carried out.



Tuta absoluta leaves small pinholes in tomatoes and has the potential to devastate 85% of yields.

A to Z Textile Mills Ltd, Arusha has constructed a net house for protected vegetable production facilities. Netting structures were donated to the Department of Crop Science and Horticulture. The structures are currently being used for demonstration of technologies, especially exclusion of insect pests.

Kenya, Kenya Agricultural and Livestock Research Organization (KALRO)

In a survey of farmers' knowledge of pests and pest management practices including use of non-pesticides for control for tomato, French bean and cabbage, it was found that the most serious diseases in tomatoes were bacterial wilt which was mentioned by 70.9% of the respondents followed by leaf blights (52.3%) and nematodes 29.7%. The most common tomato pests were white flies according to 69.8% of the interviewed farmers, leaf miners (64%), spider mites (52.3%), and *Tuta absoluta* (36%). Black rot was mentioned as a key cabbage disease by 70.2% of the respondents while diamond back moth and aphids were important arthropod pests according to 68.4% and 59.6% of the interviewed farmers, respectively. Important French bean diseases were rust (57.1%), angular leaf spot (46.9%) and anthracnose (32.7%) while pod borer,

thrips, bean fly and mites were identified by most farmers as main arthropod pests by 55.1%, 51%, 49% and 42.9% of the respondents, respectively.

Kenya, Real IPM

The Real IPM under this project has undertaken IPM activities through training which has trained 393 lead farmers for the period of 5 months (July- November 2018) of the four target Counties whom are expected to train minimum of five individual farmers within the same period.

Ethiopia:

The corky root rot of tomato caused by *Pyrenochaeta lycopersici* was noted for the first time in Ethiopia.

Pepper mottle virus is one of the major constraints of pepper production in rift valley of Ethiopia. Aphids are vectors of this disease. Covering plots with net for up to 60 days after transplanting reduced incidence of the disease.

Publications:

Kanyagha, H., Rotondo, F., Testen, A. L. and Miller, S. A. 2018. Survey and characterization of *Ralstonia solanacearum* in Solanaceous crops in Tanzania. *Phytopathology* 108: S1.128.

Ngugi, CN. Mbaka, JN., Wachira, PN, and Okoth, S. (2018) Laboratory screening for infectivity of selected indigenous entomopathogenic nematode isolates on *Tuta absoluta* in Kenya. *International Journal of Agriculture, Environment and BioResearch* Vol. 3, No. 06; 2018.

Ngugi, CN., Haukeland, S., Wachira, PM., Mbaka, JN. and Okoth.S (2019). Morphometrics and morphological characterization of entomopathogenic nematode isolate tk1 from Kenya. Accepted for publication in *Hindawi Advances in Agriculture*

Presentations:

Emanuel Lyimo (MSc.) Postgraduate seminar presentation titled “Efficacy of selected plant extracts and bio-fungicides against (*Plasmodiophora brassicae* Wor.) causal agent of clubroot disease of cabbage” (8th March 2019).

Hosea Mtui. Suppression of root-knot nematodes in tomato (*Solanum lycopersicum*) and cucumber (*Cucumis sativus*) fields by using bio-pesticides. Presented at National Scientific Conference on Pests and Pesticides 27 – 29 March, 2019.

Poster presented by Hellen Kanyagha at ICPP2018, the International Congress of Plant Pathology, Boston, MA, August 2018.

(18th Workshop on Horticultural Production in the Tropics, Taita Taveta University, Voi Kenya, 26th -30th November 2018)

Ngugi, CN, Haukeland, S., Wachira, PM., Mbaka, JN., Sheila, O, Mburu, HM (2018) Molecular characterisation of entomopathogenic nematodes from Kenya

Njenga, JN., Gathungu, GK and Mbaka JN. (2018). Evaluation of plant extracts on egg hatching and juvenile mortality of French bean root-knot nematodes.

Mbaka, J.N, Kambo, C., Kihara, S., Kuria, S., Ndungu, B., Wepukhulu, S., Muthengi, H., Mokaya, D., Cardina, J., Canas L. (2018). Enhancing Tomato IPM Adoption through Farmer Participatory Technology Transfer in Kenya

Developing Ecologically-based Participatory Packages for Rice in Cambodia (EPIC)



Project PI: Buyung Hadi, International Rice Research Institute

Collaborators:

General Directorate of Agriculture – Cambodia, Cambodian Agricultural Research and Development Institute, The Cambodian Center for Study and Development in Agriculture, Royal University of Agriculture – Cambodia, Viamo – Indonesia/Cambodia, Provincial Department of Agriculture, Forestry, and Fisheries – Cambodia (Prey Veng, Battambang, Takeo, Kampong Thom), Kasetsart University – Thailand, Nagoya University – Japan, Virginia Tech – USA.

Activities:

Completion of integrated demonstration trials from August to November (wet season)

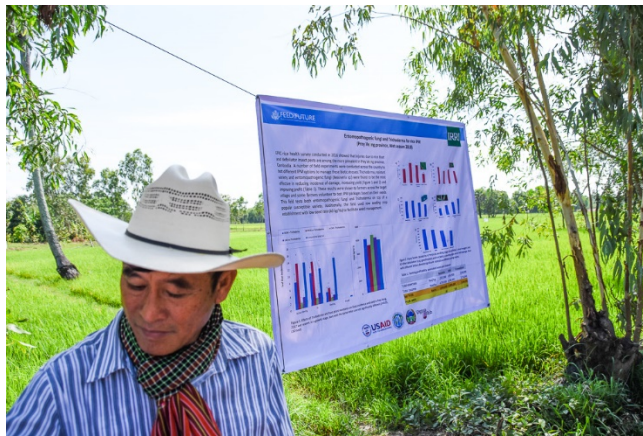
In the 3rd year of the project, the adaptive research platforms have shifted from researcher-led (single-technology in small plots, randomized design), to farmer-led, integrated demonstration trials in plot sizes that allow farmers to evaluate for themselves the performance of the

technologies. The combinations of IPM technologies tried by farmers are of their own selection. A total of 52 demonstration trials were implemented in the wet season from August to November 2018, and was reported as ongoing in the previous report. These trials have now been completed.

Nematode study with Kasetsart

Two genera of plant-parasitic nematodes (*Hirschmanniella* spp., and *Meloidogyne* spp.) were found in rice soil and roots collected from Ta Keo and Prey Veng. Both nematode genera were retrieved more from rice roots than soil and *Hirschmanniella* was the predominant nematode genus.

1. The use of CTBS/LTBS requires coordination and getting farmers to accept some risk, so that they do not fence the entire field, waste plastic, and unnecessarily increase their costs. However, given their current modification of the technology, it was still cheaper and more labor efficient compared with electric fencing.
2. Farmers realize the need to learn more about the techniques for application of *Trichoderma* and *Beauveria*; for example, using dedicated sprayer, mixing in a pail, and straining before putting the biological control agent (BCA) into the sprayer. The farmers also applied these two BCAs at the same time (mixed during spraying). Although this lessens labor, it is not known whether this practice would impact the effectiveness of either one.



Trichoderma, a naturally occurring fungus, protects plants from disease, and can be used in compost, or as a powder or liquid.

3. Some farmers hesitate to drastically reduce seed rate to 80-100 kg/ha. The seeders help them to try reduced seed rate, but there have been cases of weed problems which make farmers skeptical of this technique. Adjustments in combinations of seed rate, herbicide use, and water management after herbicide application are needed.
4. Skills have to be learned for operating the seeders, so that the row seeding and correct seed rate would work for farmers. Operators or farmers need experience to operate the

machine, time the movement so that seeds are evenly distributed, and maintain the equipment.

5. The effect of *Beauveria* and *Trichoderma* was perceived as positive by farmers. Aside from the effect on insects and disease, they relate this to the health effects observed after spraying. Extra attention has to be paid to the quality of BCA available in the market to maintain farmers' confidence.

Publications:

Flor R.J., Maat H., Hadi B.A.R., Kumar V., Castilla N. 2019 Do field-level practices of Cambodian farmers prompt a pesticide lock-in? *Field Crops Research* 235, 68-78.

Stuart A.M., Kong P., Then R., Flor R.J., Sathya K. 2019. Tailor-made solutions to tackle rodent pests of rice through community-based management approaches in Cambodia. *Crop Protection* (online first). <https://doi.org/10.1016/j.cropro.2019.01.023>

Presentations:

Hadi, B.A.R., Cheythirith, C., Sathya, K., Flor, R., Rathmuny, T., Castilla, N., Kumar, V., Stuart, A. 2018. Opportunities and constraints for ecologically-based pest management of rice in Cambodia. Paper presented at the Agroecology futures regional forum, Siem Reap, Cambodia. 6-8 November 2018.

Flor, R., Then, R., Maat, H., Chhay, K., Kumar, V., Castilla, N., Hadi, B.A.R. 2018. Lock in mechanisms affecting Integrated Pest Management in Cambodia. Paper presented at the 5th International Rice Congress, Singapore. 15-17 October 2018.

Stuart, A.M., Kong, P., Then, R., Flor, R., Sathya, K. 2018. Stuart, A.M., Kong, P., Then, R., Flor, R., Sathya, K. 2018. Reducing rodent damage to rice in Cambodia through ecologically-based rodent management approaches tailored to local conditions. 5th International Rice Congress, Singapore. 15-17 October 2018.

Flor, R. Hadi, B.A.R., Maat, H. 2018. Convergence and divergence of IPM and Agroecology: Implications for further development of IPM in Cambodia. Paper presented at the Sustainability and Development Conference. Ann Arbor, Michigan. 9-11 November 2018.

Posters:

Sathya, K., Castilla, N.P., Hadi, B., Stuart, A., Somany, S., Kumar, V. 2018. Characterization of cropping practices, pest constraints, and yield variation in irrigated lowland rice of Cambodia. Poster presented during the 5th International Rice Congress, Singapore. 15-17 October 2018.

Hadi, B.A.R., Flor R., Stuart A., Kumar, V., Castilla, N. 2018. Ecologically-based, Participatory IPM for rice in Cambodia. Poster presented during the 5th International Rice Congress, Singapore. 15-17 October 2018.

Invasive Species Modeling for the South American Tomato Leafminer and Groundnut Leafminer



Project PI: Abhijin Adiga, Biocomplexity Institute, University of Virginia Tech

Collaborators: Virginia Tech – USA, Cirad-Biopass – Dakar, Senegal; French National Institute for Agricultural Research (INRA), INRA – France

Activities:

We developed a network-based propagation model to study the spread of invasive species. This stochastic, spatially-explicit model captures the pathways of natural and human-mediated spread. It was applied to study the invasion dynamics of *Tuta absoluta* with focus on the region of South and Southeast Asia. Our analysis with respect to historical invasion records indicates two possibilities of spread of *T. absoluta* in Bangladesh, one where trade is the dominant pathway and the other where it is not. Novel machine learning techniques were applied to parameterization, capturing variability in model outcomes and sensitivity analysis.

Physiologically based demographic models (PBDMs) are used to capture the weather-driven biology of the species. When the requisite biological data is not available, the model structure

provides a useful guide for identifying the data gap. A PBDM is being developed for *T. absoluta* to identify potential new areas.

Updates for age-specific fertility of *T. absoluta* female is presented in the figure 1.

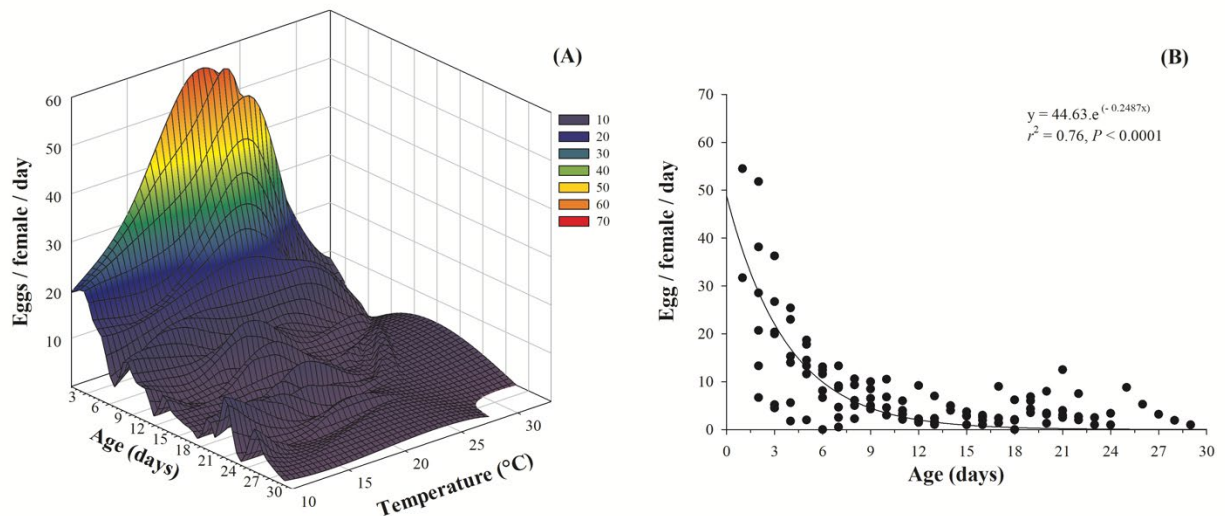


Figure 1. Age-specific oviposition of *Tuta absoluta* female on six constant temperatures. The data distribution on temperature x age (days) x eggs/female/day was plotted on three-dimension (A) and the statistical analysis in (B) where eggs/female/day and age (days) data fitted the nonlinear regression model in equation exponential decay at $P < 0.05$.



Tuta absoluta is a tomato pest that is native to South America, but was accidentally introduced to Spain in 2006. Now, it plagues Europe, Africa, the Middle East, and Central and South Asia.

Preliminary molecular analyses of *T. absoluta* showed that genetic diversity is higher in Africa compared to Europe or to native areas. We found genetic homogeneity in some countries (Argentina, Colombia, Algeria, and Tunisia) and two genetic lineages in other countries

(Mayotte, Niger, Togo, Senegal). In Senegal, we found three populations. More analyses are needed to determine the genetic flow between populations.

In Senegal, the release of indigenous predatory bugs such as *Nesidiocoris tenuis* along with insectary plants is very promising for tomato crop protection in net houses. Biological control through conservation of native natural enemies of *T. absoluta* is a way forward as a strategy accessible to small-scale farmers.

The molecular and morphological studies of the groundnut leafminer found in India and Africa led to the belief that the name *Aproaerema modicella* is a misnomer. Further studies are in progress for confirmation.

Publications:

Sylla, S., Brévault, T., Monticelli, L. S., Diarra, K., & Desneux, N. 2019. Geographic variation of host preference by the invasive tomato leaf miner *Tuta absoluta*: implications for host range expansion. *Journal of Pest Science*, 1-10.

S. Venkatramanan, S. Wu, B. Shi, A. Marathe, M. Marathe, S. Eubank, L. Sah, A. Giri, L. Colavito, K. Nitin, V. Sridhar, R. Asokan, R. Muniappan, G. Norton, and A. Adiga, "Modeling commodity flow in the context of invasive species spread: Study of *Tuta absoluta* in Nepal," *Crop Protection*, 2019

Presentation:

Adiga, A. 2018. Modeling the Spread of *Tuta absoluta* in Asia. International Conference on Biological Control. Bengaluru, India.

IPM for Exportable Fruit Crops in Vietnam



Project PIs: N.V. Hoa and T.T.M. Hanh, SOFRI, Vietnam

Collaborators: Virginia Tech – USA, Washington State University – USA, Plant Protection Research Institute – Vietnam, Fruit and Vegetable Research Institute – Vietnam, Plant Protection Department – Vietnam, Nong Lam University – Vietnam, Can Tho University – Vietnam, Vietnam National University of Agriculture – Vietnam

Activities:

This project targets four major crops in Vietnam: Dragon fruit (*Pitaya*, *Hylocereus* spp.), mango (*Mangifera* spp.), longan (*Dimocarpus longan*), and lychee (*Lychee chinensis*).

Dragon fruit

Primary pests of dragon fruit are canker, anthracnose, fruit fly and thrips. Among them, canker disease is the most serious disease in the rainy season.

IPM package for dragon fruit:

- Remove and compost pruned disease-infected cladodes from the field
- Set up sweet baits or protein baits for fruit fly and ant control
- Set up sticky blue or yellow trap for thrips control
- Use overhead sprinkler irrigation at flower bud stage in dry season for thrips control
- Use bio-pesticides such as *Beauveria bassiana*, *Bacillus amyloliquefaciens*, and *Bacillus subtilis*

- for control of pests
- Cover flower buds (12-15 days old) with plastic sleeves to prevent canker, anthracnose, fruit fly, and other pests.

Longan

Main pests consist of Longan Witches' Broom syndrome (LWB), longan gall mite *Eriophyes dimocarpi*, Litchi stinkbug *Tessaratomia papillosa*, Litchi leafminer *Conopomorpha litchiella*, fruit borers (Yellow peach moth *Conogethes punctiferalis* and Litchi shoot borer *Conopomorpha sinensis*), Longan psyllid *Cornegenapsylla sinica*, mealybug (cocoa mealybug *Planococcus lilacinus*, wax scale *Drepanococcus chiton*), Oriental fruit fly *Bactrocera dorsalis* and fruit rot.

IPM package for longan:

- Enhance use of organic fertilizer or compost inoculated with *Trichoderma*
- Prune longan canopy for easy management of pests and diseases
- Prune and safely dispose of shoots affected by LWB
- Apply Sulfur-containing pesticides to control the eriophyid mite
- Set up light traps to monitor fruit borer, shoot borer, and other pests
- Bag the fruit cluster 15 days after fruit set
- Set up Methyl Eugenol traps, sweet baits, and protein baits for control of fruit flies
- Use BTMET commercial product for mealybug control. Use sweet baits for control of ants associated with mealybugs
- Apply *Beauveria bassiana*, neem, and other bio-pesticides when needed



After years of assuming the causative organism of Longan Witches' Broom was a virus or phytoplasma, collaborative work between the IPM Innovation Lab and the Southern Horticultural Research Institute revealed it was the small white mite, *Eriophyes dimocarpi*.

Mango

Main pests consist of anthracnose *Colletotrichum* spp., bacterial black spot *Xanthomonas campestris* pv. *mangiferae*, oriental fruit fly *Bactrocera dorsalis*, fruit borer *Deanolis albizonalis*, mango leafhopper *Idioscopus niveosparsus* and chilli thrips *Scirtothrips dorsalis*.

IPM package for mango:

- Prune trees for better aeration

- Sanitation - Remove and properly dispose of fallen fruits from the ground
- Use of organic fertilizer or compost inoculated with *Trichoderma*
- Set up Methyl eugenol traps and use protein baits for fruit fly control
- Spray *Bacillus* spp. for control of anthracnose and bacterial black spot diseases two days before bagging
- Cover fruits with paper bags to prevent fruit borer, fruit flies, anthracnose and bacterial black spot disease attack at the time 30-45 days after fruit setting
- Use BTMET commercial product for pupal stage of thrips

Lychee

Main pests of lychee are stinkbug *Tessaratomia papilosa*, fruit borer *Conopomorpha sinensis*, eriophyid mite powdery mildew and anthracnose.

IPM package for lychee:

- Prune disease-infected branches and dispose of them properly
- Use compost inoculated with *Trichoderma*
- Use *Beauveria/Metarhizium* for control of stinkbugs
- Use bio-products *Beauveria* and *Metarhizium* to control stinkbug

Publications:

Hanh T.T.M., Giang N.T.C., Hoa N.V. and R. Muniappan, 2018. Study on morphology, biology of *Thrips palmi* and efficiency of different concentration of neem leaf extract on dragon fruit. *Journal of Vietnam Agricultural Science and Technology* 1 (3): 108-113 (in English).

Loc H.T., Tao L.C., Giang N.T.C., and Hoa N.V., 2019. Validation of artificial diets for rearing of *Galleria mellonella* larvae and mass multiplication of Entomopathogenic Nematodes for use in the control of fruit flies. *Proceedings International conference on tropical fruitpests and diseases*. 25-27 September 2018. Le Méridien, Kota Kinabalu, Sabah, Malaysia: 128-134.

Thoa N.T.K., Kumar N.G., Hoa N.V., 2019. Abundance of mesofauna on mango (*Mangifera indica* L.) ecosystem in Bengaluru, Karnataka, India. *Proceedings International conference on tropical fruit pests and diseases*. 25-27 September 2018. Le Méridien, Kota Kinabalu, Sabah, Malaysia: 66-72.

Hieu N.T., Thu N.N.A., Linh D.T., Thanh N.T.K., Hoa N.V., Muniappan Rangaswamy, 2019. Effect of various degree of canopy pruning on plant growth, yield and control of canker disease (*Neoscytalidium dimidiatum*) of dragon fruit crop. *Proceedings International conference on tropical fruit pests and diseases*. 25-27 September 2018. Le Méridien, Kota Kinabalu, Sabah, Malaysia: 98-103.

Presentations:

Hieu N.T., Hanh T.T.M. and Hoa N.V., 2018. Pest and disease management to promote sustainable. Agriculture for Fruit and Vegetable. Theme: Solution of sustainable development for fruit crops in Southern provinces. @ Agricultural extension forum. National Agricultural Extension Center. Ministry of Agriculture and Rural Development, Vinh Long, 12/2018: 23-33

Loc H.T., 2018. Training of Using safe and effective pesticides according to VietGAP standard (Training presentation), Cao Lanh city, Dong Thap province, October 4, 2018.

Sumner, D., 2018. Gender-focused Evaluation in the IPM Innovation Lab: The Most Significant Change

Technique and Agricultural Technology Assessment. (Training Workshop Presentation). Gender-focused evaluation Training Workshop, My Tho, VN, December 2018.

Sumner, D., Hanh T.T.M., T. Ngo Thi Thanh, M.E. Chrstie, Hoa N.V., 2019. Gender-responsive Integrated Pest Management (IPM) approaches in Vietnam: Lessons learned and insights to promote and strengthen gender integration (Poster). Seeds of Change Conference at the University of Canberra, Canberra, ACT, AU, April 2019.

Sumner, D., Hanh T.T.M., Truc N.T.T., M.E. Christie, Hoa N.V., 2019. Developing gender-responsive Integrated Pest Management (IPM) approaches in Vietnam: Lessons from a mixed-methods impact evaluation. Women and Gender in Development Conference 2019-Out of the Theory & Into the Field at Virginia Tech, Blacksburg, VA, February 2019.

Hanh T.T.M., 2019. Training of IPM on fruit crops. TOT training course for the staffs of Vinh Long Sub Plant Protection Department. Vinh Long, March 14, 2019.

Hanh T.T.M., Hieu N.T., Loc H.T., Thu N.N.A. and Hoa N.V, 2019. New pests on mango, citrus crops and Pest Integrated Management. Production Sustainable for fruit crops worshop. Tien Giang, March 28-29, 2019.

Uyen D.T.K., Hieu N.T. and Hoa N.V, 2019. New pests on dragon fruit, durian crops and Pest Integrated Management. Production Sustainable for Fruit Crops Workshop. Tien Giang, March 28-29, 2019.

IPM for Vegetable Crops and Mango in Asia



Project PI: George Norton, Virginia Tech

Collaborators:

Virginia Tech, Pennsylvania State University, Ohio State University, Washington State University – USA, Bangladesh Agricultural Research institute, iDE Nepal, National Agricultural Research Council, Agricultural and Forestry University, Himalayan College of Agricultural Sciences and Technology, Center for Environmental and Agricultural Policy Research, Extension, and Development, Plant Protection Directorate/Department of Agriculture, Agricare Pvt.Ltd., Nawasamridhi Enterprises, and Tripureshwor Kathmandu – Nepal, iDE Cambodia, Royal University of Agriculture – Cambodia.

Activities:

The Asian Vegetable and Mango IPM IL program implements ecologically-based, participatory IPM in Cambodia, Nepal, and Bangladesh, with a focus on pests of tomato, eggplant, cabbage,

cauliflower, Chili peppers, beans, cucurbits, Chinese cabbage, onion, and mango (the latter in Bangladesh).

Cambodia

Field trials for tomato IPM packages were completed with 12 cooperating farmers in the villages of Kakoh, Tropaing Trav and Ponleu Preah Phos in Chikreang district, Siem Reap province. Eight trials were conducted at the Royal University of Agriculture (RUA). A joint trial of the cucumber IPM package in combination with conservation agriculture for rainy season was completed in the CE SAIN Technology Park in Siem Reap.

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) development of management approach for mango hopper, c) dissemination of a management approach for mango Fruit fly, *Bactrocera dorsalis*, d) Field validation and upscaling of management approaches against tomato leafminer, *Tuta absoluta*, e) study of the integrated management of white mold of country bean, and f) assessment of economic impacts of vegetable IPM in Bangladesh.

Nepal

Specific research activities included a) Testing of lures for fruit fly control on cucumber and bitter melon, b) testing IPM packages on Chili and onion, c) testing an IPM package on French beans, d) evaluating different carbon sources for anaerobic disinfection, e) testing pest exclusion nets in polyhouse for *Tuta absoluta*, and f) evaluating bio-rational management tactics against *T. absoluta*.



The implementation of a “package” of technologies tailored to a single crop promotes an array of targeted pest management solutions farmers can choose from based on their specific needs, access, and abilities.

Publications:

Hossain, M. S., AQM Qamruzzaman, M.Y. Mian, G. Norton and R. Muniappan. Performance of Bt and non-Bt eggplant production under IPM package. Crop Protection. (Submitted)

Hossain, M. S., M.M. Hossain, M. Y. Mian, S. Akhter and R. Muniappan. Development of bio-rational based management approach against mango hopper, *Idioscopusnagpurensis* (Pruthi) in Bangladesh. *International Journal of Biological Control*. (Accepted)

Hossain, M. S., B.C. Sarkar, M.M. Hossain, M.Y. Mian, M.E. O'Rourke, E.G. Rajotte, and R. Muniappan. Comparison of biorational management approaches against mango fruit fly (*Bactrocera dorsalis* Hendel) in Bangladesh. *Crop Protection*. (Submitted)

Hossain, M. S., AK Das, S. Akhter, M. Y. Mian and R. Muniappan. Management of South American tomato leafminer, *Tuta absoluta* in Bangladesh. *Journal of Biological Control*. (Accepted).

Hossain, M. S., M. Y. Mian, GMA Halim and R. Muniappan. 2019. South American tomato leafminer, *Tuta absoluta* in Bangladesh: Meeting the Challenge. IPM IL, Bangladesh site, HRC, BARI, Gazipur-1701 (In press)

Success story: Fighting Fruit flies: Bangladesh uses Common materials against a Common Pest, IPMIL, 2019.

Bhandari, L. P. Sah, Y. Dhoj G.C, M. Devkota, L. A. Colavito, B.P. Rajbhandari, G. Norton, S. Miller and R. Muniappan, 2018. Evaluation of carbon sources for anaerobic soil disinfection (ASD) in tomato production in Lalitpur *Nepalese Journal of Agricultural Sciences* 16: 115-121.

Singh, L. P. Sah, Y. Dhoj G.C., M. Devkota, L. A. Colavito, B. P. Rajbhandari, G. Norton, E. G. Rajotte & R. Muniappan, 2018. Evaluation of pest exclusion net to major insect pest of tomato in Kavre and Lalitpur, *Nepalese Journal of Agricultural Sciences* 16: 128-137

Lamsal, A., L.P.Sah, A.Giri, M.devkota, L.A. Colavito, George Norton, E.G. Rajotte and R. Muniappan, 2018. Occurrence of South American tomato Leaf miner, *Tuta absoluta* and current management practices adopted by farmers in Lalitpur districts, Nepal. *Journal of Plant protections Society of Nepal* 5: 155-165.

Jyoti Kadel, Lalit P. Sah, Mukti Devkota, Luke A. Colavito, George Norton, Edwin George Rajotte and Rangaswamy Muniappan 2018, Effectiveness of different types of traps for management of *Tuta absoluta* in Nepal, *Journal of the plant protection society* 5: 166-174

Sah, L., Devkota M, Colavito, L., Muniappan, R., Rajotte, E., Norton, G. 2018. Occurrence and development of a plan to manage *Tuta absoluta* in Nepal, *Crop Protection* (Submitted).

Sah, L., Devkota, M, Tandukar, D, Colavito, L., Rajotte, E. 2018. Efficacy of biocontrol as a tactic to manage *Tuta absoluta* in Nepal. *Crop protection* (Submitted).

Rahman, Md. Sadique and George W. Norton, 2019. Adoption and Impacts of Integrated Pest Management in Bangladesh: Evidence from Smallholder Bitter Gourd Growers, *Horticulturae*, in press.

Alwang, Jeffrey, George Norton, and Catherine Larochele, 2019. Obstacles to Widespread Diffusion of IPM in Developing Countries: Lessons from the Field, *Journal of Integrated Pest Management*, in press.

Rahman, Md. Sadique and George W. Norton, 2019. Farm-level impacts of eggplant integrated pest management: a stochastic frontier production function approach, *International Journal of Vegetable Science*, DOI: 10.1080/19315260.2019.1566188

Presentations:

Seng, Kim Hian, Lessons learned from IPM trials, presented at Harvest II Friday talk, Phnom Penh, Cambodia, January 2019.

Sah, L.P. L.A.Colavito, and R. Muniappan, The Threats of Fall Armyworm Invasion and Possible Impacts on Nepalese Agriculture and Redemption of The Journal of Plant Protection Society, December 13, 2018 in MOALD, Kathmandu Nepal.

Participation in Regional workshop :New invasive species threats in Asia: Nov 21-22, 2018, organized by CABI.

National level FAW Sensitizing Stakeholders' workshop jointly by IDE, CIMMYT and PPS, Nov 30, 2018.

Norton, G.W., Integrated Pest Management and its Global Impacts, Royal Agricultural University, Phnom Penh, Cambodia, January 29, 2019.

Norton, G.W., R. Muniappan, and E.G. Rajotte, Challenges in Implementing Vegetable IPM in Developing Countries, Eastern Branch Entomology Society Meeting, Blacksburg, VA, March 11, 2019.

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



Project P.I.: Wondi Mersie, Virginia State University

Collaborators:

Ambo University, Ethiopian Institute of Agricultural Research, Haramaya University, Hawassa University – Ethiopia, Kenya Agricultural and Livestock Research Organization, Agricultural Research Council – South Africa, National Agricultural Research Organization – Uganda, Virginia State University, Virginia Tech – USA.

Activities:

Two biocontrol agents are being reared at three sites, Haramaya University (eastern Ethiopia), Wollenchiti (central Ethiopia) and Ambo University Guder campus (western Ethiopia). The two biocontrol agents are the leaf-feeding beetle, *Zygotogramma bicolorata* and the stem-boring

weevil, *Listronotus setosipennis*. Biocontrol agents reared at Wollenchiti are being released throughout Ethiopia. Between October 1, 2018 and March 31, 2019, a total of 4,200 *L. setosipennis* adults were released in Ethiopia. A total of 18,200 *Z. bicolorata* adults were released at four locations in two regional states of Ethiopia, Oromia and Southern Regions.



Parthenium hysterophorus is a native weed of tropical and subtropical South and North America, but spread to East Africa where it is invasive. In addition to wiping out native vegetation, the weed causes human health issues and taints livestock milk.

Kenya

The project in Kenya aims at introducing two biocontrol agents, *Zygogramma bicolorata* and *Listronotus setosipennis* for acclimatization, mass rearing and field releases against *Parthenium*. Application for a permit to introduce these two biological control agents has been submitted by KALRO to KEPHIS (Kenya Plant Health Inspectorate Service). Ms. Mellon Kabole, Senior Inspector at KEPHIS headquarters, participated in the training workshop at Wollenchiti, Ethiopia on December 17, 2018.

South Africa

The ARC-PHP was requested to assist with preliminary investigation of the host specificity of the seed-feeding weevil *Smicronyx lutulentus* on *Guizotia abyssinica* (niger seed) cultivars from Ethiopia. A permit was obtained from the Department of Agriculture, Forestry and Fisheries to import seed of selected *Guizotia abyssinica* cultivars from Ethiopia into South Africa (ARC-PHP Cedara), for host-specificity testing of *Smicronyx lutulentus* in 2019 for Ethiopia. This research will be conducted in the coming months on two cultivars of niger seed, Kuyu and Shambu.

Uganda

Earlier on, there were challenges in rearing *Z. bicolorata* and *L. setosipennis* in the screen house in Uganda. A training workshop was therefore organized in Ethiopia during December 2018 to improve the knowledge of staff in mass rearing. The knowledge gained from the training helped to refine the methodology being used in Uganda and to date a high number of *Z. bicolorata* (up to 4,000 adults) have been produced.

Publications:

Mersie, W., Alemayehu, L., Strathie, L., McConnachie, A., Terefe, S., Negeri, M. and Zewdie, K. 2019. Host range evaluation of the leaf-feeding beetle, *Zygogramma bicolorata* and the stem-boring weevil, *Listronotus setosipennis* demonstrates their suitability for biological control of the invasive weed, *Parthenium hysterophorus* in Ethiopia. *Biocontrol Science and Technology* 29(3): 239-251.

Book chapters:

Strathie, L. and McConnachie, A. 2019. History and Management – Southern Africa and Western Indian Ocean Islands. In: *Parthenium Weed: Biology, Ecology and Management*. Eds S. Adkins, A. Shabbir and K. Dhileepan. CAB International, pp. 264-286.

Dhileepan, K., McFadyen, R.E.M., Strathie, L. and Khan, N. 2019. Biological Control. In: *Parthenium Weed: Biology, Ecology and Management*. Eds S. Adkins, A. Shabbir and K. Dhileepan. CAB International, pp. 131-156.

Presentations:

Gareeb, M., Strathie, L., Sambo, S. and Magoso, X. 2018. Techniques to rear three insect agents for the biological control of *Parthenium hysterophorus* in South Africa. 1st International Conference on Biological Control. Approaches and Applications. p. 208. September 27-29, 2018, Bengaluru, India.

Mersie, W. 2018. Host range evaluation of the leaf-feeding beetle *Zygogramma bicolorata* and the stem-boring weevil, *Listronotus setosipennis* demonstrates their suitability for biological control of the invasive weed *Parthenium hysterophorus* in Ethiopia. 1st International Conference on Biological Control. Approaches and Applications. p. 198. September 27-29, 2018. Bengaluru, India.

Molo, R., Winnifred, A., Strathie, L. and Mersie, W. 2018. Distribution and current efforts in biological control of *Parthenium hysterophorus* in Uganda: 1st International Conference on Biological Control. Approaches and Applications. p. 207. September 27-29, 2018. Bengaluru, India.

Strathie, L., Sambo, S., Den Breeyen, A. Chidawanyika, F., Gareeb, M. and Magoso, X. 2018. Establishment and early impact of introduced natural enemies to control *Parthenium hysterophorus* in South Africa. 1st International Conference on Biological Control. Approaches and Applications. p. 204. Bengaluru, India. September 27-29, 2018.

Mersie, W. and Alemayhu, L. 2018. Helping Workitu Eirgu and other rural women in Ethiopia tackle the scourge of the invasive weed parthenium.” IPM IL Website at Virginia Tech.

Update on biological control of Parthenium (*Parthenium hysterophorus* L.) in Ethiopia.” IPM IL website at Virginia Tech.

“Biological control of *Parthenium hysterophorus* with the USA and African partners.” Plant Protection News 110: 6. 2018.

“Killer weed in East Africa no match for Virginia’s land-grant institutions.” Virginia Tech Magazine–Spring 2018 page 8.

“The invasive alien plant *Parthenium hysterophorus* and livestock production in KwaZulu-Natal.” KZN DARD Livestock Research Symposium, Cedara, March 8, 2018. About 180 participants attended the symposium.

Modeling for Biodiversity and Climate Change



Project PIs: Pramod Jha, Tribhuvan University, Nepal and Madhav Marathe, Biocomplexity Institute, University of Virginia.

Collaborators:

Tribhuvan University – Nepal, University of Virginia – USA

Activities:

Invasion by alien plant species has been increasing in Nepal at an alarming rate. In Nepal, *Chromolaena odorata*, *Lantana camara*, *Ageratina adenophora*, *Parthenium hysterophorus*, *Mikania micrantha*, and *Eichhornia crassipes* have been reported as the most problematic weeds in different ecosystems. The suitable habitats of these IAPs are likely to increase beyond the current distribution in future climate change scenarios as indicated by ecological niche modeling. The goal is to map the habitat distribution of the major IAS over the time between 1990 and 2017.



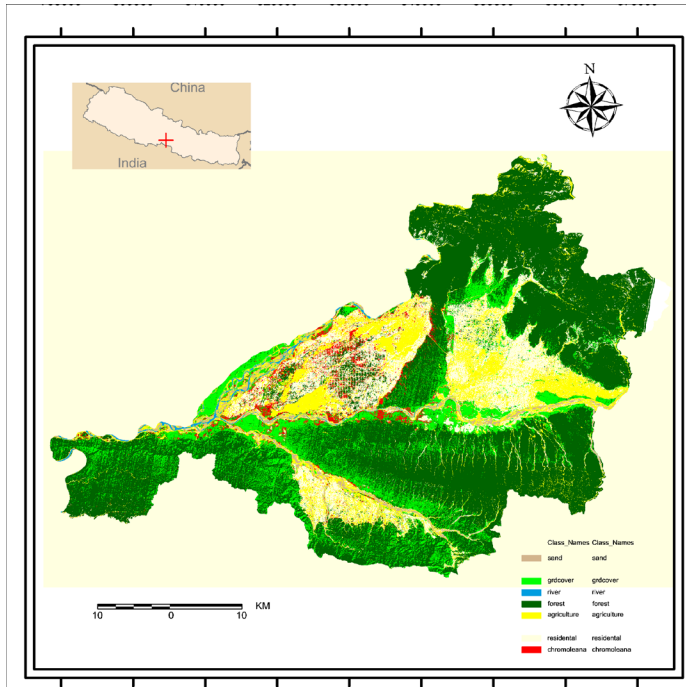
As students and researchers continue to see that invasive species spread more quickly with the rise of climate change, their work also projects future land availability for important crops like buckwheat and finger millet also being threatened, which could have major impacts on food security.

The species distribution of *Parthenium*, *Ageratina*, finger millet and buckwheat have been completed using Maxent Model under different climatic scenarios, and manuscripts have been prepared.

MSc students have completed Remote sensing and GIS training, collected field data for plotting current distribution of invasive species in selected districts.

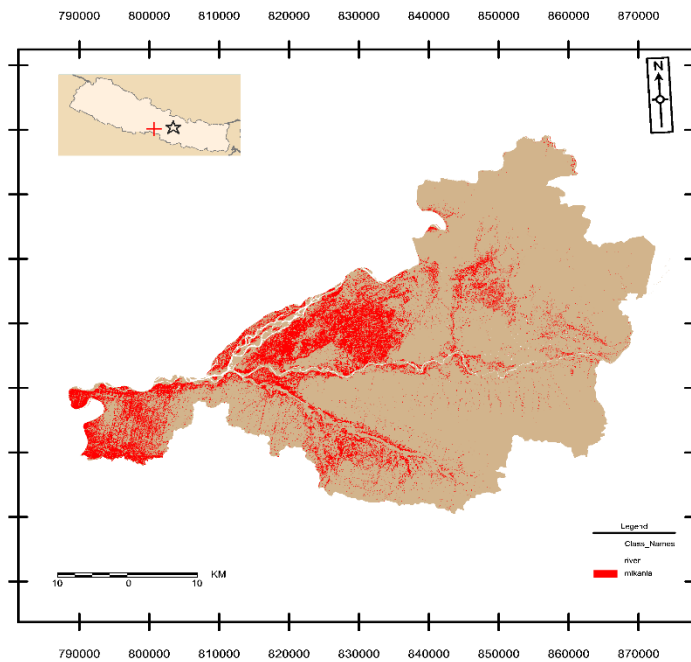
Field visits were made to take GPS coordinates of invasive plant species in Makawanpur, Chitwan, Tanahun, Kaski, Lamjung, Gorkha, Parbat, Baglung, Nuwakot and Rasuwa districts from 200 m to 3100 m elevation to determine presence and absence data of invasive species. Satellite images of Digital Globe were purchased for three additional areas of interest in Baglung, Syngja and Palpa, and Nawal Parasi districts.

Students had training on GIS and RS from October-November 2018, and field training in Chitwan, Kaski, Tanahu area. Prof Krishna Poudel provided the training. All MSc and PhD students have determined the probable area of distribution of altogether nine species (seven invasive and two crop species) by hypothesizing basis of slope, aspect, and elevation observed from field and from literature.



Chromolaena distribution (current) in Chitwan District.

Distribution of Lantana in Chitwan District.



Mikania distribution in Chitwan district.

Publications:

Luitel, D. R., Siwakoti, M. , Jha, P. K. 2018. Relationship between Climatic Variables and Finger Millet Yield in Syangja, Central Nepal. *Journal of Forest and Livelihood* 16 (2):1-13

Luitel, D.R., Siwakoti, M., Jha, P.K. 2019. Climate change and finger millet : Perception, trend and impact on yield in different ecological regions in Central Nepal. *Journal of Mountain Science*.16(4): 821-835. doi.org/10.1007/s11629-018-5165-1

Poudel A S, Jha P K, Rangaswamy M and Shrestha B B. 2019. Biology and management of invasive weed *Ageratina adenophora* (Asteraceae) : Current state of knowledge and prospect for future research. *Weed Research* (Accepted) DOI10.1111/wre.12351.

Upreti., R., Shrestha A K, Tripathi, K M, Shrestha B, Krakauer N, Devkota N R, Jha P K and Thapa, B. 2019. Effect of Fruit Thinning and Defoliation on Yield and Quality of Papaya (*Carica papaya*) cv. Red Lady in Chitwan”. *Acta Scientific Agriculture* 3.4 (2019): 130-136.

Maharjan S, Shrestha B B, Devkota A, Muniappan R. and Jha P K. Temporal and spatial pattern of research on globally significant invasive weed *Parthenium hysterophorus*: A bibliographic review. *Journal of Crop Protection* PEER REVIEWED (Reviewers comment received , and ms finally submitted).

Manuscripts Submitted:

Luitel, D.R., Siwakoti, M., Joshi, M.D., Rangaswami, M and Jha, P.K. Potential suitable habitat of *Eleusine coracana* (L) Gaertn under the climate change scenarios in Nepal using Maxent model. *Ecological processes* (Under Review for publication).

Maharjan S, Shrestha B B, Devkota A, Rangaswamy M and Jha P K ‘Biocontrol Science and Technology’ is being incorporated to research paper “How does the release of biocontrol agent, *Zyogramma bicolorata* reduce growth in *Parthenium hysterophorus* in Nepal . *Indian Journal of Weed Science*.

Presentations:

Maharjan S, Shrestha B B, Devkota A, Rangaswamy M and Jha P K. Functional traits of invasive weed *Parthenium hysterophorus* L. along the elevation gradients in central Nepal” in Mountains in the Changing world held in Kathmandu, Nepal (9-10 October 2018)(Oral presentation).

Luitel, D. R., Siwakoti, M. , Jha, P. K. Yield variation of finger millet and buckwheat local landraces along elevation gradient in Chitwan-Annapurna Landscape, Nepal” International conference on Climate change, Biodiversity and sustainable agriculture (ICCBSA-2018)(Dec 13-16, 2018), Jorhat, ASSAM, INDIA (Oral presentation).

Poudel A S, Jha P K, Rangaswamy M and Shrestha B B . Predicting the present and potential distribution of *Ageratina adenophora* in climate change scenarios' in a *National Climate Change Conference* held in Sindhupalchowk, Nepal (31 Dec 2018-1 Jan 2019 (Poster presentation).

Luitel, D. R., Siwakoti, M. , Jha, P. K. Potential suitable habitat of *Eleusine coracana* (L) Gaertn (Finger millet) under the climate change scenarios in Nepal using Maxent model". *National Climate Change Conference* Guphadanda, Sindhupalchok, Nepal (31 Dec 2018-1 Jan 2019)(Poster presentation).

Maharjan S, Shrestha B B, Devkota A, Rangaswamy M and Jha P K. Potential suitable habitat of *Parthenium hysterophorus* under climate change scenario in Chitwan Annapurna Landscape, Nepal. *Conference* held in Sindhupalchowk, Nepal (31 Dec 2018-1 Jan 2019 (Poster presentation).

Human and Institutional Capacity Development

a. Short-Term Training:

Innovative Scientific Research and Technology Transfer to Develop and Implement Integrated Pest Management Strategies for Vegetable and Mango Pests in Asia								
Type	Location	Date (Month, day, year)	Who was Trained	Number Female Participants	Number Male Participants	Total Participants	Home Institution	Training Institution
IPM package trials undergrad theses	Cambodia	Nov 18 to May 2019	Students	4	5	9	Royal University of Agriculture (RUA); IPM IL	RUA
Guest lecture	Cambodia	Jan 29, 2019	George Norton	5	12	17	Virginia Tech	Royal University of Agriculture (RUA)
Guest lecture	Cambodia	Feb 08, 2019	Jonathan Jacobs	9	4	13	Ohio State	Royal University of Agriculture (RUA)
Presentation	Cambodia	Jan 23, 2019	Project partners	7	16	23	IPM IL	Harvest II project
Presentation	Cambodia	Feb 20, 2019	Project partners	5	16	21	IPM IL	CODES project
Presentation	Cambodia	Mar 11, 2019	Private sector	7	6	13		Harvest II
Farmers training	Bangladesh	March 9, 2019	Farmers	14	36	50		BARI
Field day	Bangladesh	March 10, 2019	Farmers	48	52	100		BARI
Undergrad studies theses on IPM for Tuta and on ASD	Nepal	2018 Nov.- Jan. 2019	Agriculture Students	4	0	4	Himalayan College of Agri. Sciences and Tech. (HICAST)	IPM IL/IDE Research Site
Course	Nepal	2018 September to March 2019	Junior Technician of Agriculture	1	0	1	Technical training and research institute (TTRI)	IPM IL/IDE Research Site

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

Type	Location	Date (Month, day, year)	Who was Trained	Number Female Participa nts	Number Male Participa nts	Total Participa nts	Home Institution	Training Institution
Training on pesticide safety	Cambodia	02-Oct- 18	Farmers, extension staff	7	21	28		IRRI
Field visit	Cambodia	05-Oct- 18	Farmers	2	25	27		PDAFF
Field visit	Cambodia	19-Oct- 18	Farmers	10	15	25		PDAFF
Field visit	Cambodia	30-Oct- 18	Farmers	11	22	33		PDAFF
Field Day	Cambodia	31-Oct- 18	Farmers	20	29	49		PDAFF
Field visit	Cambodia	10- Nov-18	Farmers	23	20	43		PDAFF
Field visit	Cambodia	08- Nov-18	Farmers	10	27	37		PDAFF
Field visit	Cambodia	12- Nov-18	Farmers	13	16	29		PDAFF
Field visit	Cambodia	17- Nov-18	Farmers	2	23	25		PDAFF
Field Day	Cambodia	20- Nov-18	Farmers	13	48	61		PDAFF

Field visit	Cambodia	26-Nov-18	Farmers	13	16	29		PDAFF
Reflection meeting	Cambodia	07-Dec-18	Farmers	7	16	23		PDAFF
Reflection meeting	Cambodia	07-Dec-18	Farmers	2	13	15		PDAFF
Field Day	Cambodia	07-Dec-18	Farmers	26	35	61		PDAFF
Field visit	Cambodia	13-Dec-18	Farmers	6	22	28		PDAFF
Field visit	Cambodia	27-Dec-18	Farmers	1	14	15		PDAFF
Farmer exchange visit (KPT to PV-Thom)	Cambodia	27-Dec-18	Farmers	7	14	21		PDAFF
Farmer exchange visit (Boeung Bring to Otagea)	Cambodia	02-Jan-19	Farmers	7	27	34		PDAFF
Field visit	Cambodia	13-Jan-19	Farmers	4	24	28		PDAFF
Field visit	Cambodia	14-Jan-19	Farmers	12	15	27		PDAFF
Field visit	Cambodia	12-Jan-19	Farmers	3	28	31		PDAFF
Field Day	Cambodia	16-Jan-19	Farmers	27	19	46		PDAFF

Field visit	Cambodia	18-Jan-19	Farmers	17	12	29		PDAFF
Field visit	Cambodia	21-Jan-19	Farmers	6	26	32		PDAFF
Farmer field day	Cambodia	25-Jan-19	Farmers	12	46	58		PDAFF
Field visit	Cambodia	08-Feb-19	Farmers	20	9	29		PDAFF
Farmer exchange visit (Traeng to Bati)	Cambodia	08-Feb-19	Farmers	8	9	17		PDAFF
Farmer exchange visit (Sdao to Thom)	Cambodia	03-Mar-19	Farmers	6	43	49		PDAFF
Field visit	Cambodia	13-Mar-19	Farmers	12	13	25		PDAFF
Field day and trade fair	Cambodia	25-Mar-19	Farmers	34	46	80		PDAFF
Reflection meeting	Cambodia	26-Mar-19	Farmers	4	9	13		PDAFF
Reflection meeting	Cambodia	26-Mar-19	Farmers	6	8	14		PDAFF
Reflection meeting	Cambodia		Farmers	4	17	21		PDAFF
Reflection meeting	Cambodia		Farmers	2	20	22		PDAFF

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

Type	Location	Date (Month, day, year)	Who was Trained	Number Female Participants	Number Male Participants	Total Participants	Home Institution	Training Institution
Experiential training on mass rearing of <i>Zygogramma</i> and <i>Listronotus</i>	Ethiopia	Dec 17, 2018		6	13	19	VSU – <i>Parthenium</i> Project	

Assessment of Invasive Species Distribution in Chitwan Annapurna Landscape (CHAL) region, Nepal with the application of Satellite Imageries

Type	Location	Date (Month, day, year)	Who was Trained	Number Female Participants	Number Male Participants	Total Participants	Home Institution	Training Institution
sRemote Sensing and GIS Training	Nepal	Oct-November 2018	M Sc and Ph D Students	4	4	8	Tribhuvan University	Expert Prof K P Paudel

Rice, Maize, and Chickpea IPM for East Africa

Type	Location	Date (Month, day, year)	Who was Trained	Number Female Participants	Number Male Participants	Total Participants	Home Institution	Training Institution
Integrated management methods of chickpea wilt pod borer-field day	Ethiopia	4 October 2018	Farmers, extension workers, experts and bureau of Agriculture head representatives	4	36	40	DZ ARC	icipe
Mass production and use of <i>Trichoderma</i> and growth promoting bacteria	Ethiopia	17-21 Sept 2018		2	15	17		icipe
Farmers field day	Ethiopia	22 Dec. 2018	Farmers	5	55	60		icipe
Farmers field day	Kenya	15-17 Oct. 2018		57	32	89		icipe

Integrated Pest Management for Vegetables in East Africa

Type	Location	Date (Month, day, year)	Who was Trained	Number Female Participants	Number Male Participants	Total Participants	Home Institution	Training Institution
demo plots on tomato IPM	Tanzania	November, 2018	Farmers and extension officers	82	277	359	TARI-Mikocheni	TARI
Demo plots	Tanzania	Dec, 2018	Farmers and extension officers	34	106	140	TARI-Mikocheni	TARI
Tomato GAPs and IPM approaches	Tanzania	Jan, 2019	Farmers	1	7	8	TARI-Mikocheni	TARI
Demo plots	Tanzania	Feb, 2019	Farmers	9	28	37	TARI-Mikocheni	TARI
Demo plots	Tanzania	Mar, 2019	Farmers	4	37	41	TARI-Mikocheni	TARI
Demonstration of IPM Package	Tanzania	10/02/2018	Farmers	8	26	34		SUA
Farmers field Day on IPM Package for tomato	Tanzania	07/14/2018	Farmers DED – Mvomero DAICO Extension Officers	91	119	210		SUA
On farm tomato disease identification	Tanzania	01/22/2019	Farmers	5	18	23		SUA
Undergraduate Research Project	Tanzania	11/01/2018	Nangale, Allan	1		1	SUA	SUA
Undergraduate Research Project	Tanzania	11/01/2018	Magembe, Shigela	1		1	SUA	SUA
Undergraduate Research Project	Tanzania	11/01/2018	Michael, Michael Olaf	1		1	SUA	SUA
Undergraduate Research Project	Tanzania	11/01/2018	John Richard	1		1	SUA	SUA
Undergraduate Research Project	Tanzania	11/01/2018	Msogoya K. Gaetan	1		1	SUA	SUA
Train the Trainer on IPM, tomato, French beans and brassica and use of WhatsApp in pest diagnosis	Kenya	28 th January to 1 st February 2019	Extension officers and Lead farmers	13	21	34	N/A	KALRO
Train the trainer on biopesticides, vegetable Production under high, tunnels, seedling health and	Kenya	8 th to 12 th April 2019	Extension officers and Lead farmers	13	21	34	N/A	KALRO Fortune Irrigation and Green houses Limited Symon Ndambiri

tomato grafting, farming as a business								
IPM system training IPM Communication	Kenya	26 th July , 2 nd and 18 th August 2018	Lead farmers – French beans , Leafy vegetables , Tomato Growers	82	31	113		
IPM system training IPM Communication	Kenya	27 th July 2018	Lead farmers Tomato, Capsicum, leafy vegetable growers	16	14	30		
IPM system training IPM Communication	Kenya	10 th August 2018	Lead farmers , French beans ,snow peas cauliflowers , Tomato growers	48	42	90		
IPM system training IPM Communication	Kenya	27 th August 2018	Lead farmers Hydroponic lettuce , Cherry Tomato ,	45	15	60		
IPM system training IPM Communication	Kenya	3 rd October / 7 th November 2018	Lead farmers , French beans, leafy vegetables growers	60	40	100		
Images Collection and disease identification and whatsapp	Kenya	July- February 2019						

groups follow ups								
Training workshop	Hawassa	08-12 April 2018	Graduate students	5	3	8	Hawassa University	IPM project Partners
			The Vice president for Research and Technology Transfer, Hawassa University	1		1	Hawassa University	
			Head, Extension	1		1	Bureau of Agriculture, SNNPR	
			Faculty members	4		4	Hawassa University	
			Arbaminch, Hawassa, Ziway Plant Health Clinics	3	7	10	Bureau of Agriculture, SNNPR	
			Ministry of Agriculture , Plant Health and Regulatory Department	6		6	MoA	
			Bureau of Agriculture and Natural resource SNNPR	2		2	Bureau of Agriculture, SNNPR	
			Ziway Irrigation. Horticulture Office(1	2		2	Ziway Bureau of Agriculture	

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

Type	Location	Date (Month, day, year)	Who was Trained	Number Female Participants	Number Male Participants	Total Participants	Home Institution	Training Institution
Training: Intensive English course and IPM course		August 12-December 17, 2018	Prof. Donita Moore, Virginia Tech Language and Culture Institute; Prof. Douglas G. Pfeiffer Department of Entomology, Virginia Tech	1		1		Virginia Tech, the U.S
Training: Internal Auditor training course (Use for VietGAP standard)		April 12-13, 2019	Dr. Vo Huu Thoai; Dr. Tran Thi My Hanh; Dr. Tran Kim Cuong	3	8	13		SOFRI
Training courses on dragon fruit cultivation, pest and disease management		February 25, 2019	Farmers and extension staffs	2	21	23		SOFRI
Training courses on dragon fruit cultivation, pest and disease management		December 20, 2017	Farmers and extension staffs	8	23	31		SOFRI
Advanced farming techniques on Edor variety		February 27, 2019	Local extension staffs and longan growers in enlarged model	3	30	33		SOFRI
Advanced IPM package on longan		April 2, 2019	Local extension staffs and longan growers in enlarged model	5	37	42		SOFRI
Technical requirements for export longan		February 27, 2019	Local extension staffs and longan growers in enlarged model	3	31	34		SOFRI
Advanced IPM package on mango		March 12, 2019	Farmers and local extension staffs of IPM sites	2	40	42		SOFRI
New pests on mango and management		March 28, 2019	Farmers and local extension staffs of IPM sites	2	43	45		SOFRI
Training and transferring IPM technological protocol		March, 2019	Local technicians, local government officers and famers in litchi growing region	29	21	50		SOFRI

Training and transferring VietGAP protocol		March, 2019	Famers who participated in litchi model	15	25	40		SOFRI
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b. Long-Term Training

Innovative Scientific Research and Technology Transfer to Develop and Implement Integrated Pest Management Strategies for Vegetable and Mango Pests in Asia								
Name	Gender	Home Institution	Training Institution	Degree (BS, MS, PhD, Postdoc)	Major	Start Date (month, year)	Graduation Date (month, year)	Home Country
Sulav Paudel	Male	Penn State University		PhD	Entomology		Sept 2020	Nepal
Lauren Knaresboro	Female	Virginia Tech		MS	Economics		June 2020	USA
Farhanaz Sharma	Female	Virginia Tech		PhD	Economics		May 2020	Bangladesh
Arjun Khanal	Male	Tribbuvan University		PhD	Economics		July 2019	Nepal
Ram Khadka	Male	Ohio State University		PhD	Plant Pathology		Expected: May 2020	Nepal

Development of Ecologically-based Participatory Integrated Pest Management (IPM) Package for Rice in Cambodia (EPIC)								
Name	Gender	Home Institution	Training Institution	Degree (BS, MS, PhD, Postdoc)	Major	Start Date (month, year)	Graduation Date (month, year)	Home Country
Cheythyrith Chou	M	GDA	Nagoya University	PhD	Plant Pathology		July 2019	Cambodia

			Sattelite Campus					
Socheath Ong	F	RUA	Nagoya University Sattelite Campus	PhD	Plant Pathology		September 2020	Cambodia
Makarakpakp hea Keo	F	GDA	Royal University of Agriculture	MS	Entomology	April 2018	April 2020	Cambodia
Corey Riedel	M	Virginia Tech University	Virginia Tech University	MS	Entomology		September 2019	USA
Chhun Sokunroth	M	PDAFF	University of Battambang	MS	Agronomy		February 2019	Cambodia
Sydni Jackson	F	Virginia Tech University	Virginia Tech University	MS	Economics		June 2017	USA
Sek Pisey	M	RUPP	RUPP	MS	Biology		Dec 2017	Cambodia

Assessment of Invasive Species Distribution in Chitwan Annapurna Landscape (CHAL) region, Nepal with the application of Satellite Imageries								
Name	Gender	Home Institution	Training Institution	Degree	Major	Start Date (month/year) (Registration date)	Graduation Date (month/year)	Home Country
Ms Seerjan Maharjan	F	TU	CDB-TU	Ph.D (Bot)	Ecology	20 May 2015	Sept 2019	Nepal

Ms Anju Sharma Paudel	F	TU	CDB-TU	Ph D (Bot)	Ecology	15 June 2016	Sept. 2019	Nepal
Mr Dol Raj Luitel	M	TU	CDB-TU	Ph D (Bot)	Ecology	20 may 2016	Sept.2019	Nepal
Ghan Shyam Bhandari	M	AFU	DOE-AFU	Ph D (Entom)	Entomology	Feb 2016	Sept 2019	Nepal
Mr Hom Nath Giri	M	AFU	DOH-AFU	Ph D (Hort)	Horticulture	Feb 2016	Sept. 2019	Nepal

Ms Sita Gyawali	F	TU	CDB-TU	M Sc (Bot)	Ecology	May 2018	July 2019	Nepal
Mr.Himal Yonjon	M	TU	CDB TU	M Sc (Bot)	Ecology	May 2018	July 2019	Nepal
Ms..Srijana Poudel	F	TU	CDB TU	M Sc (Bot)	Ecology	May 2018	July 2019	Nepal
Mr.Sandeep Dhakal	M	TU	CDB TU	M Sc (Bot)	Ecology	May 2018	July 2019	Nepal
Mr Abhisek Singh	M	TU	CDB TU	M Sc (BEM)	Biodiversity	May 2018	July 2019	Nepal

Rice, Maize, and Chickpea IPM for East Africa								
Name	Gender	Home Institution	Training Institution	Degree	Major	Start Date (month/year)	Graduation Date (month/year)	Home Country
Bonaventure January	M	AfricaRice Centre	Sokoine University of Agriculture, Tanzania	PhD	Agricultural entomology	July 2016	June 2019	Tanzania

Ibrahim Hashim	M	Dakawa Agricultural Research Institute	Sokoine University of Agriculture, Tanzania	PhD	Plant Pathology	July 2016	June 2019	Tanzania
Josphat Korir	M	University of Nairobi	University of Nairobi, Kenya		Agricultural Economics	Sept 2016	June 2019	Kenya
Tarekegn Fite	M	Ministry of Agriculture	Ambo University, Ethiopia	PhD	Agricultural entomology	July 2016	June 2019	Ethiopia
Gezahegn Getaneh	M	EIAR (Ethiopian Institute of Agricultural Research)	Jimma University, Ethiopia	PhD	Plant Pathology	July 2016	June 2019	Ethiopia
Denberu Kebede	M	EAAR (Ethiopian Institute of Agricultural Research)	Addis Ababa University	MSc	Applied Microbiology	Jan 2017	Graduated in Dec 2018	Ethiopia
Birhanu Sisay	M	EAAR (Ethiopian Institute of Agricultural Research)	Haramaya University	MSc	Crop Protection	Jan 2017	Graduated in June 2018	Ethiopia
Nana Ameri	F	University of Dar Es Salam	University of Dar Es Salam	MSc	Applied Microbiology	Jan 2017	Dec 2018	Ethiopia

Integrated Pest Management for Vegetables in East Africa

Name	Gender	Home Institution	Training Institution	Degree (BS, MS, PhD, Postdoc)	Major	Start Date (month, year)	Graduation Date (month, year)	Home Country
Hellen Elias Kanyagha	F	SUA	OSU	PhD	Plant Pathology	March, 2017	May, 2020	Tanzania
Zuwena E. Msuya	F	SUA	SUA	MSc.	Plant Protection	2017	2019	Tanzania

Reagan Nyoni	M	SUA	SUA	MSc.	Plant Protection	October, 2018	September, 2019	Tanzania
Peter A. Maerere	M	SUA	SUA	MSc.	Plant Protection	October, 2017	September, 2018	Tanzania
Cecilia Ngugi	F	KALRO	University of Nairobi	PhD	Entomology	September 2016	September 2019	Kenya
Joshua Kinene	M	Chuka University	Chuka University	MS	Nematology	September 2017	September 2019	Kenya
Dennis Nyamu	M	Mwea Horticultural growers Self Help Group	OSU	MS	Entomology	August 2017	May 2020	Kenya
Kumsa Dida	M	Jinka University	Hawassa University	MSc	Crop Protection		2017	
Feyisa Bekele	M	Taya University	Hawassa University	MSc	Crop Protection		2019	

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

Name	Gender	Home Institution	Training Institution	Degree (BS, MS, PhD, Postdoc)	Major	Start Date (month, year)	Graduation Date (month, year)	Home Country
Uyen, Dang Thi Kim	Female		Can Tho University	PhD	Plant Protection	November 2021	November 2020	Vietnam
Duyen, Luong Thi	Female		Can Tho University	MSc.	Plant Protection	June 2020	August 2019	Vietnam
Trinh Ho Quoc Tien	Male		Nong Lam University	Bachelor	Plant Protection		April 2019	Vietnam

Nguyen Cuong	Huu	Male		Nong Lam University	Bachelor	Plant Protection		April 2019	Vietnam
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Agri-business Blooms out of IPM Innovation Lab Partnership



Samir Regmi, owner of Laxmi Agrovet Center in Nepal.

In 2015, amongst fields of tomatoes, cucurbits, and other vegetables, the IPM Innovation Lab conducted a training in Nepal. It was not long before the team made the distressing discovery that almost 100 percent of the crops were virus-infected, and a further assessment revealed that many of the viruses were seed-borne. The IPM Innovation Lab recommended to the group of farmers, agri-business owners, and extension agents in attendance that they immediately change their seed source to avoid potential economic and food security losses.

Samir Regmi, a business owner participating in the training, listened.

Regmi opened Laxmi Agrovet Center in Nepal in 2012—selling agricultural and veterinary supplies, his Integrated Pest Management (IPM) products brought in minimal earnings. Proving difficult to maintain the slow-selling supplies, Regmi partnered with the IPM Innovation Lab to develop a supply chain of IPM products. He also began attending trainings, like the one in 2015, to ensure that his supplies addressed farmer's most pressing crop needs.

Now, not only is Regmi successfully selling virus-free seeds of tomato, chili, and other crops per the IPM Innovation Lab's recommendation, he is a wholesale provider of IPM products and his business is booming.

"The IPM Innovation Lab has always supported me in my business promotion," Regmi said. "Currently, my business is one of the renowned agrovet [agricultural supply store] in this region, especially for the supply of bio-pesticides, insect traps, lures, irrigation technologies, and now for disease-resistant seeds. This is all because of the IPM Innovation Lab's support. My transactions have tremendously increased in recent years."



Amer Fayad (left) and Naidu A. Rayapati (right) display virus-infected chillies at an IPM Innovation Lab training.

In 2018, Regmi earned over ten times the average yearly income in Nepal from selling IPM products alone. Recently, he moved his business into a bigger facility to support the growing demand for his products, which annually reach more than 3,500 households.

Regmi mobilizes IPM products through community business facilitators (CBFs), or local entrepreneurial farmers with IPM training who promote his products to interested buyers. He also coordinates with local governmental bodies and is an agricultural program advisor for a municipality in Surkhet.

As reliance on synthetic pesticides builds around the world, and human and environmental life bear the effects, IPM products aim to provide inexpensive, comparable alternatives to crop protection.

Naidu A. Rayapati, professor in plant pathology at Washington State University, co-lead the 2015 training in Nepal with IPM Innovation Lab Associate Director Amer Fayad. Strengthening seed supply systems, he said, is critical to maintaining enduring vegetable crops.

"Training courses and field workshops conducted by the IPM Innovation Lab not only help subsistence farmers learn about new pests and diseases," Rayapati said, "but they help agri-business owners become aware of serious crop issues, like viruses spreading through compromised seed, and can then improve their business prospects by providing that clean seed to farmers."

Agri-business owners, he added, can also offer best practice guidelines to farmers, especially for promoting clean seeds as a key IPM component for raising healthy crops for increased family income and food security.

The IPM Innovation Lab has an extensive history of implementing programs based on immediate farmer needs, such as the numerous awareness workshops the team provided on the tomato pest *Tuta absoluta* upon its arrival. Further, virus and disease diagnostic training has long been a central program objective in strengthening the scientific capacity of farmers, extension personnel, and others involved in agricultural development. The proof resides along the shelves of Samir Regmi's business in Nepal, and others like it, but most importantly, in the surrounding fields now strengthened and bearing a healthy, bountiful harvest.

A Partnership Celebrated: Former IPM Innovation Lab Collaborator Continues to Make Agricultural Strides across Uganda



Godfrey Asea

Between 1999 and 2005, the IPM Innovation Lab funded Godfrey Asea's graduate studies in his pursuit of improving and protecting maize from insect pests and diseases—nearly two decades later, this collaboration has laid the foundation for enhanced livelihoods across Ugandan communities and the development and dissemination of high quality, stress-tolerant maize.

In 2015, after several years working with the National Agricultural Research Organization (NARO), Asea became Director of Research at the National Crops Resources Research Institute (NaCRRI), one of the seven national constituent research institutes with a mandate focus on crops research. NaCRRI addresses critical farmer challenges through development and deployment of technologies especially adapted to Uganda including disease and pest resistance, yield improvement, and drought tolerance, to name a few. The technologies developed by the organization contribute benefits to nearly 86 percent of Uganda's smallholder farmers.

Maize is a vital and strategic crop as a food source as well as a non-traditional cash crop exported regionally throughout East Africa. In addition to addressing climatic and pest issues around maize, Asea and his team also work to increase access to better quality seed and maintain access to food and resources through expanded collaborations and initiatives.

Asea said one of the major stepping stones to his current leadership role was his research collaboration and experience with the IPM Innovation Lab. The training and mentoring was "results-oriented," he said, and prepared him for the relationships he would need for battling and succeeding against the challenges to building food security.

"The IPM Innovation Lab," he said, "helped me network with U.S. maize researchers and industries who share experiences and provide technologies addressing challenges in the maize sub-sector. Those networks have been



In a past phase, the IPM Innovation Lab visited the National Crops Resources Research Institute in Uganda, where Asea is now Director of Research.

maintained, helping us to address emerging challenges for maize such as maize lethal necrosis and, most recently, the fall armyworm.”

As Director of Research, Asea provides professional, technical, and administrative guidance for development and promotion of crop technologies that will enhance social and economic development in Uganda. In October 2018, he was invited, along with over 200 other leading experts from international organizations, to the International Conference on Fall Armyworm in Addis Ababa, Ethiopia.

Muni Muniappan, Director of the IPM Innovation Lab and one of the meeting’s organizers, noted the value of seeing an IPM Innovation Lab student alumni at such a critical meeting for the future of Africa’s crops.

“World leaders were coming together to deliberate on one of the present most dangerous pests to sub-Saharan Africa,” Muniappan said, “and it was incredible to see Asea as one of those leaders. The control of a pest like the fall armyworm will require multiple approaches. Over the years, our alumni have chosen different scientific paths and it’s comforting to know that we already have built-in relationships with different scientific communities. Maize is this pest’s preferred host, so expertise like Asea’s will help us more productively forge ahead in solving this problem.”

Asea said that the IPM Innovation Lab has long helped to search for sustained funding for maize research in Uganda. Annually, the country’s farmers produce more than 4 million tons of the crop, but could produce even more if the major threats of drought and pests were addressed. Asea is hopeful those threats won’t last long.

“I am passionate about Uganda’s agricultural transformation,” Asea said. “The country has immense agricultural potential and there are vast opportunities, tools and partnerships to make that happen.”

Since Asea’s graduate studies through Makerere University in Uganda and The Ohio State University, his work has not gone unnoticed, and has earned him numerous prestigious awards. In 2017, he was a part of the team that won the Regional Maize Breeding Team Award in Eastern Africa, and in 2016, he was the recipient of the International Alumni Award from the College of Food, Agriculture, and Environmental Sciences at The Ohio State University.

In more than one million hectares of Uganda, you can see the maize varieties developed by NaCRRI being grown, steadily increasing the country’s ability to feed itself and its neighboring countries. Asea’s passion for “agricultural transformation” is clear—it grows, in bounty and abundance, from strong roots.

Fighting Fruit Flies: Bangladesh uses Common Materials against a Common Pest



Internal symptoms of fruit fly damage.



Mango bagging in Bangladesh.



Mangoes grown using bags.

Bangladesh produces one million tons of mango every year, and it's no surprise why. The bold shades of red, orange, and yellow that mark a mango's flesh are only in-part indicative of the experience of biting into one—its fruit is tender, sweet, and sun-like. Mango is also rich in vitamins, making it the second most important fruit to Bangladesh, and its demand increases every year.

Nevertheless, due to Bangladesh's tropical and sub-tropical climate, the mango fruit fly plays a major role in diminishing the fruit's yield and harvest quality.

Fruit flies threaten up to 70 percent of mango yields in Bangladesh, and historically, farmers have turned to pesticides to manage the pest, sometimes using up to 62 applications in a season. Pesticide use poses a risk to human life, in addition to eliminating important pollinators, parasitoids, and predators, and oftentimes resulting in excessive residues on marketable fruits.

The Bangladesh Agricultural Research Institute (BARI), an IPM Innovation Lab collaborator, has developed a fruit bagging technology whose impact on mangoes in the South Asian country have been paramount. By wrapping mangoes in a double layer of brown paper, nearly 100 percent of mango fruit fly damage has been prevented.

"Farmers are saying that mango bagging is a good technique for them," said Yousuf Mian, a coordinator with BARI. "Because it is a pollution-free method of pest control, they can sell the mango at a higher price and bagging improves the keeping quality of the mango."

Bagged mangoes can be sold at a price almost



(Left) Yousuf Mian, BARI collaborators, and Bangladeshi farmers with IPM IL Associate Director Amer Fayad (third from left) in Bangladesh.



A farmer field day for mango bagging in Bangladesh.

double that of non-bagged mangoes and the bags can be reused for two seasons.

Shahadath Hossain, principal scientific officer in entomology at BARI, said that in Bangladesh, the areas of Rajshahi and Chapai Nawabgonj are producing mangoes commercially and exporting to areas such as the Middle East and Japan, increasing demand for better fruit.

While bagging requires labor, inversely it is “creating employment opportunities,” Hossain said. “Laborers are getting handsome money from it.”

With only one pesticide spray required before bagging, chemical residues on the fruit have been reduced to nearly zero, in addition to protecting mangoes from mechanical injury. Testing for pesticide residues can be expensive, and eliminating that step increases Bangladesh’s potential for entering more global markets with ease, not to mention the unblemished, flawless fruit that will help them get there as well.

“Farmers can very easily adopt this technique,” Mian said. “If you show this technique to the farmers just one time, they can do it. Since bagged mangoes are sold at a higher price in the market, farmers are using this money for purchasing good clothes, hiring new land, paying school fees for their children, and so on.”

Currently, there are two companies selling the bags to Bangladeshi communities. Last year alone, almost 40 million bags were used.

