



# FEED THE FUTURE

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



## 2018 Integrated Pest Management Innovation Lab Annual Report (2017-2018)

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icipe

## Countries 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, University of Minnesota, Virginia State University, Virginia Tech, Washington 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

Center for Agriculture and Bioscience International (CABI), Food and Agriculture Organization (FAO), 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).

## **Host Country Universities, Government Agencies, Institutions, and NGOs**

Agriculture and Forestry University (Nepal), Agricultural Research Council and Plant Protection Research Institute (South Africa), Ambo University (Ethiopia), Amhara Regional Agricultural Research Institute (Ethiopia), Bangladesh Agricultural Research Institute (Bangladesh), Can Tho University (Vietnam), Cambodian General Directorate of Agriculture, Cambodian Center for Study and Development in Agriculture, Ecological Services Centre (Nepal), Ethiopian Institute for Agricultural Research (Ethiopia), Fruit and Vegetable Research Institute (Cambodia), Grameen Krishok Sohayak Sangstha (Bangladesh), Haramaya University (Ethiopia), Hawassa University (Ethiopia), Horticultural Development Council (Tanzania), iDE (Nepal and Cambodia), Indian Institute of Horticultural Research, Kenya Agricultural and Livestock Research Organization (Kenya), Mikochei Agricultural Research Institute (Tanzania), Nagoya University (Japan), Nong Lam University (Vietnam), Real IPM (Kenya), Sokoine University of Agriculture (Tanzania), Southern Horticultural Research Institute (Vietnam), Tribhuvan University (Nepal), and Vietnam National University of Agriculture (Vietnam)

## Acronyms

BARI	Bangladesh Agricultural Research Institute
Bt	<i>Bacillus thuringiensis</i>
CABI	Center for Agriculture and Biosciences International
CARDI	Cambodian Agricultural Research and Development Institute
CEDAC	Cambodian Center for Study and Development in Agriculture
CIRAD	Agricultural Research for Development
DAI	DAI Global
EPIC	Ecologically Based Participatory IPM Package for Rice in Cambodia
FAO	Food and Agricultural Organization
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
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
USAID	United States Agency for International Development
VT	Virginia Tech



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## I. Executive Summary

Over the past 12 months, the IPM Innovation Lab (IPM IL) Management Entity (ME) has participated in the annual planning meetings of its eight projects. Additionally, these projects were individually reviewed by the IPM IL ME.

- The IPM Innovation Lab conducted three webinars, namely: neem, *Tuta absoluta* and *Trichoderma*. It organized a *Tuta absoluta* symposia at 1. 22nd Meeting and Conference of the African Association of Insect Scientists, Wed Madani, Sudan, October 2017, 2. Twelfth Arab Congress of Plant Protection, Hurghada, Egypt, November 2017, 3. Annual meeting of the Entomological Society of America, Denver, U.S.A, November 2017, 4. Ninth International IPM Symposium, Baltimore, U.S.A., March 2018, and 5. First International Conference on Biological Control, Bengaluru, India, September 2018.
- A symposium on IPM packages for tropical crops was conducted at the annual meeting of the Entomological Society of America, Denver, U.S.A, November 2017 and Ninth International IPM Symposium, Baltimore.
- A symposium on biological control of *Parthenium* was conducted at the First International Conference on Biological Control, Bengaluru, India. A symposium on Plant Virus Diseases was conducted at the International Congress of Plant Pathology, Boston, May 2018.
- We participated in the Fall Armyworm meetings in Washington, DC, February 2018.
- Muniappan presented keynote addresses at 1. 22nd Meeting and Conference of the African Association of Insect Scientists, Wed Madani, Sudan; 2. Twelfth Arab Congress of Plant Protection, Hurghada, Egypt; and 3. International Symposium on Biological Control of Weeds, Engelberg, Switzerland.
- Reviews of all the projects were conducted either attending project planning meetings or conference calls. Opportunities were given to several host country collaborating scientists and students to participate and present papers in international conferences.
- We have prepared PERSUAPs for 1. Vegetable Crops in Bangladesh, Cambodia, and Nepal; 2. Fruit Crops in Vietnam; 3. Rice in Cambodia; and 4. Grain Crops in Ethiopia, Kenya, and Tanzania.
- A Buy-in for Fall Armyworm Risk Assessment was received from the USAID mission in Egypt.
- A newly modified project on Climate Change and Biodiversity in Nepal was implemented
- Reviewed Western IPM regional project proposals.
- Management Entity participated in the BIFAD meetings in May and September 2018.
- In May 2018, IPM IL Technical Advisory Committee meeting was conducted in Phnom Penh, Cambodia.
- Mr. Laouali Amadou, a PhD student from University of Maradi in Niger, who spent six months at Virginia Tech supported by a sub-award from the Sorghum and Millet Innovation Lab, received BIFAD award for Scientific Excellence.
- Dr. George Norton, Principal Investigator of the IPM Innovation Lab sub-award “Innovative Scientific Research and Technology Transfer to Develop and Implement Integrated Pest Management Strategies for Vegetable and Mango Pests in Asia” was recognized as Fellow of the Agricultural and Applied Economics Association.
- Mango fruits are bagged in Bangladesh and Vietnam to prevent fruit fly attack. Longan fruit clusters are covered with nylon netted bags in Vietnam to prevent fruit fly and other pests attack. Dragon fruit flowers are covered with plastic sleeves to prevent fruit fly and a fungal disease attack.
- *Trichoderma* is used for control of neck blast disease of rice in Cambodia.



- Bt-eggplant has been incorporated as a component of eggplant IPM in Bangladesh.
- An effective non-chemical pesticide management technology has been developed for *Tuta absoluta* in Nepal. Modeling of *T. absoluta* in Asia is continued. Invasive species spread and impact due to climate change is being assessed using remote sensing images and machine learning in Nepal.
- Field release of two natural enemies Parthenium in Ethiopia and Uganda has been carried out.
- Two egg parasitoids and five larval parasitoids have been collected on fall armyworm in East Africa.
- Workshops on diagnostics of vegetable pests in Ethiopia and vegetable viral diseases in Tanzania were conducted. In Kenya, *Trichoderma* sp. found to control root knot nematode.
- Entomopathogenic nematodes were tested for control of *T. absoluta*.

### Press Releases/Articles

- [A Dangerous Pest is on its way to Nepal](#). *Spotlight Magazine*. 12.9.18
- [Virginia Tech teams up with researchers in Niger to improve livelihoods](#). *VT News*. 11-26-18
- [Entomologist from Vietnam gains global perspective at Virginia Tech](#). *VT News*. 11.27.18
- [Not Just Maize: Africa's Fall Armyworm Crisis Threatens Sorghum, Other Crops, Too](#). *Entomology Today*. 11-20-18
- [Virginia Tech to host gender and international development conference](#). *VT News*. 10-29-18
- [Value-Added Food and Processes: Biocontrol Opens New Prospects in the Sahel](#). *Agrilinks*. 10-24-18
- [Center for International Research, Education, and Development names communications director](#). *VT News*. 10-17-18
- [Training on \*Trichoderma\* and Plant Growth Promoting Rhizobacteria](#). *IAPPS*. 10-1-18
- [Professor awarded for research contributions and four decades of service](#). *VT News*. 10-2-18
- [How Science and Extension Services Benefit from International Collaboration](#). *Agrilinks*. 9-24-18
- [Virginia Tech researchers make small discovery that could keep millions from going hungry](#). *VT News*. 9-14-18
- [Male Out-Migration: A Change in Households, a Change in Public Spaces](#). *Agrilinks*. 9-19-18
- [Fighting Nature with Nature: Scientists Mobilize Biological Control Against Devastating Fall Armyworm](#). *PreventionWeb*. 9-11-18
- [Fighting Nature with Nature: Scientists Mobilize Biological Control Against Devastating Fall Armyworm](#). *Entomology Today*. 9-11-18
- [Fall Armyworm's Arrival in India Sparks Fear of its Spread Through Asia](#). *Earth Island Journal*. 8-20-18
- [Virginia Tech's simple fix for Vietnam cuts pesticide use, sends bugs packing](#). *VT News*. 7-30-18
- [Mapping Climate Change, Invasive Species, and Semblances of Hope](#). *Agrilinks*. 4-27-18
- [March of the Armyworm](#). *Earth Island Journal*. 6-6-18
- [Countries Get Heads Up About Leafminer Invasion Thanks to Virginia Tech](#). *Growing America*. 3-9-18
- [Biological Control of Parthenium \(\*Parthenium hysterophorus\* L.\) in Ethiopia](#). *IOBC Newsletter*. 12-1-18
- [Two Sides of the Same Leaf: Controlling Pests in Cambodia](#). *Feed the Future Newsletter*. 2-1-18
- [Bangladesh: Women entrepreneurs produce \*Trichoderma\*](#). *Global Plant Protection News*. 4-17-18
- [IPM Innovation Lab Presents Webinars on Neem and \*Trichoderma\*](#). *IAPPS Newsletter*. 9-1-18
- [BIFAD Award for Scientific Excellence](#). *IAPPS Newsletter*. 9-1-18

- [Student from Niger with ties to Virginia Tech wins major award.](#) *VT News*. 3-15-18
- [Killer weed in East Africa no match for Virginia's land grant institutions.](#) *Virginia Tech Magazine*. Spring 2018
- [Killer weed in East Africa no match for Virginia land-grant institutions.](#) *Augusta Free Press*. 1-20-18
- [Bangladesh: Women entrepreneurs produce \*Trichoderma\*.](#) *Global Plant Protection News*. 4-17-18
- [Virginia Tech provides key intel in U.S. an Egyptian-led battle against a major pest.](#) *VT News*. 3-30-18
- [Using Integrated Pest Management to Reduce Pesticides and Increase Food Safety](#) *Agrilinks*. 3-6-18
- [Countries get heads up about tomato leafminer thanks to Virginia Tech](#) *VT News*. 3-7-18
- [Killer Weed in East Africa No Match for Virginia's Land-Grant Institutions.](#) *CBS*. 1-18-18

## II. Program Activities and Highlights

### Activities:

- Program activities implemented were development and implementation of IPM packages for fruit crops in Vietnam; vegetable crops in Bangladesh, Cambodia, Ethiopia, Kenya, Nepal and Tanzania; for maize and chickpea in Ethiopia; maize in Kenya; and rice and maize in Tanzania. It also monitored spread of *T. absoluta* in Asia, and fall armyworm in Africa and South Asia.

### Highlights:

- Identification of two egg parasitoids and five larval parasitoids of fall armyworm in maize fields in Eastern Africa.
- Organized *T. absoluta* symposia in the national and international conferences in Egypt, India, Sudan, Denver and Baltimore.
- Organized IPM packages for crops symposium in international conference in Baltimore.
- The correct identity of longan eriophyid mite in Vietnam has been determined.
- A revised project on spread and impact of invasive species due to climate change has been implemented.
- Bt-eggplant has been incorporated in the IPM package for eggplant in Bangladesh.
- PERSUAPs for fruit crops IPM in Vietnam; vegetable crops IPM in Bangladesh, Cambodia and Nepal; vegetable crops IPM in Ethiopia, Kenya and Tanzania; and rice IPM in Cambodia have been prepared.
- A fall armyworm risk assessment was prepared for Egypt.
- Technologies for control of witches' broom syndrome in longan, fruit fly on mango, and a fungal disease on dragon fruit in Vietnam have been developed.
- Pheromone traps for fall armyworm monitoring in Nepal and Bangladesh were procured.
- A workshop on production and use of *Trichoderma* spp. and *Pseudomonas fluorescens* in Ethiopia was conducted.

### III. Key Accomplishments

- Confirmation of the correct identity of longan witches' broom syndrome in Vietnam.
- Identification of two egg and five larval parasitoids of fall armyworm in Eastern Africa.
- Organization of *T. absoluta* symposia in international conferences.
- Presentation of three webinars on neem, *Trichoderma* spp. and *T. absoluta*.
- Receipt of a Buy-in from the Egypt USAID mission.
- Receipt of \$50,000 from the Associate Vice President, Outreach and International Affairs, Virginia Tech for conducting impact assessment of introduction of coconut pith and *Trichoderma* in Bangladesh, India and Nepal.
- BIFAD award Excellence in Research for one of the graduate students from Niger who spent six months at Virginia Tech supported by a sub-award from the Sorghum and Millet Innovation Lab.
- Implementation of IPM packages for selected crops in various host countries.
- Support of over 64 graduate students.
- Production and dissemination of several success stories.

#### IV. Research Program Overview and Structure

There are eight projects operating in seven countries.



## V. Research Project Reports

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

**PI:** Hoa Van Nguyen, SOFRI

**Location:** Vietnam

**Collaborators:** Hanh Tran, M.E. Christie, N. Rayapati

**Description:** Development of IPM packages for exportable fruits: dragon fruit, longan, lychee, and mango in Vietnam.

**Achievements:**

The causative organism for witches' broom syndrome of longan has been diagnosed as an eriophyid mite. A knitted nylon bag was developed for bagging longan fruit clusters to prevent insect damage. A waxed paper bag was developed to cover mango fruits to prevent fruit fly infestation. A plastic sleeve was developed to cover dragon fruit flowers to prevent fruit fly damage and to reduce the incidence of the disease caused by the fungus *Neoscytalidium dimidiatum*.

**Capacity building:** Seventeen training courses were conducted for 596 farmers and extension staff. Two MS, one PhD and seven BS students were supported by this project.

**Lessons learned:** The identity of eriophyid mites found on longan determined by a specialist is important.

**Publications/Presentations:**

- Nguyen Van Hoa, Dang Thi Kim Uyen, Muniappan Rangaswamy, 2018. Oral presentation on "Effect of *Bacillus* spp. and plant extracts from *Impatiens balsamina* L. on anthracnose disease caused by *Colletotrichum* spp. on mango in Vietnam" at the First International Conference of Biological Control Approaches and Applications, at Bengaluru, India, September 27-29, 2018.
- Dang Thi Kim Uyen, Muniappan Rangaswamy, Tran Vu Phen, Nguyen Van Hoa, 2018. Poster presentation on "The efficacy of *Streptomyces* spp., *Bacillus* spp and extract of *Impatiens balsamina* on the mycelial growth of the fungi *Colletotrichum truncatum*, *C. gloeosporioides* causing anthracnose disease on dragon fruit" at the First International Conference of Biological Control Approaches and Applications, at Bengaluru, India, September 27-29, 2018.
- Nguyen Thanh Hieu, Nguyen Ngoc Anh Thu, Dang Thuy Linh, Ngo Thi Kim Thanh, Nguyen Van Hoa and Muniappan Rangaswamy, 2018. Oral presentation on "Effect of various degree of canopy pruning on plant growth, yield and control of canker disease (*Neoscytalidium dimidiatum*) of dragon fruit crop." *International Conference on Tropical Fruit Pests and Diseases (TROPED 2018)*, Sabah, Malaysia, September 24-29, 2018.
- Nguyen Thi Kim Thoa, 2018. Oral presentation on "Abundance of mesofauna on mango (*Mangifera indica* L.) ecosystem in Bengaluru, Karnataka, India." *International Conference on Tropical Fruit Pests and Diseases (TROPED 2018)*, Sabah, Malaysia, September 24-29, 2018.
- Huynh Thanh Loc, 2018. Oral presentation on "Validation of Artificial Diets for Rearing of *Galleria*

*mellonella* Larvae and Mass Multiplication of Entomopathogenic Nematodes for Use in the Control of Fruit Flies". *International Conference on Tropical Fruit Pests and Diseases (TROPED 2018)*, Sabah, Malaysia, September 24-29, 2018.

- Dang Thi Kim Uyen, Tran Vu Phen and Nguyen Van Hoa, 2018. ICAS poster "Efficacy of *Streptomyces* spp., *Bacillus* spp. on the mycelial growth of the fungi *Colletotrichum truncatum* causing anthracnose disease on dragon fruit. International Conference "Sustainable Agriculture Development in the Impact of Climate Change: Challenges and Opportunities" Can Tho University, Vietnam, August 17-18, 2018.
- Dang Thi Kim Uyen, Tran Vu Phen and Nguyen Van Hoa, Rangaswamy Muniappan, 2018. Oral paper "Identification of *Colletotrichum truncatum* causing anthracnose disease on dragon fruit and the efficacy of some biological tools on the mycelia growth of the fungus and disease control." Proceedings International Dragon Fruit Regional Network Initiation Workshop, Taipei, Taiwan, April 22-25, 2018
- Nguyen Thanh Hieu, Nguyen Van Hoa, Tran Thi My Hanh, Le Quoc Dien, Dang Thi Kim Uyen, Nguyen Ngoc Anh Thu and Dang Thuy Linh, 2017. Application of biological methods, stimulation of resistance pest production control 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, Ben Tre, 16/2017: 31-40
- Tran Thi My Hanh and Nguyen Van Hoa, 2017. Integrated pest management on mango and longan in Southern provinces. Theme: Solution of sustainable development for fruit crops in Southern provinces. @ Agricultural extension forum. National Agricultural Extension Center. Ministry of Agriculture and Rural Development, Ben Tre, 16/2017: 54-60
- Tran Thi My Hanh and Nguyen Van Hoa, 2018. Morpho-biological characteristics of predatory mite (*Amblyseius longispinosus*), a biological control agent of *Aceria (Eriophyes) dimocarpis* on longan. *Journal of Agricultural Science and Technology of Vietnam* 1 (86): 64-68
- Dang Thi Kim Uyen, Tran Vu Phen and Nguyen Van Hoa, 2018. Identification of *Colletotrichum truncatum* causing anthracnose on dragon fruit and effect of botanical extracts on fungus growth. *Journal of Vietnamese Agricultural Science and Technology* 1 (86): 83-88
- Dang Thi Kim Uyen, Tran Nhan Dung and Nguyen Van Hoa, 2018. Primary results of the establishment of phylogenetic tree *Colletotrichum* spp. causing anthracnose disease in the Southern provinces. *Journal of Vietnamese Agricultural Science and Technology* 1 (86): 68-72
- Le Thi Tuong, Dang Thi Kim Uyen, Nguyen Thanh Hieu and Nguyen Van Hoa, 2018. Study on the antagonism of actinomycetes to causing anthracnose and canker disease on dragon fruit in vitro. *Journal of Vietnamese Agricultural Science and Technology* 1 (86): 78-82.
- Technical bulletin: Manual of insect and disease identification and their management on dragon fruit crop
- Technical bulletin: Manual of insect and disease identification and their management on longan crop
- Technical bulletin: Manual of insect and disease identification and their management on mango crop.



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

**PI:** George Norton, Virginia Tech

**Location:** Nepal, Bangladesh, and Cambodia.

**Collaborators:** Megan O'Rourke, M.E. Christie, E.G. Rajotte, C. Rosa, S. Miller, N. Rayapati, Y. Mian, S. Hossain, M.S. Nahar, M. Masud, L. Colavito, L. Sah, K. Pradhan, P. Sharma, B. Mahto, Michael Roberts, Seng Kimhian, An Chanratha, Ong Socheath and Soth Sereyboth.

**Description:** Implementation of IPM for tomato, Chinese kale, cucumber, long bean, and cabbage in Cambodia, for tomato, onion, chili, bitter melon, French beans, and okra in Nepal, and for tomato, eggplant, cabbage, bitter melon, cauliflower, country bean, and mango in Bangladesh.

### **Achievements:**

Cambodia: Field trials on yard long bean were conducted with 24 cooperating farmers. Cultural practices including liming, raised beds, mulching, trellising, drip irrigation, and fertilizer application were standardized. The IPM package components include bio-agents, *Bacillus thuringiensis*, *Bacillus subtilis*, *Beauveria bassiana*, and *Trichoderma* sp., orange oil, yellow sticky traps, and pheromone traps for *Maruca vitrata*. At Royal University of Agriculture, trials on bio-efficacy of *Trichoderma* spp. for controlling damping off on tomato and evaluation of rootstocks resistant to bacterial wilt on grafting tomato and eggplant were conducted. A joint trial with conservation agriculture on IPM Package for yard long bean was conducted at the CE SAIN technology park.

Bangladesh: Field trials were conducted on assessment of the performance of Bt and non-Bt eggplant under an IPM package, mango leafhopper and fruit fly management, and management of white mold of country bean. Bt eggplant recorded 90.3% reduction in fruit damage.

Nepal: Activities include testing lures for control of fruit fly on cucumber and bitter melon, IPM packages for chili, onion and French bean, and management of *Tuta absoluta*. Local companies Nawa Sambriddhi and Karma and Sons are selling *Tuta* lures in Nepal.

**Capacity building:** Over 1,231 farmers adopted IPM packages and various individual components. 42,000 *Tuta* lures were sold and the IPM IL-facilitated supply chain reached an estimated 22,000 households. Two MS and five PhD students are supported by this project.

**Lessons learned:** It was a challenge to keep the control completely free from bio- or chemical pesticides as farmers do not want to lose part of their crop. Demand for *Tuta* lures is increasing. It is possible to eliminate chemical sprays for eggplant fruit and shoot borer when planting Bt eggplant. IPM protocols developed in Nepal for control of *T. absoluta* have proven effective in managing this pest.

### **Publications/Presentations:**

- Sah, L. P., M. Devkota, L. A. Colavito, Y. Dhakal, Shiva Yendyo, Dilli Ram Sharma, Yubak Dhoj G. C., George Norton, Edwin George Rajotte, R. Muniappan and Sulav Paudel 2017. Tomato leafminer,

*Tuta absoluta*, and its management in Nepal. Presentation at ESA's 65th Annual Meeting, November 5-8, Denver, Colorado.

- Sah, L. P., M. Devkota, L. A. Colavito, Kiran Bhusal, George Norton, Edwin George Rajotte, R. Muniappan 2018. Designing IPM approaches for management of Tomato leafminer, *Tuta absoluta* and its management in Nepal. Presentation at 9th International IPM Conference, March 18-22, 2018, Baltimore, Maryland.
- Sah, L.P. M. Devkota, K. Bhusal, L.A. Colavito, G. Norton, E.G. Rajotte, and R. Muniappan, Evaluations of management options against South American tomato leafminer, *Tuta absoluta* in Nepal. Oral Presentation at 1st International Conference on Biological Controls, September 27-29, 2018, Bengaluru, Karnataka, India
- Devkota, M, Sah, L.P. and L. Colavito. 2017. Designing IPM solutions for vegetable pests and management of *Tuta absoluta* in Nepal, presentation at 11th National Organic Fair organized at Rupandehi Butwal, February 15 to 19, 2018.
- Seng, Kim Hian and Megan O'Rourke, IPM Cucumber Package in Cambodia, Presentation at ESA's 65th Annual Meeting, November 5-8, Denver, Colorado.
- Seng, Kim Hian, Lessons learnt from IPM trials, presented at the dissemination workshop on the Prakas of BCAs, jointly organized by the government & GIZ, December, 2017, Phenom Penh, Cambodia.
- Seng Kim Hian, IPM package for high value vegetable crops in Cambodia, Presentation at the International Congress of Plant Pathology Annual Meeting, July 28 to August 03, 2018, Boston, Massachusetts.
- Norton, George W., Why IPM Makes a Difference, Plenary presentation at 9th International IPM Conference, March 18-22, 2018, Baltimore, Maryland.
- Naidu, R.A., Sah, L., Hossain, S., Seng, K.H., and Fayad, A. 2018. Managing virus diseases in vegetable and legume crops in Bangladesh, Cambodia, and Nepal. The 9th International IPM Symposium, March 19-22, 2018, Baltimore, Maryland.
- Hossain, Shahadath, Development of bio-rational based management approach against mango hopper, *Idioscopus nagpurensis (pruthi)*, First International Conference on Biological Control Approaches and Applications, September 27-29, 2018, Bengaluru, India.
- Rahman, Sadique, (2018) Returns to Investment in Developing IPM Research and Efficiency of Vegetable Growers in Selected Areas of Bangladesh, PhD dissertation, Bangladesh Agricultural University, March.
- Rahman, S., G.W. Norton, and M.H-A. Rashid, (2018). Economic Impacts of Integrated Pest Management Technology Adoption on Vegetables Production in Bangladesh, *Crop Protection*, 113: 6-14.
- Goffar, M.A. Rahman, M.A., Hanson, P., Acedo, A.L., Easdown, W., Hughes, J.A. and Keatinge, J.D.H. (2017). Evaluation of AVRDC tomato advanced lines for high yield, multiple disease resistance and long shelf life in Bangladesh. *Acta Hort.* (ISHS) 1179:311-316.
- Goffar, M.A. Rahman, M.A., Hanson, P., Acedo, A.L., Easdown, W., Hughes, J.A. and Keatinge, J.D.H. (2017). Evaluation of AVRDC tomato advanced lines for processing and fresh marketing in Bangladesh. *Acta Hort.* (ISHS) 1179:299-304.

- Hossain, MS, MY Mian, R. Muniappan and GMA Halim. 2017. Tuta leafminer in Bangladesh: Meeting the Challenge. IPM IL, Bangladesh site, Horticulture Research Center, Bangladesh Agricultural Research Institute, Gazipur-1701. 17 pp. (in press).
- Bhandari., A. L.P. Sah, Y.D. GC., M. Devkota, L.A. Colavito., B. P. Rajbandari, G. Norton., S. Miller and R. Muniappan. (2018). Evaluation of carbon sources for anaerobic soil disinfestation (ASD) in tomato production in Lalitpur Districts. *Nepalese Journal of Agricultural Sciences*, 16: 122-128.
- Singh., A., L.P. Sah, Y.D. GC, M. Devkota, L.A. Colavito., B. P. Rajbandari, G. Norton., E.G. Rajjotte and R. Muniappan. (2018). Evaluations of pest exclusions net to major insect pests of tomato in Kavre and Lalitpur. *Nepalese Journal of Agricultural Sciences*, 16: 135-144.

### 3. Assessment of Invasive Species distribution in Chitwan-Annapurna Landscape (CHAL) Region, Nepal with the Application of Satellite Imageries

**PI:** Pramod Jha, Tribhuvan University, Nepal.

**Co-PI:** Madhav Marathe, Biocomplexity Institute, University of Virginia.

**Location:** Nepal.

**Collaborators:** Abhijin Adiga, S. Venkataramanan, Krishna Poudel, Bharat Shrestha, M. Siwakoti

**Description:** Invasion of alien species has been increasing at an alarming rate. A few them threaten the structure and functions in the tropical and temperate ecosystems of Nepal. The negative impacts of these invasive species have been exacerbated by climate change. The resultant increase in temperature due to climate change aiding the spread of invasive species to higher altitudes. To assess this relationship, we are studying the spread of the invasive species *Chormolaena odorata*, *Ageratina adenophora*, *Lantana camara*, *parthenium hysterphorus*, *Mikania micrantha* and *Eichhornia crassipes* in the Chitwan-Annapurna landscape for the past 30 years by comparing their spread, especially upwards in altitude, since 1988 by identifying them in the remote sensing maps produced by satellites. Machine learning will be employed to identify their spread and correlate with the climate change.

**Achievements:**

An earlier project on Climate Change and Biodiversity awarded to the City University of New York was terminated in September 2017. The current project is an extension of the earlier one with some modifications, and began in May 2018.

Field trips were made to identify patches of plant species of interest at Chitwan, Tanahu, and Kaski districts ranging in elevation from 150 m to 1700 m. Satellite images of these areas and also Aster images of these sites have been procured since 1988. Five MS and five PhD students have been trained in GIS and remote sensing.

**Capacity building:** Five MS and five PhD students are supported by this project.

**Lessons learned:** Invasive species are damaging the ecosystem in Nepal. Climate change is exacerbating the situation.

**Publications/Presentations:**

- Three presentations were made at International Conference on Biological Conference (ICBC 2018) at Bengaluru, India (September 27-29, 2018) including Invasive plant species in Nepal by P K Jha, Impact of *Zygodrama bicolorata* on growth of *Parthenium hysterophorus* in Nepal by Seerjana Maharjan, and Functional traits variation of an invasive weed *Ageratina adenophora* (Asteraceae) along an altitudinal gradient in Chitwan Annapurna Landscape Nepal by Anju Sharma Poudel.
- Giri H N, Sharma M D, Thapa R B, Pande K R and Khatri B B. 2018. Growth yield and post harvest quality of late season cauliflower grown at two ecological zones of Nepal. *Journal of Agriculture and Forestry University (Nepal)*, 2:119-126.
- Bhandari G S, Thapa R B, Giri Y P and Manandhar H K. 2018. Effect of planting dates of maize on the incidence of borer complex in Chitwan, Nepal. *Journal of Agriculture and Forestry University (Nepal)*, 2:107-118.
- Poudel A S, Jha P K, R. Muniappan and Shrestha B B. Biology and management of invasive weed *Ageratina adenophora* (Asteraceae): Current state of knowledge and prospect for future research. *Weed Research*.
- Maharjan S, Shrestha B B, Devkota A, R. Muniappan and Jha P K. Temporal and spatial pattern of research on globally significant invasive weed *Parthenium hysterophorus*: A bibliographic review. *Journal of Crop Protection*.
- Luitel D R, Siwakoti M and Jha P K. Perception versus trends of different indicators under climate change in central Nepal. *Journal of Mountain Science*.

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

**PI:** Buyung Hadi, IRRI

**Location:** Cambodia

**Collaborators:** General Directorate of Agriculture, CARDI, CEDAC, Nagoya University, Virginia Tech

**Description:** Development and implementation of IPM for rice crop in Cambodia.

**Achievements:**

Introduction of the variety CAR14 was effective in reducing the incidence of leaf and neck blast disease. Application of *Beauveria bassiana* reduced damage caused by grasshoppers, leaf feeder and hispa beetle. Laser leveling, use of quality seeds, mechanized direct row seeding with low seed rate, one pre- and one post-emergent herbicide application, significantly reduced weed density. Both community trap barrier system and linear trap barrier system were effective in controlling rat damage in the fields. Rodent and disease management trials were set up at the CE SAIN technological park in Battambang.

**Capacity building:** In collaboration with CARDI, GDA, and PDAFF, several training events were conducted. One Post-Doc, two PhD and five MS candidates are supported by this project.

**Lessons learned:** Trap barrier system, optimized herbicide application, and use of *Trichoderma* and *Beauveria* are effective in controlling insect and rodent pests, diseases and weeds. Availability of IPM options such as *Trichoderma*, resistant varieties, and others, locally enhances adoption by farmers.

**Publications/Presentations:**

- Hadi, BAR, Vegetable based ecological engineering: Participatory development of a conservational biological control method for Asian rice landscape. Presentation at 2017 annual meeting of Entomological Society of America. November 8, 2017.
- Hadi BAR , Flor R , Stuart A , Kumar V , Castilla N , Khay S , Cheythirith C. EPIC: Developing Ecologically-Based Participatory IPM Package for Rice in Cambodia. Presentation at the International Sustainable Agriculture and Nutrition Conference, Royal University of Agriculture, Phnom Penh, Cambodia. January 10 2018.
- Flor, R., Then, R. Hadi, BAR. Can Adaptive Research approach facilitate innovation process for Integrated Pest Management in Cambodia? Presentation at the International Sustainable Agriculture and Nutrition Conference, Royal University of Agriculture, Phnom Penh, Cambodia. January 10 2018.
- Flor, R. Innovation systems and technological lock-in for Integrated Pest Management. Seminar given at the Knowledge, Technology and Innovation Seminar Series, Wageningen University, Wageningen, Netherlands. November 28 2017. <https://www.wur.nl/en/activity/Rica-Joy-Flor-Innovation-systems-and-technological-lock-in-for-Integrated-Pest-Management.htm>
- Pisey S, Stuart A, Hadi BAR, Furey N. Activity of Insectivorous Bats Over Rice Fields Surrounding Free-Range Bat Guano Farms in Cambodia Poster presentation at the International Sustainable Agriculture and Nutrition Conference, Royal University of Agriculture, Phnom Penh, Cambodia. January 10 2018.
- Flor R.J., Chhay, K., Sorn, V., Maat, H., and Hadi, B.A.R. 2018. The technological trajectory of Integrated Pest Management for rice in Cambodia. *Sustainability* 10: 1732; DOI: <https://dx.doi.org/10.3390/su10061732> (peer-reviewed).

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

**PI:** Abhijin Adiga, Biocomplexity Institute, University of Virginia.

**Locations:** Nepal, Bangladesh, India, Senegal, France.

**Description:** Model the spread of *Tuta absoluta* around the world and determine the identity of groundnut leafminer.

**Collaborators:** Young Yun Chung Baek, Madhav Marathe, Joseph McNitt, Henning Mortveit, Stephan Eubank, Madhurima Nath, S. Venkataramanan, Achla Marathe, Thierry Brevault, Anais Chailleux, Nicolas Desneux and Mateus Ribeiro de Campos

**Achievements:**

*Tuta absoluta*: A network based propagation model to study the spread of invasive species has been developed. It has been applied to study the possible spread of *T. absoluta* the Southeast Asia region comprising Bangladesh, Myanmar, Laos, Cambodia, Thailand, Malaysia, Indonesia and the Philippines. The model predicts a faster southward spread from Bangladesh, Myanmar, Thailand, Malaysia and Singapore than eastward due to higher trade activity. Country specific analysis shows that once introduced to a major production area, the pest will spread all over Nepal within two to three years.

By analyzing the international trade networks corresponding to four solanaceous crops using the FAO trade database and Moore-Shannon network reliability, a novel approach to identify important dynamics-induced clusters of highly-connected nodes in a directed weighted network was prepared.

From the datasets collected in Senegal and India, physiologically-based demographic models are integrated with multipathway models.

A Memorandum of Understanding with USDA-APHIS was finalized to access PestID to start the assessment on the threat of *T. absoluta* to North America.

Groundnut leafminer: The project was started to model the spread of the invasive species *Aproaerema modicella*. However, early on in the project, we came to know that there is discrepancy in the identity of the groundnut leafminer. *Aproaerema modicella* is known to occur in Asia and it was first reported from Uganda in 1998, Mozambique in 1999, Malawi in 2000 and South Africa in 2000. Buthelezi and his associates carried out molecular analysis of the groundnut leafminer specimens collected in South Africa and confirmed them to be *Aproaerema simplexella*, a species reported from Australia. Currently we are collecting specimens from Eastern and Southern Africa, Asia and Australia to determine the correct identity of groundnut leaf miner in Africa, Asia and Australia.

**Capacity Building:** Three MS students, two PhD students, and two postdocs are supported by this project.

**Lessons learned:** We need to determine the correct identity and distribution of the groundnut leafminer before we could develop a model for its spread.

**Publications/Presentations:**

- M. Nath, S. Venkatramanan, B. Kaperick, S. Eubank, M. Marathe, A. Marathe, A. Adiga (2018), Using Network Reliability to Understand International Food Trade Dynamics, Complex Network 2018 (Conference proceedings).
- Diatte M, Brévault T, Sylla S, Tendeng E, Sall-Sy D, Diarra K (2018) Arthropod pest complex and associated damage in field-grown tomato in Senegal. *International Journal of Tropical Insect Science*, 38, 243-253.
- Sylla S, Seydi O, Diarra K, Brévault T (2018) Seasonal decline of the tomato leafminer, *Tuta absoluta*, in the shifting landscape of a vegetable-growing area. *Entomologia Experimentalis et Applicata* (doi 10.1111/eea.12722).
- Mansour R, Brévault T, Chailleux A, Cherif A,..., Desneux N, Biondi A (2018) Current knowledge of biology, fortuitous natural enemies and management of the South American tomato pinworm in Africa and future priorities for its sustainable control. *Entomologia Generalis* (in press).



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

**PI:** Wondi Mersie, Virginia State University

**Locations:** Ethiopia, Kenya, South Africa, and Uganda.

**Collaborators:** Tesfaye Amare, Fula Gelana, Kassahun Zewdie, Lisanework Nigatu, Ferdu Azerefegne, Muo Kasina, Lorraine Strathie, Richard Malo, Lidya Alemayhu, M.E. Christie, and Daniel Sumner.

**Description:** Biological control of the invasive weed, *Parthenium hysterophorus* in Ethiopia, Kenya, and Uganda using natural enemies.

### **Achievements:**

Two biocontrol agents approved for release by the Ethiopian Government 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, *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) and the stem-boring weevil, *Listronotus setosipennis* (Coleoptera: Curculionidae). The mass rearing at the three sites have been improved immensely in 2018 as compared to the previous years. Staff are now more trained and skilled in rearing bioagents. Agents reared at Wollenchiti are being released throughout Ethiopia. In FY 2018, a total of 7,900 *L. setosipennis* adults and 25,200 *Z. bicolorata* adults were released throughout Ethiopia.

A field experiment has been laid to determine the rate of *Z. bicolorata* dispersal from the release site. Permanent quadrats have been established in four different directions at different intervals from the release spot to monitor the rate of spread.

In Kenya, the government is yet to issue a permit to introduce the agent, *Z. bicolorata*.

South African scientists are providing technical advice on biocontrol of *Parthenium* to the project, assisting in training personnel from Ethiopia, Kenya and Uganda, and providing supplementary cultures of the approved biocontrol agents.

In February 2018, Ugandan scientists Richard Molo and James Ogwang visited South Africa, underwent training on rearing of biocontrol agents and returned with cultures of *Z. bicolorata* and *L. setosipennis*. In May 2018, the Ugandan government accepted results of host specificity trials conducted in Ethiopia and issued permits to field release both the agents. A total of 500 *Z. bicolorata* and 398 *L. setosipennis* have been released at Jinja district. Both the agents are reared in the screen houses for additional field releases.

**Capacity building:** Ms. Strathie and Dr. Mersie constantly communicated with the personnel in the field and provided periodic training. Personnel were given opportunities to attend international meetings and present findings of the project.

**Lessons learned:** Producing high quality *Parthenium* stock plants in pots remains critical to producing a large number of *Z. bicolorata* and *L. sitosipennis*. Removal and trampling of *Parthenium* plants in field release sites is a recurring problem.

### **Publications/Presentations:**

- Mersie, W., Alemayehu, L., Strathie, L., McConnachie, A., Terefe, S. and Negeri, M. 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. Submitted to *Biocontrol, Science and Technology* in 2018.
- Dhileepan, K., McFadyen, R., Strathie, L. and Khan, N. 7. Biological Control. In: Editors S. Adkins. K. Dhileepan, A. Shabbir. *Parthenium Weed: Biology, Ecology and Management*. CABI Invasives Series. *In press*.
  - Strathie, L.W. and McConnachie, A.J. 14. History and Management – Southern Africa and Western Indian Ocean Islands. In: Editors S. Adkins. K. Dhileepan, A. Shabbir. *Parthenium Weed: Biology, Ecology and Management*. CABI Invasives Series. *In press*.
  - Alemayehu, Lidya and Mersie, W. 2018. Host specificity of the stem-boring weevil, *Listronotus setosipennis* (Hustache). Poster - Session 2-p6. XV International Symposium on Biological Control of Weeds. August 26-31, 2018. Engelberg, Switzerland.
  - Christie, M., Sumner, D., Alemayhu, L., Amare, T., and Mersie, W. 2018. Gender, household decision-making and invasive pest management in a rural Ethiopian community. Annual Meeting of the American Association of Geographers. April 12, 2018, New Orleans, USA.
  - Cowie, B., Venter, N., Strathie, L., Goodall, J., Witkowski, E. and Byrne, M. 2018. New insights and prospects into *Parthenium hysterophorus* biocontrol from South Africa. Poster - Session 2-p6. XV International Symposium on Biological Control of Weeds. August 26-31, 2018. Engelberg, Switzerland.
  - 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. 1<sup>st</sup> 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. 1<sup>st</sup> 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: 1<sup>st</sup> 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. 1<sup>st</sup> International Conference on Biological Control. Approaches and Applications. p. 204. Bengaluru, India. September 27-29, 2018.
  - Strathie, L., Den Breeyen, A., Sambo, S., Chidawanyika, F., Goodall, J, Gareeb, M. and Magoso, X. Evaluating establishment and impact of four biological control agents on *Parthenium hysterophorus* in South Africa. Poster - Session 9-P24. XV International Symposium on Biological Control of Weeds. August 26-31, 2018. Engelberg, Switzerland
  - 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. 180 participants attended.

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

**PI:** Tadele Tefera, icipe

**Location:** Ethiopia, Kenya, and Tanzania.

**Description:** Development of IPM packages for chickpea in Ethiopia, rice in Tanzania and for maize in Ethiopia, Kenya and Tanzania.

### **Achievements:**

Over 700 farmers demonstrated on farm push-pull technology in Hawassa area. Farmers benefitted from reduction in stem borer and fall armyworm damage, increased milk yield, and improved soil fertility.

Out of eleven botanicals screened against FAW, *Azadiracta indica*, *Schinus molle*, and *Phytolacca dodecandra* produced high larval mortality 72 hrs after treatment. Egg parasitoids, *Trichogramma* sp. and *Telenomus* sp. and larval parasitoids, *Cotesia icipe*, *Palexorist zonata*, *Coccygidium luteum*, and *Charops ater* were collected from eggs and larvae of FAW collected in maize fields in Kenya.

In Tanzania, rice stem borer was parasitized by *Cotesia flavipes*. Rice varieties TXD 306 (SARO 5) and Komboka were tolerant to rice blast, late bacterial blight, and rice yellow mottle virus diseases.

About 21,211 women and 30,566 men farmers are aware of rice, maize, and chickpea IPM in the three countries. About 410 women and 1,237 men are directly involved in demonstrating IPM. Women demonstrated IPM on 69 hectares of land and men on 111 hectares. About 74 women groups are involved in demonstrating IPM technologies.

**Capacity building:** Four PhD and three MS students were supported by this project. Disciplines involved were Agricultural Entomology, Agricultural Economics, Plant Pathology, Applied Microbiology, and Crop Protection.

**Lessons learned:** Push-pull technique is popular with farmers because of multiple benefits derived from it. Farmers' field days are better methods to disseminate information. Women have little decision making roles on matters pertaining to maize production. Women should be empowered through trainings to participate in all activities of maize production. Rice blast infected crop residue may be contributing to the transmission of this disease from one season to the next.

### **Publications/Presentations:**

- Fite, T., Tefera, T., Negeri, M., Damte, T. and Sori, W. (2018) Management of *Helicoverpa armigera* (Lepidoptera: Noctuidae) by Nutritional Indices and Botanical Extracts of *Millettia ferruginea* and *Azadirachta indica*. *Advances in Entomology*, 6, 235-255. <https://doi.org/10.4236/ae.2018.64019>.
- Ibrahim Hashim, Delphina Mamiro, Robert B. Mabagala and Tadele Tefera. 2018. In vitro and in vivo Evaluation of Microbial Agents for Management of Rice Blast Disease in Tanzania. *World Journal of Agricultural Sciences* 14 (4): 108-117, 2018.
- Bonaventure January, Gratian M. Rwegasira<sup>1</sup> and Tadele Tefera. Efficacy of Selected Biopesticides and Botanical Extracts in Managing Rice Stem Borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) in Tanzania. *Journal of Agriculture and Ecology Research International*, Vol.: 15 (4): 1-16, 2018.

- Kimani Anne, Tadele Tefera, Olubayo Florence & Kilalo Dora. 2018. Effect of Sealing Method and Lighting Candle in Metal Silos on Survival of the Larger Grain Borer, *Prostephanus Truncatus*, in Stored Maize. *Journal of Agricultural Science*; Vol. 10 (8), 90-98, 2018
- Sisay, B. et al. 2018. First report of the fall armyworm natural enemies from Africa. *Journal of Applied Entomology*. 142:800–804,2018
- Kumela, T., J. Simiyu, B. Sisay, P. Likhayo, E. Mendesil, L. Gohole, and T. Tefera. (2018). Farmers' knowledge, perceptions, and management practices of the new invasive pest fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya. *International Journal of Pest Management*. DOI: 10.1080/09670874.2017.1423129.
- January, B; Rwegasira, G. M and Tefera, T (2018). Distribution of rice stem borers and their parasitoid in irrigated low land rice ecosystem in Kilombero valley, Morogoro, Tanzania. *J. Entomology and Zool. Studies* 6(2): 237-242, 2018.
- January, B; Rwegasira, G. M and Tefera, T (2018). Farmers' Perceptions of Rice Production Constraints and Stem Borers Management Practices in Tanzania. *J. Agric. Science*, Vol.10 (6):57-71, 2018.
- January, B; Rwegasira, G. M and Tefera, T (2018). Lepidopteran Stem Borer Species Abundance and Associated Damages on Irrigated Kilombero Low Land Rice Ecosystem in Tanzania. *J. of Entomology*, Vol. 15 (1), 28-35, 2018.
- Hashim, Ibrahim; Mamiro, Delphina, B. Mabagala, Robert; Tefera, T. (2018). Smallholder farmers' knowledge, perception and management of rice blast disease in upland rice production in Tanzania. *Journal of Agricultural Science*, Vol 10, (7), 137-145, 2018. DOI: <https://doi.org/10.5539/jas.v10n7p137>
- Hashim, Ibrahim; Mamiro, Delphina, B. Mabagala, Robert; Tefera, T. (2018). Reduction of initial inocula of rice blast disease on rice seeds by microbial and hot water seed treatments. *Australian Journal of Crop Science*.
- Tadesse, Desalegne and Tefera, Tadele. Proceedings of the Annual Review Meeting of Rice, Maize and Chickpea IPM for East Africa Project, Nairobi, Kenya 24-27, 2018.
- Tadesse, D. 2018. Rice, Maize and Chickpea IPM for East Africa project: Banners ([Push-Pull in Ethiopia: The Driving Force for the livelihoods changes of smallholder farmers](#)), posters and leaflets
- Tadesse, D and Kumela, T. 2018. Rice, Maize and Chickpea IPM for East Africa project: Manual titled "Push-Pull Technology manual for farmers and extension workers (March 2018)".
- Tefera, T. 2018. Rice, maize and chickpea project highlights, Trichoderma management training workshop, 21 September 2018, Addis Ababa, Ethiopia.
- Tefera, T. 2018. Progress report on rice, maize and chickpea project presented on the annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Kassie, Menale 2018. Baseline survey results, Tanzania presented on the annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Muniappan, R. 2018. IPM Innovation Lab - An Overview presented on the annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Muniappan, R. 2018. *Trichogramma* and *telenomus* for management of Fall Armyworm and

other Lepidopteran pests in East Africa, presented on annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.

- Kassie, Menale 2018. Gender and grain IPM project in number, annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Kassie, Menale 2018. The push-pull farming system in Kenya and Ethiopia: Implications for economic and social welfare, annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Likhayo, P. 2018. Promotion of Push - Pull Technology for the control of stem borers in Kericho and Nakuru counties in Kenya, annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Elibariki, S. 2018. Maize stem borers and striga management in Tanzania using Push-Pull technology presented in annual review and planning meeting, 24-27 July 2018, Nairobi, Kenya.
- Zewdie, A. 2018. On-farm verification and demonstration of integrated wilt/ root rot and pod borer management method on chickpea in East Shewa Zone, annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Sisay, Birhanu. 2018. Evaluation of Different Management Options of Fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) and Assessment of Their Parasitoids Enemies in Some Parts of Ethiopia, annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Sisay, Birhanu. 2018. Management of Maize Stem borers using Push- Pull technology in Hawassa, Ethiopia, annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Hashim, Ibrahim. 2018. Rice blast disease (*Pyricularia oryzae* Cav.) incidence, severity, genotype reaction and management in Tanzania, annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Chuwa, C. 2018. Screening and disseminating tolerant rice varieties to rice yellow mottle virus (RYMV), rice blast, and bacterial late blight (BLB) diseases in Mvomero district, Morogoro region. Progress report presented in annual review and planning meeting, 24-27 July 2018.
- Simiyu, Josephine N. 2018. Distribution, Damage and Preliminary Biology of the Fall Armyworm in Kenya, annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Boniventure J. 2018. Management options for rice stem borers in irrigated low land rice ecosystem in Tanzania, annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya
- Getaneh, Gezahegn. 2018. Integrated Chickpea diseases management for Fusarium wilt and Ascochyta blight, annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya
- Korir, Josphat. 2018. Potential Demand for IPM Technologies and Practices in East Africa, annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Kebede, Denberu. 2018. Pathogenecity of Maize endophytes and selected EPF isolates against the spotted stem borer *Chilo partellus*, presented on annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Fite, Tarekegn. 2018. Management of Chickpea Pod Borer in Ethiopia, presented on annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Diro, Debela. 2018. Integrated Termite Management in maize in Western Ethiopia, presented on annual planning and review meeting, 24-27 July 2018, Nairobi, Kenya.
- Tadesse, Desalegne. 2018. IPM Approach for Communications. Progress report presented on annual review and planning meeting. Hawassa, July 24-27, 2018.

## 8. Integrated Pest Management for Vegetables in East Africa

**PI:** Luis Canas, Ohio State University

**Location:** Ethiopia, Kenya and Tanzania

**Collaborators:** Amon Maerere, Sokoine University of Agriculture, and Peter Sseruwagi, Mikocheni Agricultural Research Institute, Tanzania; Jesca Mbaka, KALRO, Stephen New, KAVES, Henry Wainwright, Real IPM, and Danny Coyne, IITA, Kenya; Ferdu Azerrefegne, Hawassa University, Ethiopia.

**Description:** Development and implementation of IPM packages for vegetable crops in Ethiopia, Kenya, and Tanzania.

**Achievements:** In Tanzania, onion varieties Jambar and Russet yielded more than other five varieties tested, however, they were more susceptible to thrips and purple blotch disease. A farmers' field day was conducted at Msufini village which was attended by a total of 180 farmers. Training workshops on vegetable viral diseases and insect vectors were conducted at Morogoro, Mvomero, Iringa, Ilula, and Kilolo. WhatsApp IPM diagnosis groups have been formed in Morogoro and Iringa. In Kenya, entomopathogenic nematodes are being tested against *Tuta absoluta*. *Trichoderma harzianum* treatment reduced the incidence of bacterial wilt in tomato plots. In another experiment, *Trichoderma* sp. treatment reduced incidence of root knot nematodes in tomato plants. At the Hawassa University in Ethiopia a workshop was conducted on diagnostics and management of key pests of vegetable crops. Another workshop was conducted on management of nematodes in vegetable crops. Pesticides indoxacarb, emamectin benzoate, and chlorantraniliprole proved effective in controlling *T. absoluta*.

**Capacity building:** Two PhD, five MS and three undergraduate students are supported by this project. Several field days and workshops were conducted.

**Lessons learned:** Better coordination within the project is needed.

## VI. Buy-in

[Fall Armyworm Risk Assessment for Egypt](#): A fall armyworm risk assessment report was prepared and submitted to the USAID Mission in Egypt.



## VII. 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					
Country of Training	Brief Purpose of Training	Who was Trained	Number Trained		
			M	F	Total
Cambodia	Guest lecture by Ed Rajotte, Penn State	Students at Royal Agricultural University	9	8	17
Cambodia	Research (IPM trials) to fulfill requirement for a B.S. degree	Undergraduate students	5	7	12
Cambodia	Field day: yard long bean IPM package	Vegetable producers	29	71	100
Cambodia	Field day: cucumber IPM package	Vegetable producers	46	38	84
Cambodia	IPM practice training in collaboration with Horticulture Innovation Lab	Vegetable producers members of Tasey Agriculture Cooperative	24	10	34
Bangladesh	Farmers' Field Day on Production of Bt and Non-Bt eggplant under IPM package	Farmers	77	23	100
Bangladesh	Farmers' Field Day on Management of Mango hopper through spraying biopesticide, <i>Beauveria bassiana</i>	Farmers	52	48	100
Bangladesh	Farmers training on Production of Mango through IPM Technology	Farmers	9	41	50
Bangladesh	Farmers' Field Day on Management of Mango fruitfly through Fruit Bagging	Farmers	78	22	100
Bangladesh	Farmers training on Production of Mango through IPM Technology	Farmers	36	14	50
Bangladesh	Farmers' Field Day on Management of Mango fruitfly through Fruit Bagging	Farmers	85	15	100
Bangladesh	Farmers training on Production of Mango through IPM Technology	Farmers	40	10	50
Bangladesh	Farmers' Field Day on Management of Mango fruitfly through Fruit Bagging	Farmers	52	48	100
Bangladesh	Farmers training on Production of Mango through IPM Technology	Farmers	48	2	50
Bangladesh	Farmers training on Production of Mango through IPM Technology	Farmers	48	2	50
India	Attend International Conference on Biological control	Scientist	1	0	1
Nepal	IPM trials undergraduate theses at HICAST	undergrads	0	4	4

Nepal	IPM training in School by iDE and ANUKULAN	High school students	23	36	59
Nepal	Training of staff of LIBRD project on Tuta absoluta	Technical staff	7	4	11
Nepal	15 farmer field days/demonstrations on IPM practices	Farmers	44	150	194
Nepal	Tuta management for NGOs, private sector and government	NGOs, private sector and government	30	20	50
Nepal	IPM package demonstrations jointly with other projects such as KISAN II, PAHAL, ENBAITA, SUAHARRA II	Farmers	500	1020	1520

<b>A High-resolution Interaction Based Approach to Modeling the Spread of Agricultural Invasive Species</b>					
Country of Training	Brief Purpose of Training	Who was Trained	Number Trained		
			M	F	Total
India	<i>T. absoluta</i> workshop in ICBC Bangalore A talk covering importance of multipathway models and our methodologies.	Scientists and students	20	20	40
India	ICAR-IARI, Delhi A talk covering importance of multipathway models and our methodologies.	Scientists and students	20	20	40
France	Biology and Modeling of <i>Tuta absoluta</i>	Students/ Postdocs	3		3

<b>Development of Ecologically-based Participatory Integrated Pest Management (IPM) Package for Rice in Cambodia (EPIC)</b>					
Country of Training	Training Activity	Who was trained	Number Trained		
			M	F	Total
Philippines	Ecological pest management Training (IRRI_HQ)	PDAFF (government) partners and IRRI EPIC staff	0	3	3
Cambodia	Weed Science Lecture and Practical Course	BSc Students of Agronomy from University of Battambang	12	31	43
Cambodia	Training on pesticide safety	Farmers	4	24	28
Cambodia	Pest management and identification	Research and extension (government) staff	7	21	28
Cambodia	Training on pesticide safety	Farmers	5	18	23
Cambodia	Training on pesticide safety	Farmers	11	16	27
Cambodia	Farmer Field visit	Farmers	3	23	26

Cambodia	Farmer field visit	Farmers	30	16	46
Cambodia	Exchange visit for Prey Veng farmers	Farmers	25	0	25
Cambodia	Exchange visit for Takeo farmers	Farmers	25	2	27
Cambodia	Farmer field visit	Farmers	4	14	18
Cambodia	Farmer Field visit	Farmers	1	15	16
Cambodia	Farmer Field visit	Farmers	11	18	29
Cambodia	Farmer Field visit	Farmers	7	23	30
Cambodia	Farmer Field visit	Farmers	11	18	29
Cambodia	Farmer field visit	Farmers	10	21	31
Cambodia	Farmer Field visit	Farmers	3	25	28
Cambodia	Farmer Exchange Visit (Bati to Traing)	Farmers	6	14	20
Cambodia	Farmer Field visit	Farmers	11	8	19
Cambodia	Field Day	Farmers	16	39	55
Cambodia	Field Day	Farmers	20	29	49
Cambodia	Farmer Field visit	Farmers	8	29	37
Cambodia	Field Day	Farmers	23	33	56
Cambodia	Farmer Field visit	Farmers	14	12	26
Cambodia	Farmer Field visit	Farmers	8	19	27
Cambodia	Farmer Field visit	Farmers	4	19	23
Cambodia	Field Day	Farmers	18	27	45
Cambodia	Farmer Field Visit	Farmers	11	16	27
Cambodia	Farmer Field Visit	Farmers	6	13	19
Cambodia	Farmer Field Visit	Farmers	14	15	29
Cambodia	Farmer Field Visit	Farmers	7	20	27
Cambodia	Farmers reflection meeting	Farmers	10	8	18
Cambodia	Farmers reflection meeting	Farmers	7	8	15

Cambodia	Farmers Field Visit	Farmers	17	13	30
Cambodia	Field Day	Farmers	4	40	44
Cambodia	Farmer Exchange Visit (BB to KPT)	Farmers	7	3	10
Cambodia	Farmer reflection meeting	Farmers	4	16	20
Cambodia	Farmer reflection meeting	Farmers	1	16	17
Cambodia	Farmer reflection meeting	Farmers	9	10	19
Cambodia	Farmer reflection meeting	Farmers	3	11	14
Cambodia	Farmer Field Visit	Farmers	29	23	52
Cambodia	Field Visit	Farmers	7	8	15
Cambodia	Field visit	Farmers	6	13	19
Cambodia	Field visit	Farmers	11	14	25
Cambodia	Field visit	Farmers	9	18	27
Cambodia	Field visit	Farmers	9	18	27
Cambodia	Field visit	Farmers	17	23	40
Cambodia	Reflection meeting	Farmers	5	4	9
Cambodia	Field Day	Farmers	11	28	39
Cambodia	Farmer meeting	Farmers	4	18	23
Cambodia	Farmer meeting	Farmers	3	19	22
Cambodia	Field visit	Farmers	1	31	32
Cambodia	Field visit	Farmers	2	23	25
Cambodia	Field visit	Farmers	10	20	30
Cambodia	Reflection meeting	Farmers	14	13	27
Cambodia	Field visit	Farmers	14	16	30
Cambodia	Field visit	Farmers	23	18	41
Cambodia	Field visit	Farmers	1	32	33
Cambodia	Field day and Trade Fair	Farmers	17	78	95

Cambodia	Reflection meeting	Farmers	1	14	24
Cambodia	Field visit and trade fair	Farmers	17	51	68
Cambodia	Reflection meeting	Farmers	0	11	11
Cambodia	Reflection meeting	Farmers	3	6	9

<b>Biological Control of the Invasive Weed <i>Parthenium hysterophorus</i> in East Africa</b>						
Country Training	of	Brief Purpose of Training	Who was Trained	Number Trained		
				M	F	Total
Ethiopia		Training on weed biocontrol	Farmers	56	43	98
Ethiopia		Training on weed biocontrol	Students	46	15	61
South Africa		Experiential training on weed biocontrol (including parthenium)	Students	0	3	3
South Africa		Training on biocontrol of parthenium, biocontrol of other invasive plants and insects	Scientists	1	0	1

<b>Rice, Maize, and Chickpea IPM for East Africa</b>						
Country Training	of	Brief Purpose of Training	Who was Trained	Number Trained		
				M	F	Total
Ethiopia		Training on PPT for new recruited farmers and technology adopters (for experience sharing)	Farmers	616	30	646
Ethiopia		Field day on PPT sites to share experience on PPT farm management	Farmers/ extension agents			
Ethiopia		Push Pull Technology Establishment and management -for Development Agents	Development agents	92	16	108
Ethiopia		Consultative meeting with SNNPR regional, zone and district Higher Officials	Extension agents	7	0	7
Kenya		Train the Trainers	Extension agents/ farmers	5	6	11
Kenya		Train the Trainers	Extension agents/ farmers	4	22	26
Kenya		Farmers training on the onset of Push Pull technique demos	Farmers	17	20	37

Kenya	Consultative meeting	Scientists/ farmers	23	12	35
Kenya	Farmers training on the onset of Push Pull technique demos	Farmers	17	19	36
Kenya	Farmers training on the onset of Push Pull technique demos	Farmers	50	70	120
Kenya	Farmers training on the onset of Push Pull technique demos	Farmers	23	12	35

<b>Integrated Pest Management for Vegetables in East Africa</b>					
<b>Country of Training</b>	<b>Brief Purpose of Training</b>	<b>Who was Trained</b>	<b>Number Trained</b>		
			<b>M</b>	<b>F</b>	<b>Total</b>
Tanzania	Share knowledge about the efficient IPM technologies	Farmers at Mkuyuni and Msufini villages	103	77	180
Tanzania	Training on usefulness of IPM techniques	Farmers at Dibamba and Mvomero	13	10	23
Tanzania	Demonstration of IPM techniques	Farmers at Morogoro	10	0	10
Tanzania	Demonstration of IPM techniques	Farmers at Iringa	21	5	25
Tanzania	Create awareness of tomato viral diseases and IPM	Farmers at Morogoro	44	25	69
Tanzania	Create awareness of tomato viral diseases and IPM	Farmers at Iringa	85	34	119
Tanzania	Create awareness of tomato viral diseases and IPM	Farmers at Morogoro	27	6	33
Tanzania	Create awareness of tomato viral diseases and IPM	Farmers at Iringa	41	7	48
Tanzania	Create awareness of tomato viral diseases and IPM	Farmers at Morogoro	25	3	28
Tanzania	Create awareness of tomato viral diseases and IPM	Farmers at Iringa	45	2	47
Kenya	On farm demonstration of the use of biopesticides for management of nematodes	Farmers from Tharaka- Nithi County, Chuka Sub-County, Mbwiru Mwanjati Village	15	30	45
Kenya	On farm demonstration on tomato IPM Package	Farmers from Tharaka- Nithi County, Chuka Sub-County, Mbwiru Mwanjati Village	19	31	50
Kenya	Adoption of Integrated Pest Management Practices in Chuka, Tharaka Nthi County, Kenya	Chuka, Tharaka Nithi County	27	43	70

Kenya	Real IPM organized workshop to train farmers about vegetable IPM	Meru County	23	8	31
Kenya	Real IPM organized workshop to train farmers about pest and disease identification	Kiambu County	12	12	24
Kenya	Real IPM organized workshop to train farmers about the IPM package for vegetables	Kiambu County	11	39	50
Kenya	Real IPM organized workshop to train farmers about the IPM package for tomato	Homa Bay County	68	12	80
Kenya	Capacity building in plant nematology at Kenyatta University	Kenyatta University	39	31	70
Kenya	Nematology Awareness and Training Day	Interplant Roses East Africa, Naivasha, Kenya	75	15	90
Ethiopia	To train farmers and extension personnel about the use of IPM packages on vegetables	Farmers	30	10	40
Ethiopia	Established contact with the main government office working on horticulture crops	Farmers and extension personnel	91	12	103
Ethiopia	Nematode management training day	Farmers and extension personnel	13	4	17

## b. Long-Term Training

Strengthening Production and Export of Vietnamese Fruit Crops through Innovative and Market-orientated IPM							
Name (first, last)	Gender	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Dang Thi Kim Uyen	F	Can Tho University	PhD	Plant Protection	November 2020	N	Vietnam
Duyen Luong Thi	F	Can Tho University	MS	Plant Protection	August 2019	N	Vietnam
Tuyen Le Ngo Nhu	F	Can Tho University	MS	Agricultural Economics	January 2019	N	Vietnam

Innovative Scientific Research and Technology Transfer to Develop and Implement Integrated Pest Management Strategies for Vegetable and Mango Pests in Asia							
Name (first, last)	Gender	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country



Arjun Khanel	M	Virginia Tech	PhD	Economics	December 2018	N	Nepal
Farhanaz Sharma	F	Virginia Tech	PhD	Economics	May 2020	N	Bangladesh
Kaitlyn Spangler	Female	Virginia Tech	MS	Geography (Gender Studies)	June 2018	Y	USA
Lauren Knaresboro	Female	Virginia Tech	MS	Economics	May 2020	N	USA
Ram Khadka	M	Ohio State University	PhD	Plant Pathology	May 2020	N	Nepal
Sadique Rahman	M	Bangladesh Agriculture University and Virginia Tech	PhD	Economics	March 2018	Y	Bangladesh
Sulav Paudel	M	Pennsylvania State University	PhD	Entomology	May 2020	N	Nepal

<b>Participatory Biodiversity and Climate Change Assessment for Integrated Pest Management in the Annapurna-Chitwan Landscape, Nepal</b>							
Name (first, last)	Gender	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Abhisek Singh	M	Tribhuvan University	MSc	Biodiversity	July 2019	N	Nepal
Anju Sharma	F	Tribhuvan University	PhD	Ecology	September 2019	N	Nepal
Bidya Maya Shrestha	F	Tribhuvan University	MSc	Biodiversity	May 2018	Y	Nepal
Bibeka Nand Mahat	M	Agriculture and Forestry University	MSc	Entomology	July 2018	Y	Nepal
Dol Raj Luitel	M	Tribhuvan University	PhD	Ecology	September 2019	N	Nepal
Ganga Shah	M	Tribhuvan University	MSc	Ecology	December 2017	Y	Nepal
Ghan Shyam Bhandari	M	Agriculture and Forestry University	PhD	Entomology	September 2019	N	Nepal

Himal Yonjon	M	Tribhuvan University	MSc	Ecology	July 2019	N	Nepal
Hom Nath Giri	M	Agriculture and Forestry University	PhD	Horticulture	September 2019	N	Nepal
Madhu Sudhan Ghimire	M	Agriculture and Forestry University	MSc	Plant Pathology	July 2018	Y	Nepal
Pratiksha Sharma	F	Agriculture and Forestry University	MSc	Environment and Conservation	July 2018	Y	Nepal
Pristi Dangol	F	Tribhuvan University	MSc	Ecology	May 2018	Y	Nepal
Ramesh Upreti	M	Agriculture and Forestry University	MSc	Horticulture	July 2018	Y	Nepal
Sagar Khadka	M	Tribhuvan University	MSc	Plant Pathology	December 2017	Y	Nepal
Sandeep Dhakal	M	Tribhuvan University	MSc	Ecology	July 2019	N	Nepal
Sanjeev Bhandari	M	Tribhuvan University	MSc	Biodiversity	December 2018	N	Nepal
Sarita Sapkota	F	Agriculture and Forestry University	MSc	Entomology	July 2018	Y	Nepal
Seerjana Maharjan	F	Tribhuvan University	PhD	Ecology	September 2019	N	Nepal
Srijana Poudel	F	Tribhuvan University	MSc	Ecology	July 2019	N	Nepal
Vishubha Thapa	F	Tribhuvan University	MSc	Ecology	December 2017	Y	Nepal
Yashoda Panthy	F	Agriculture and Forestry University	MSc	Biodiversity	October 2018 2019	Y	Nepal

<b>Development of Ecologically-based Participatory Integrated Pest Management (IPM) Package for Rice in Cambodia (EPIC)</b>							
Name (first, last)	Gender	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Chhun Sokunroth	M	University of Battambang	MS	Agronomy/ Weed Science	December 2018	N	Cambodia
Chou Cheythyrih	M	Nagoya University	PhD	Plant Pathology	July 2019	N	Cambodia
Corey Riedel	M	Virginia Tech	MS	Entomology	September 2018	N	USA
Makaraphakpea Keo	F	Royal University of Agriculture	MSc	Entomology	September 2019	N	Cambodia
Ong Socheath	F	Nagoya University	PhD	Plant Pathology	September 2020	N	Cambodia
Rica Joy Flor	F	IRRI	Postdoc	Agricultural Economics	September 2019	NA	Philippines
Sek Pisey	M	Royal University of Phnom Penh	MS	Conservation Biology	December 2017	N	Cambodia
Sydni Jackson	F	Virginia Tech	MSc	Economics	June 2017	Y	USA

<b>A High-resolution Interaction Based Approach to Modeling the Spread of Agricultural Invasive Species</b>							
Name (first, last)	Gender	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Ahmadou Sow	M	CIRAD-BIOPAS	PhD	Entomology	April 2019	N	Senegal
Bryan Kaperick	M	Virginia Tech	BS	Computation Modeling and Data Analysis	May 2018	Y	USA

Joseph McNitt	M	Virginia Tech	MS	Mathematics	May 2018	Y	USA
Mame Diarra Bousso	F	Université Cheikh Anta Diop (UCAD)	MS	Entomology	January 2018	Y	Senegal
Mateus Ribeiro de Campos	M	INRA	Postdoc	Entomology	January 2019	N	France
Saliou Djiliw	M	Université Cheikh Anta Diop (UCAD)	MS	Entomology	April 2018	Y	Senegal
Serigne Sylla	M	Université Cheikh Anta Diop (UCAD)	PhD	Entomology	April 2018	Y	Senegal
Srinivasan Venkatramanan	M	Virginia Tech	Postdoc	Computer Science		N	USA

<b>Biological Control of the Invasive Weed <i>Parthenium hysterophorus</i> in East Africa</b>							
Name (first, last)	Gender	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Ethel Xolile Magoso	F	Tshwane University of Technology	B Tech	Agriculture (Crop Production)	May 2018	Y	South Africa

<b>Rice, Maize, and Chickpea IPM for East Africa</b>							
Name (first, last)	Gender	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Birhanu Sisay	M	Haramaya University	MS	Crop Protection	December 18	N	Ethiopia
Bonaventure January	M	Sokoine University of Agriculture	PhD	Agricultural entomology	June 2019	N	Tanzania

Denberu Kebede	M	Addis Ababa University	MS	Applied Microbiology	December 18	N	Ethiopia
Gezahegn Getaneh	M	Jimma University	PhD	Plant Pathology	June 2019	N	Ethiopia
Ibrahim Hashim	M	Sokoine University of Agriculture	PhD	Plant Pathology	June 2019	N	Tanzania
Josphat Korir	M	University of Nairobi	PhD	Agricultural Economics	June 2019	N	Kenya
Nana Ameri	F	University of Dar Es Salam	MS	Applied Microbiology	December 18	N	Ethiopia
Tarekegn Fite	M	Ambo University	PhD	Agricultural entomology	June 2019	N	Ethiopia

Integrated Pest Management for Vegetables in East Africa							
Name (first, last)	Gender	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Cecilia Ngugi	F	University of Nairobi	PhD	Entomology	June 2018	Y	Kenya
Denis Nyamu	M	Ohio State University	MS	Entomology	December 2019	N	Kenya
Ester Rehema Matendo	F	SUA	MS	Entomology	December 2017	N	Tanzania
Feyisa Bekele	M	Hawassa University	MS	Weed Science	June 2019	N	Ethiopia
Gaetan Kinahingi	M	SUA	Und.	Plant Protection	2018	Y	Tanzania
Happiness Christopher	F	SUA	MS	Plant Protection	November 2018	N	Tanzania
Hellen Kanyagha	F	Ohio State University	PhD	Plant Pathology	August 2020	N	Tanzania
Joshua Kinene	M	Chuka University	MS	Plant Pathology	December 2018	N	Kenya
Kumsa Dida	M	Hawassa University	MS	Entomology	June 2019	N	Ethiopia

Olaf Michael	F	SUA	Und.	Plant Protection	2017/2018	Y	Tanzania
Peter A. Maerere	M	SUA	MS	Entomology	November 2018	N	Tanzania
Shigela Magembe	F	SUA	Und.	Plant Protection	2018	Y	Tanzania
Tumsifu Samwel	M	SUA	MS	Plant Protection	November 2018	N	Tanzania
Zuwena Msuya	F	Sokoine University of Agriculture	MS	Plant Protection	November 2018	N	Tanzania

## c) Institutional Development

### i) Description:

*Bangladesh:* Bangladesh Agricultural Research Institute Bacteriology section was strengthened by providing PhD degree training to one of its staff members.

*Nepal:* Several students at the Tribhuvan University and Agriculture and Forestry University in Nepal being trained in PhD and MS degree programs. A student from Nepal Agricultural Research Council is being trained at the Ohio State University in Plant Pathology.

*Cambodia:* A candidate from General Directorate of Agriculture and a candidate from Royal University of Agriculture are being trained in PhD degree programs.

*Vietnam:* Two candidates of SOFRI are being trained in MS program.

*Tanzania:* Two candidates from Sokoine University are receiving MS training at the Ohio State University.

### ii) Partners:

Please see list of Program Partners in page 2.

## VIII. Innovation Transfer and Scaling Partnerships

### Plan of Action

#### i) Steps taken:

- Worked with value chain projects, KISAN in Nepal, AVC in Bangladesh, KAVES in Kenya, and NAFKA in Tanzania for dissemination of IPM technologies to farmers.
- Provided training on bio-pesticide scientists, extension agents, NGOs, private companies on production and use of *Trichoderma* spp.
- Participated in national, regional, and international conferences.
- Conducted several field days.

#### ii) Partnerships made:

DAI in Bangladesh; Real IPM and KAVES in Kenya; KISAN in Nepal; NAPAKA and TAHA in Tanzania; and BCRL and Agricare in Nepal.

#### iii) Technologies ready to scale:

- Biological control of fall armyworm, and pearl millet headminer.
- Push-Pull technology for maize stem borer and fall armyworm control.
- Bt eggplant in Bangladesh.
- Control of witches' broom syndrome of longan in Vietnam.
- Control of a fungal disease of dragon fruit in Vietnam.
- Control of fruit flies on mango in Bangladesh and Vietnam.
- Mass production of egg and larval parasitoids in Niger.



- Use of pheromone traps for Fall Armyworm in Ethiopia, Kenya and Tanzania.

iv) Technologies transferred:

1. *Trichoderma* use in Ethiopia, Kenya, and Tanzania.
2. Use of pheromone traps for monitoring and management of *Tuta absoluta* in Nepal, and Bangladesh
3. Use of coconut pith for raising vegetable seedlings in seven countries.

v) Technologies scaled:

- *Trichoderma* use in Nepal, Bangladesh, and Cambodia.
- Use of coconut pith for raising seedlings in Bangladesh and Nepal.
- Field establishment of two natural enemies of the weed, *Parthenium* in Ethiopia.
- Use of nylon nets for protection of vegetable seedlings in the nursery.

## IX. Environmental Management and Mitigation Plan (EMMP)

- PERSUAPs for pesticides to be used in the IPM IL projects have been submitted and approved by the Environmental Officer, BFS, USAID Washington.
- Use of bio-pesticides, neem and pheromone traps by replacing use of chemical pesticides for control *Tuta absoluta* in Nepal.

## X. Open Date Management Plan

The IPM IL had its data management plan (DMP) approved by the AOR and the ME ensures the program is compliant with ADS 579, including data registration and submission. Raw data from individual projects are available from the site coordinators in each country upon request. When mature data becomes available, the PIs and/or the ME will register and submit the data and data reference to the DDL.

## XI. Governance and Management Entity Activity

- Worked closely with AOR and Virginia Tech administration.
- Attended planning meetings of the individual projects.
- Organized a meeting for the Technical Advisory Committee and the Program Coordinating Committee in Cambodia in May 2018.
- Attended the Feed the Future Partners Meeting in Uganda in May 2018.
- Attended the Innovations Lab Council Meeting in Washington DC in September 2018.
- Encouraged host country scientists to participate in national, regional and international conferences.
- Prepared several success stories and released them through different media.
- Actively promoted publications.
- Reviewed workplans, semi-annual and annual reports submitted by the PIs through conference calls and written communications.

## XII. Other Topics

### Sub-award from Sorghum and Millet Innovation Lab: Biological Control of Pearl Millet Headminer in Niger and Senegal.

**Principal Investigator:** Malick Ba, ICRISAT, Niger

**Location:** Niger and Senegal.

**Description:** Mass multiplication of parasitoids and field releasing them for control of pearl millet headminer in Niger and Senegal.

**Collaborators:** Ibrahim Baoua, INRAN, Niger; Ibrahim Sarr, ISRA, Senegal; R. Muniappan, IPM Innovation Lab; and George Norton, Virginia Tech.

**Updates:** An egg parasitoid, *Trichogrammatoidea armigera* (Hymenoptera: Trichogrammatidae) of the millet headminer, *Heliochilus albipunctella* (Lepidoptera: Noctuidae) was identified and it is being mass cultured in the laboratory for eventual field releases. The larval parasitoid, *Habrobracon hebetor* (Hymenoptera: Braconidae) has been mass reared and field released for control of the millet headminer for the past few seasons. The time of release of the parasitoids and the number of bags of the parasitoids to be placed in a given area have been determined. Farmer cooperatives have been organized for production and field release of the larval parasitoid.

#### **Publications:**

- Karimoune L., Ba N.M., Baoua I.B., Muniappan R. (2018). The parasitoid *Trichogrammatoidea armigera* Nagaraja (Hymenoptera: Trichogrammatidae) is a potential candidate for biological control of the millet head miner *Heliocheilus albipunctella* (de Joannis) (Lepidoptera: Noctuidae) in the Sahel. *Biological Control* 127, 9-16.
- Guerci MJ, Norton G, Ba NM, Baoua I, Alwang J, Amadou L., Moumouni O, Laouali K, Muniappan R (2018) Economic feasibility of an augmentative biological control industry in Niger. *Crop Protection* 110, 34-40.
- Amadou L., Baoua I., Ba M.N. and Muniappan R. (2018). Development of an optimum diet for mass rearing of the rice meal moth *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae) and production of the parasitoid *Habrobracon hebetor* Say (Hymenoptera: Braconidae) for the control of pearl millet head miner. Submitted
- Amadou L., Ba M.N., Baoua I., Muniappan R. and Sidhu J. (2018). Timing of releases of the parasitoid *Habrobracon hebetor* Say (Hymenoptera: Braconidae) and numbers needed in augmentative biological control against the millet head miner *Heliocheilus albipunctella* (de Joannis) (Lepidoptera: Noctuidae). Submitted
- Goudiaby M.F., Sarr I., Sembene M and Ba M. Efficacy of augmentative release of *Bracon hebetor* against the pearl millet headminer in Senegal (In preparation)

### XIII. Issues

Not receiving funds in time from USAID causes havoc in project management and implementation.

### XIV. Future Directions

Continue development and implementation of IPM packages for vegetable, fruit, cereal, and legume crops in Asian and African countries. Address management technologies for the invasive species, *Tuta absoluta* and *Spodoptera frugiperda*. Develop collaboration with private institutions such as Biocontrol Research Laboratories, Russell IPM, Real IPM, ISCA, and others, and also with national, regional, and international public organizations and institutions.

Continue working with value chain projects in disseminating information to farmers. Additionally, assist bio-pesticide producing companies in production, quality control, and distribution. Promote use of botanical pesticide in Asian and African countries. Conduct webinars on selected topics for wider participation.

Organize symposia in national, regional, and international conferences for dissemination of IPM technologies beyond the current host countries. Provide opportunities for host country scientists to participate in regional and international conferences.

Scale up technologies such as control of eriophyid mite to tackle withches' broom syndrome of longan and use of plastic sleeves on dragon fruit to control fungal diseases in Vietnam. Use brown paper bags for control of mango fruit flies in Bangladesh and Vietnam. Adoption of push-pull technique for control of maize stem borer and Fall Armyworm in Eastern Africa. Increasing the use of bio-pesticides such as *Trichoderma*, *Beauveria*, *Metarhizium*, *Bacillus thuringiensis*, and nucleopolyhedrosis viruses.

Obtain permits and establish natural enemies of *Parthenium* in Uganda and Kenya. Spread and establish natural enemies *Zygogramma hysterothorax* and *Listronotus setosipennis* throughout Ethiopia. Model spread of *Tuta absoluta* and other invasive species. Estimate spread of invasive species due to climate change in Nepal.

Seek additional funding support to effectively disseminate our successful technologies to different parts of the world.

## Appendix A: Success Story on bagging longan to manage insect pests in Vietnam



# Longan Bagging: Multi-purpose Bags Give Farmers More Fruitful Futures



Longan farmer Hai Dong explains how he uses IPM technologies on his farm.

In order to find Hai Dong's longan orchard tucked into a commune within the Cai Lay-Tien Giang province of Vietnam, you have to straddle the back of a motorbike, duck beneath the arched bodies of willow trees, and cross the slender bridges that run over the channel. Dong is one of several volunteers to use IPM technologies in his longan orchard; 44 members encompass his commune, and many have begun to notice a steady improvement in the egg-shaped fruit that gathers at the ends of the trees' branches.

In 2015, longan, a small stone fruit, brought Vietnam over \$100 million in earnings from its export; the United States alone spent over \$1.5 million. It is the third most cultivated crop in the country after mango and banana, the second most exported crop after dragon fruit, and is especially popular in Southern Vietnam. With that, longan is highly susceptible to pests like fruit borers, stinkbugs, and fruit flies that relish in the juice of the gelatinous fruit.



(Left) Plastic mesh bags for longan bagging. (Right) A light trap to monitor longan pests.

The IPM Innovation Lab, funded by USAID, collaborates with the Southern Horticultural Research Institute (SOFRI) in Vietnam on a project that develops IPM technologies for exportable fruit crops. To protect longan from pests as well as to catch dropping longan, one-gallon mesh plastic bags enclose the fruit 15 days after fruit set. After a series of trials testing non-woven bags, cloth bags, and others, the mesh plastic bags created the perfect microenvironment for longan—adequate air moisture, light transmittance, and temperature. Using IPM technologies in longan orchards not only reduced chemical sprays by 3 to 4 times, but also increased fruit yield and profit. In an orchard in the Nhi Quy-Tien Giang province, for example, there was a 7.08% profit increase from IPM plots compared to control plots.

"Ordinarily we would have applied pesticides to grow longan before we learned about IPM technologies," Hai Dong said, pointing to his orchard. Dong said that 90% of the farmers he knows use chemical pesticides to protect their plants from pests and diseases, which makes it difficult for export to the states and kills natural enemies that might be beneficial to plant growth.



(Left) Longan. (Right) SOFRI Deputy Head of Plant Protection Hanh Tran greets IPM IL.

The mesh plastic bags are also multi-purpose; attached to lights, they serve as light traps that attract fruit borers and stem borers, helping farmers monitor pests that enter the orchard.

Longan has a history not just with pests, but diseases. Witches' broom (Lg WBS) is a syndrome that in 2017 the IPM Innovation Lab and SOFRI were some of the first to discover is caused by an eriophyid mite. SOFRI has now surveyed 20 longan orchards in the Mekong Delta to find two natural predators of the mite, and is currently working on ways to apply the findings large-scale. In the meantime, they teach farmers to prune and apply organic fertilizer to decrease the rate of longan WBS, which can cause 90% crop loss.

Dong's orchard may be a little difficult to reach deep in the thralls of trees and winding pathways, but he said at 67 years old, he feels more at peace.

"I'm very happy with IPM. It gives me less to worry about and more time to spend with my family."



## Appendix B: Success Story on bagging mango to manage fruit fly damage in Vietnam



# Mango Bagging: Farmers Stay Happy, Fruit Flies Stay Away



(Left) Mango bagging in a Vietnam orchard. (Right) A fruit fly-infested mango.

Under the braided canopy of mango tree branches, Nguyen Van Hoa points to a fruit fly inhaling the green skin of an exposed mango suspended like a teardrop.

"You see?" he asked, pointing to the other mangos wrapped and twisted into wax paper bags. "This one is not protected and look at what has happened." The fruit fly was laying an egg, one of many it will lay on unprotected fruit.

Hoa is the Director of the Southern Horticultural Research Institute (SOFRI) and the principal investigator of IPM for Exportable Fruit Crops in Vietnam, an IPM Innovation Lab project funded by USAID; mango is one of four high export potential crops chosen for development toward and implementation of IPM practices.

One of the most successful IPM technologies implemented by SOFRI is mango bagging, the process of wrapping individual mangos in wax paper bags to help jettison pre-harvest insects, namely, fruit flies, but also leafhoppers, fruit borers, and thrips. Bagging also helps abate diseases such as anthracnose, which favors wet, humid conditions.



Nguyen Van Thanh (Center) explains the benefits of IPM on his farm in Dong Thap.

Nguyen Van Thanh is a mango farmer in the Dong Thap province of Vietnam and said that there are nearly 70 wax paper bags on each tree in his orchard. Hundreds of trees grow out of the earth in his backyard, which means thousands of bags protect his mangos.

The bags have cut chemical spraying of the trees by two times and the mango yield of IPM plots versus control plots is in the thousands of pounds more. Thanh said that while the process of bagging mangos is strenuous (he employs several farm workers to climb ladders to reach the sometimes 130 foot tall trees), the bags can be reused for at least three seasons and only cost around .025 cents each.

For each tree in his orchard, he can mitigate pests and diseases the entire year with a handful of quarters.



(Left) Top working. (Right) IPM IL Director Muni Muniappan assesses mango bagging.

"I am so thankful for what this orchard has developed into," Thanh said when asked about using IPM technologies. "It's much easier for me to sell my products since I'm using less spray."

Bagging isn't the only technology SOFRI has taught Thanh, or provided resources for; in addition to using the beneficial fungus *Trichoderma* in his soil, he also prunes dead materials from the trees and disposes of the waste to maintain appropriate light, aeration, and ensure healthy tree growth for seasons to come. Further, Thanh performs "top working," a grafting technique that connects an existing tree to a new variety of mango by wrapping them together. New shoots of a new variety will produce and help farmers to avoid cutting down all of their trees, and instead, recycle them.

It is a common theme when advocates of IPM practices are involved in the growth of plants and crops, to embolden the tools that already exist, and be rewarded with an even bolder, luminous, and fruitful harvest.

## Appendix C: Success Story on push-pull technique to manage maize stem borers in East Africa



### Push-Pull:

## One Simple Farming Technique Successfully Battles Africa's Key Agricultural Constraints



A Push-Pull demonstration plot: *Desmodium* is planted between maize rows and *Brachiaria* is planted along the field border.

Pests, weeds, and poor soil conditions are among just a few of the threats to food security in sub-Saharan Africa. One wouldn't think that a farming method relying on adding more plants into the mix would solve any of those problems, but the Push-Pull technique is doing just that.

Push-pull is a technique developed over the last two decades by the International Centre of Insect Physiology and Ecology (*icipe*), one of the IPM Innovation Lab's collaborators, in partnership with Rothamsted Research, U.K. The cropping system reaches thousands of farmers throughout Africa and is steadily increasing access to healthy, pest-free, pesticide-free crop yields.



A farmer-field day for Push-Pull demonstration.

While Push-Pull is relatively simple, its outcomes are complex. The "push" refers to intercropping, where plants that repel pests, like *Desmodium*, are planted alongside maize or sorghum in a field. The stemborer, an insect that tunnels its way into plant stems and significantly decreases crop yields, is thus pushed away from attacking the central crops. Meanwhile, the "pull" refers to trap crops, like Napier grass or *Brachiaria*, planted around the border of a field, pulling in the stemborer before it enters the primary growing area. The grasses attract natural enemies of the stemborer as well, adding another layer of protection to maize and sorghum, two of Africa's staple cereal crops.

"Evidence indicates that food security is achieved through higher crop yields and improved livestock production from an integrated push-pull technology approach," said Tadele Tefera, country head for *icipe* in Ethiopia. "It can support rural households under existing socioeconomic and agro-ecological conditions. Push-pull technology guarantees increased grain yields from one to three tons per hectare."



*Striga* infestation of maize.

The benefits of Push-Pull don't just lie in the cereal crops it helps nourish, but everything, or everyone, it nourishes along the way as well.

A pest-repellant plant like *Desmodium* inhibits the growth of harmful invasive weeds like *Striga*, whose spread results in almost complete yield losses in maize and sorghum. *Desmodium* also naturally adds nitrogen to soil, improving soil fertility, and is a low-growing plant that won't impede on the growth of the tall cereal crops it's meant to protect. Napier





Associate Director of the IPM Innovation Lab, Amer Fayad (middle), discusses the benefits of using Push-Pull with farmers and *icipe* collaborators.

Grass and *Brachiaria* are perennial—their long-lasting and resilient growth conserves soil moisture, improves soil stability, and prevents run-off.

Further, when Napier grass or *Brachiaria* aren't rooted in the earth, they can also be of use above ground, by acting as high-quality, significant sources of fodder for livestock. Farmers have reported a substantial increase in improved milk yields as a result of using Push-Pull.

"Push-Pull suppresses weed activity, but benefits other living things, too," Tefera said. "Women and children, for example, benefit significantly from it, as weeding is often left to women and children in Africa. Comparing Push-Pull adopters to non-adopters, you'll see an increase in income and household dietary diversity in Push-Pull adopters, which is a significant win from a nutritional perspective."

Tefera said that the increased cereal productivity that comes from Push-Pull also helps to reduce the presence of aflatoxin (mycotoxin), toxins common in grains that deeply constrain the economic value of important crops.

Since its inception, Push-Pull has both decreased stemborer exit holes and reduced the presence of *Striga* by up to 50 percent. It has also increased plant height, and as an example of just one country it's helping to feed, Tanzania has seen crop yields increase by up to a quarter.

"We are very pleased to collaborate with *icipe* towards transforming communities in Africa," said Muni Muniappan, director of the IPM Innovation Lab. "Most recently, we've seen the invasion of the fall armyworm in Africa and we are hopeful the Push-Pull technique will be effective in helping to suppress the pest that can destroy acres of crops in very little time."

With the fall armyworm now threatening hundreds of plant species across Africa, and now Asia, Muniappan's hope about the future is shared—in reports from *icipe*, farmers are calling Push-Pull a "lifesaver."

So, when you imagine a field of healthy maize, by any means, don't imagine it alone. Like many relationships, a little give and a little take is needed for growth to begin to happen.



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