FEED THE FUTURE

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

2017 Integrated Pest Management Innovation Lab

Annual Report (2016-2017)

Center for International Research, Education, and Development
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USAID FROM THE AMERICAN PEOPLE

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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).

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 Center for Agricultural Research in the Dry Areas (ICARDA), 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), Mikocheni 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	*Bacillus thuringiensis*
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
CUNY	City University of New York
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
icipe	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 Management Entity has participated in the annual planning meetings of its projects. In addition, the projects were individually reviewed.

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

One of our main focuses has been the South American tomato leafminer pest, *Tuta absoluta*. The presence of this invasive pest was confirmed in Bangladesh and Nepal last spring. Given how quickly this pest is able to spread, we unfortunately predict it will get as far as Myanmar and Thailand by 2018, and will move into Cambodia, one of our project countries, thereafter. In order to prepare Cambodian farmers, the IPM Innovation Lab conducted two awareness workshops in Phnom Penh and Siem Reap in November. Each of these workshops had over 60 participants including government officials, NGO representatives, and farmers. We then led two more *Tuta absoluta* workshops in December, this time in Dhaka and Jessore, Bangladesh to aid stakeholders already dealing with the pest problem. These workshops were co-organized by USAID's Value Chain project managed by DAI.

We also prepared a PERSUAP to address *Tuta absoluta* in Nepal and fall armyworm in Africa, which were accepted by USAID in April and May, 2017, respectively.

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

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

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

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

Looking ahead, a proposal to conduct a symposium on "Integrated Pest Management of Tropical Crops" at the Annual Meeting of the Entomological Society of America, in Denver, Colorado was accepted. Our request to conduct two sessions in 2018 at the International IPM Symposium, Baltimore, Maryland and one session at the International Congress of Plant Pathology, Boston, Massachusetts have been approved.

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

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

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

II. Program Activities and Highlights

Activities:
The program actively implemented IPM packages for fruit crops in Vietnam; for vegetable crops in Bangladesh, Cambodia, Ethiopia, Kenya, Nepal, and Tanzania; for maize and chickpea in Ethiopia; maize in Kenya; and maize and rice in Tanzania. Additionally, it monitored the spread of *Tuta absoluta* in Nepal and South Asia and documented changes in biodiversity due to climate change in Nepal. It is developing management technologies for fall armyworm in Eastern Africa.

Highlights:

- Development of regional trade in bio-pesticides among India, Nepal, and Bangladesh. The IPM Innovation Lab was instrumental in introducing and establishing contacts between bio-pesticide companies in this region. As a result, a thriving regional bio-pesticide trade has been established. This enhanced the availability of bio-pesticides in villages and reduced the use of chemical pesticides in crop production.
- Sent a group consisting of scientists, extension agents, NGOs, and private company representatives to India to observe production and use of bio-pesticides in collaboration with the value chain project managed by DAI in Bangladesh.
- An international conference on biodiversity was conducted in Nepal in January 2017. The president of Nepal attended the event.
- Prepared PERSUAPs for the South American tomato leafminer, *Tuta absoluta* and the fall armyworm, *Spodoptera frugiperda*.
- Published a book incorporating the achievements of the IPM Innovation Lab in the last two decades.
- Identified local egg parasitoids in Niger that attack eggs of fall armyworm.
- Participated in the Regional IPM Centers joint meeting in Washington, DC.
- Diagnosed the causative organism of the witches' broom disease of longan in Vietnam.
- Field established the natural enemy *Zygogramma* for control of *Parthenium* in Ethiopia.

III. Key Accomplishments

- Diagnosed the causative organism of the witches' broom disease of longan and development of management technologies to control the disease in Vietnam.
- Introduced the plastic sleeves for control of the fungal disease on dragon fruit in Vietnam and the elimination of the residue concern problem in the exported fruits.
- Introduced paper bags to cover mango fruits to prevent fruit fly infestation in Bangladesh.
- Evaluated the performance of Bt-eggplant against non-Bt-eggplant in Bangladesh.
- Controlled *Tuta absoluta* on tomato crops in Nepal with non-synthetic chemical pesticide technologies.
- Modeled the spread of *T. absoluta* in Nepal.
- Organized *T. absoluta* awareness workshops in Cambodia.
- Organized *T. absoluta* management workshops in Bangladesh.
- Organized symposia on IPM packages for tropical crops and *T. absoluta* in national, regional, and international conferences.
- Organized an international conference on biodiversity and climate change in Nepal.
- Identified natural enemies locally recruited by the fall armyworm in Africa.
- Disseminated push-pull technology for control of caterpillar pests of corn in East Africa.
- Provided consultancies for the management of red palm weevil and parthenium.
- Field established two natural enemies of parthenium in Ethiopia.
- Published a book on the achievements of the past two decades of IPM Innovation Lab activities in the developing world.
- Prepared a book compiling a list of publications from the IPM Innovation Lab in the last two decades.

- Produced and disseminated over a dozen news releases.
- Supported 42 graduate students.

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

Location: Southern Horticultural Research Institute (SOFRI), Chau Thanh District, Tien Giang Province, Vietnam.

Principal Investigator: Nguyen, Van Hoa, SOFRI, Vietnam.

Description: Developing and implementing IPM programs of the following fruit crops: longan, lychee, mango, and dragon fruit.

Collaborators: Maria Elisa Christie, Virginia Tech; Naidu Rayapati, Washington State University; Plant Protection Research Institute; Fruit and Vegetable Research Institute; Plant Protection Department, Nong Lam University; Can Tho University; and Vietnam National University of Agriculture, Vietnam.

Achievements: *Diagnosis of the causative organism of witches' broom syndrome of longan*. This syndrome causes the trees' leaves to be deformed, looking more like a claw than a leaf, and causes malformed flowers that do not develop fruits. Eventually these affected shoots and inflorescence dry up and die, causing what remains to look like a witches' broom. In southern Vietnam, where over 40,000 hectares are used for growing longan, damage due to witches' broom is about 50% crop loss. For over 25 years, witches' broom syndrome was thought to be caused by a virus or phytoplasm. Without knowing the cause, witches' broom was very difficult to control. This past winter, IPM IL scientists confirmed the causative agent to be the eriophyid mite, *Aceria* (=*Eriophyes*) *dimocarphi* Kuang (Acari: Eriophyidae). Now that the cause has been confirmed as a mite, the innovation lab is working on a strategy to reduce crop damage by controlling the mite and stopping it from spreading the syndrome.
Plastic sleeves for control of canker disease of dragon fruit. It is a fungal disease caused by *Neoscytalidium dimidiatum*. It was first recorded in Vietnam in 2009 when it had spread to 10,000 hectares. Farmers apply a fungicide to control this disease. However, several shipments exported to the U.S. were rejected due high pesticide residue level in the fruits. The project has developed a technique of using a plastic sleeve to cover the fruit that prevented the fungus from getting on the fruits. This technique also controlled fruit fly attack, resulting in the production of pesticide residue-free fruits and meeting the export requirements without rejection of shipments.
Bagging mango fruits: A technique of bagging mango fruits was introduced to prevent fruit fly infestation. This technique is being validated in the field.
Lychee: Because last winter season was atypically warm, lychee trees did not flower and little or no pest problems were encountered.

Capacity Building: Eighteen training courses were conducted for farmers and extension staff in Hoa Ninh District, Vinh Long Province; Cai Lay town, Cai Lai and Cho Gao district, Tien Giang Province; Chau Thanh district, Long An Province; Cao Lanh district, Dong Thap Province in the South and Hung Yen town, Hung Yen Province; and Luc Ngan district, Bac Giang Province in the North. The project supported two staff members pursuing a MS and one staff member pursuing a PhD at Can Tho University.

Lessons Learned: More field days are needed to show the farmers proper pruning and use of sulfur to control mites in longan, use of plastic sleeves in dragon fruit and mango fruit bagging.

Presentations and Publications:

- Hanh, T,T.M. and Hoa, NV. 2017. IPM for longan and mango. In Agricultural Extension Conference on "Solutions for Developing Sustainable Fruit Crops in the South", Ben Tre Provinve.Aug. 4, 2017.
- Hieu, N.T., Hoa. N.V., Hanh, T.T.M. and Dien, L.Q. and Uyen, D.T.K.Thu, N.N.A. and Linh, D.T. 2017. Use of biological control agents and safe agricultural chemicals for management of fruit and vegetable pests. In, Agricultural Extension Conference on "Solutions for Developing Sustainable Fruit Crops in the South", Ben Tre Provinve.Aug. 4, 2017.
- SOFRI. 2017. Manual for pests and diseases identification of dragon fruit and their management.
- SOFRI. 2017. Manual for pests and diseases identification of longan and their management.

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

Principal Investigator: George Norton, Virginia Tech

Locations: Cambodia (Siem Reap, Battambang, Phenom Penh), Bangladesh (Gazipur, Narsingdi, Mymensing, Comilla, Moulvibazar, Hobigonj, Sylhet, Jessore, Bogra, Pabna, Rjshahi, Gaibanda, panchaghar), and Nepal (Banke, Surkhet, Lalitpur, Kavre).

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

Collaborators: Megan O'Rourke and Maria Elisa Christie, Virginia Tech; Edwin Rajotte, and Cristina Rosa, Pennsylvania State University; Sally Miller, Ohio State University; Naidu Rayapati, Washington State University; Yousuf Mian, Shahadath Hossain, M.A. Goffar, M.S. Nahar, and A.T.M. Masud, Bangladesh Agricultural Research Institute; Luke Colvito, Sulav Paudel, Lalit Sah, Komal Pradhan, iDE; P. Sharma and B. Mahto, National Agricultural Research Council; Keshab Datta Joshi and Yubraj Dhakal, CEAPRED, Nepal; M. Roberts, Kimhian Seng, An Moyngech and An Chanratha, iDE Cambodia; Khun Kimkhuy, Ong Socheath, and Soth Seyboth, Royal University of Agriculture, Cambodia.

Achievements: *Cambodia:* Field trials adopting IPM components on Chinese kale, cucumber, and yard long bean were conducted in farmers' fields. Trials on evaluation of efficacy of *Trichoderma* species on Chinese kale and cucumber and rootstocks for bacterial wilt resistance in tomato were conducted at RUA. Baseline survey was completed.

Bangladesh: Field trials with Bt and non-Bt eggplants showed that Bt eggplants had a 88% reduction in eggplant fruit and shoot borer damage than in non-Bt eggplants. Bt eggplants gave a profit of Taka 126,300 per hectare more than non-Bt eggplants.

Covering mango fruits with China brown paper bags gave 100% protection against fruit fly infestation and provided Taka 1560 higher net return per tree. In tomato rootstock trials, BARI brinjal 8 performed better than *Solanum sysimbrifolium* and EG 203. Bitter gourd IPM trials conducted in Joydebpur and Narsingdi, produced more marketable fruits than farmers' practice. Since its introduction in 2016, *Tuta absoluta* has spread throughout Bangladesh.

Nepal: An IPM program for management of *Tuta absoluta* in the tomato crop with pheromone traps and bio-pesticides has been developed. A gender impact assessment was completed. Field trials with eggplant, onion, and bitter gourd were conducted comparing IPM packages with farmers' practice.

Capacity Building: The project is supporting one student for a BS degree, one student for a MS degree, and six PhD students. Two *Tuta absoluta* awareness workshops were conducted in Cambodia in addition to several field days and workshops conducted in all the three countries.

Lessons Learned:

- In Bangladesh, late planting of Bt eggplant results in lower yield due to high temperatures and heavy rainfall.
- Demand for *Tuta absoluta* lures has increased and must be made available in local markets.
- Pheromone traps for eggplant fruit and shoot borer should be set up in non-Bt eggplant plots.
- In Nepal, the IPM package developed for tomato incorporating *Tuta absoluta* management practices has received international recognition.
- In Cambodia, quality of bio-pesticides needs to be regulated.

Presentations and Publications:

- Bhusal, K., B.P. Bhattarai, and L. Sah. 2017. Pest and disease surveillance of vegetable crops and farmer's pest management practices in Banke and Surkhet districts. Nepalese Journal of Agricultural Sciences, 15: 160-165.
- Hossain, M.S., M.Y. Mian and R. Muniappan. 2016. First record of *Tuta absoluta* (Lepidoptera: Gelechiidae) from Bangladesh. Journal of Agriculture and Urban Entomology, 32: 101-105.
- Hossain, M.S., M.Y. Mian, G.M.A. Halim, and R. Muniappan. 2016. Bangaldeshe *Tuta* leafminer er abirvab ebong amader karaniya (Bengali) 14p.
- Hossain, M.S., B.C. Sarker and M.M. Hossain. 2017. Fruit bagging: An effective and eco-friendly approach for controlling fruit fly (in Bangla). IPM IL Bangladesh Site, BARI, Gazipur 12p.
- Joshi, J., B.P. Rajbhandari and L. Sah. 2017. Management practices adopted by commercial tomato growers against *Tuta absoluta*. Nepalese Journal of Agricultural Sciences, 15: 93-97.
- Mian, M.Y., M.S. Hossain and A.N.M.R. Karim. 2016. Integrated pest management of vegetable crops in Bangladesh. In, R. Muniappan and E.A. Heinrichs (eds.). Integrated Pest Management of Tropical Vegetable Crops. Springer, pp 235-250.
- Norton, G.W., J. Alwang and M.S. Issa. 2016. Impact of IPM on vegetable production in the tropics. In, R. Muniappan and E.A. Heinrichs (eds.). Integrated Pest Management of Tropical Vegetable Crops. Springer, pp 289-304.
- Paudel, S., L.P. Sah, K. Pradhan, L.A. Colavito, B.P. Upadhyay, E.G. Rajotte and R. Muniappan. 2016. Development and dissemination of vegetable IPM practices and packages in Nepal. In, R. Muniappan and E.A. Heinrichs (eds.). Integrated Pest Management of Tropical Vegetable Crops. Springer, pp 251-269.

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

Principal Investigator: Nir Krakauer, City University of New York

Location: Chitwan, Kapilbastu, Nawalparasi, Kaski, Syangja

Description: To study changes in fauna, flora, crop phenology, and incidence of pests and diseases due to variation in temperature, rainfall, and humidity from the Terai region to higher altitudes in the Himalayas.

Collaborators: J.D. Anadon, D.L. Lohman, T. Lakhankar, and A. Jha, CUNY, New York; Pramod Kumar Jha, Tribhuvan University, Nepal; and Nab Raj Devkota, Agriculture and Forestry University, Nepal.

Achievements: A three-day international research conference on "Biodiversity, Climate Change Assessment and Impacts on Livelihood" was conducted in Kathmandu, Nepal. A review of the present state of knowledge and research needs regarding climate change impacts on biodiversity in Nepal was done.

Capacity Building: Five PhD and 12 MS students at Nepal Universities are supported by this project. Training on GPS, GIS mapping, statistical software, species distribution modeling and DSAAT were conducted for the project-supported students.

Lessons Learned: Researchers and students have learned to conduct scholarly outreach work on biodiversity and climate change.

Presentations and Publications:

- Bhattacharjee, A., J.D. Anadon, D.L. Lohman, T.. Doleck, T. Lakhankar, B.B. Shrestha, P. Thapa, D. Devkota, S. Tiwari, A. Jha, M. Siwkoti, N.R. Devkota, P.K. Jha, and N.Y. Krakauer, 2017. The impact of climate change on biodiversity in Nepal: current knowledge, lacunae, and opportunities. Climate, 5: 80, doi:10.3390/cli5040080
- Krakauer, N.Y., T. Lakhankar, J.D. Anadon. 2017. Mapping and attributing normalized difference vegetation index trends for Nepal. Remote Sensing, 9: 986, doi:10:3390/rs9100986
- Over 20 oral and poster presentations were made at the international conference on biodiversity, climate change assessment, and impacts on livelihood, January 10-12, 2017, Kathmandu, Nepal.

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

Principal Investigator: Buyung Hadi, IRRI

Location: Cambodia (Battambang, Kampong Thom, Prey Veang, Takeo)

Description: To develop a rice IPM package validated for Cambodian biophysical conditions in collaboration with rice value chain projects in Cambodia. It will reduce losses due to pests and diseases, minimize pesticide use, and include tactics such as cultural control, host plant resistance, and biological control.

Collaborators: Chou Cheythyrith, General Directorate of Agriculture; Khay Sathya, CARDI; Keam Makarady, CEDAC; Sotaro Chiba, Nagoya University; George Norton and Doug Pfeiffer, Virginia Tech; and Harvey Reissig, Cornell University.

Achivements: Field trials were conducted on use of *Trichoderma* and resistant varieties, rodent control, and weed control at Prey Veng, Takeo, Battambang, and Kempong Thom. The project has also empowered Cambodian rice value chain actors in IPM research and scaling out.

Capacity Building: One post-doctoral candidate, one PhD, and five MS degree students are supported by this project.

Lessons Learned:

- Resistant variety and application of *Trichoderma* reduced rice neck blast incidence.
- Integrated weed management provided a 8% to 11% increase in yield.
- Rodent control system gave 0.5 T/Ha increase in yield.

Presentations and Publications:

- Flor, R.J., K. Chhay, V. Sorn, H. Maat and B. Hadi. 2017. Analysis of Lock-in Mechanisms: A case study on rice IPM in Cambodia. European Seminar of Extension and Education, Chania, Greece, July 2017.

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

Principal Investigator: Abhijin Adiga, Biocomplexity Institute, Virginia Tech

Location: Virginia Tech; North Carolina State University, University of California-Davis; Senegal; France.

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

Collaborators: Madhav Marathe, Stephen Eubank, Achla Marathe, Srinivasan Venkataramanan, Sichao Wu, Bowen Shi, George Norton, Joseph McNitt, and Henning Mortveit, Virginia Tech; J. B. van Kretschmar, and Godshen Robert Pallipparambil, North Carolina State University
Lalit Sah, Ajay P. Giri, and Luke Colavito, iDE, Nepal; V. Sridhar, S. Nitin, and R. Asokan, Indian Institute of Horticultural Research, India; Thierry Brevault, Anais Chailleux, and Arame Ndiaye, Senegal; Nicolas Desneux, Mateus Ribeiro de Campos, and Philippe Bearez, France; Antonio Biondi and Luigi Ponti, Italy; and Andrew Gutierrez, University of California-Berkeley.

Achievements: Development of an integrated data-driven methodology for synthesizing realistic spatio-temporal networks of seasonal agro products between major markets. Conducted in-depth sensitivity

analysis to quantify the role of input parameters to validate synthesized networks. Risk assessment of *Tuta absoluta* invasion of North America, and the dynamics of its spread within the region in the event of entry. Physiologically based demographic model (PBDM) being developed for *Tuta absoluta*. Identity of groundnut leafminer in East and South Africa being worked on using molecular technology.

Capacity Building: Two post-doctoral, two PhD and five MS candidates are supported by this project.

Lessons Learned: Tomato trade is spreading *T. absoluta* in Nepal. Some cultivated solanaceous crops and weeds act as a reservoir for *T. absoluta* populations.

Presentations and Publications:

- Campos, M.R., A. Biondi, A. Adiga, R.N. Guedes and N. Desneux. 2017. From the Western Palearctic region to beyond: *Tuta absoluta* 10 years after invading Europe. Journal of Pest Science 1-10.
- Sylla, S., T. Brevault, A.B. Bal, A. Chailleux, M. Diatte, N. Desneux and K. Diarra. 2017. Rapid spread of the tomato leafminer, *Tuta absoluta* (Lepidoptera: Gelechidae), and invasive pest in Sub-Saharan Africa. Entomologia Generalis, 269-283.
- Sylla, S., T. Brevault, J.C. Streito and K. Diarra. 2016. First record of *Nesidiocoris tenuis* (Reuter) ((Heteroptera: Miridae) as potential predator of the tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), in Senegal. Egyptian Journal of Pest Control, 26: 851-853.

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

Principal Investigator: Wondi Mersie, Virginia State University

Location: Ethiopia, South Africa, Tanzania, and Uganda

Description: Biological control of the invasive weed *Parthenium hysterophorus,* in Ethiopa, Tanzania, and Uganda using the natural enemies *Zygogramma bicolorata* and *Listronotus setosipennis*.

Collaborators: Arne Witt, CABI; Melkamu Birhanie and Wallelign Zegeye, Amhara Regional Agricultural Research Institute; Tesfaye Amare, Ambo University; Kassahun Zewdie, Ethiopian Institute of Agricultural Research; Lisanework Nigatu, Haramaya University; Ferdu Azerefegne, Hawassa Univerity; Asmare Dejen Demeke, Wollo University; Lorraine Strathie, Agricultrural Research Council, South Africa; Richard Molo, National Agricultural Research Organization, Uganda; Samora Macrice (Sokoine University, Tanzania); Ramadhan Kilewa, Tropcial Pesticide Research Institute, Tanzania; and Lidya Alemayehu, Virginia State University.

Achievements: Natural enemies *Zygogramma bicolorata* and *Listronotus sestosipennis* are being mass-reared at Ambo University, Wollenchiti, and Haramaya University. These are also being field released in different parts of Ethiopia.

Capacity Building: One student supported by the project obtained her MS at Haramaya University.

Lessons Learned: Several critical steps involved in mass rearing of the natural enemies have been elucidated. The project also identified favorable field release sites.

Presentations and Publications:

- Belaynesh Assema. 2017. Gauging women's interest in and ability to participate in the adoption of bio-control agents for control of parthenium infestation in Tullo District, West Hararghe Zone, Oromia Regional State, Ethiopia. M.S. Thesis. Haramaya University.
- Mersie, W. 2017. Ethiopia: Biological control of the famine weed – *Parthenium hysterophorus.* International Association for Plant Protection Sciences Newsletter, Crop Protection, August, 2017.

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

Principal Investigator: Tadele Tefera, *icipe*, Ethiopia

Location: Ethiopia, Kenya, and Tanzania

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

Collaborators: *Ethiopia* - Ethiopian Institute of Agricultural Research, Ambo University, Haramaya University, Addis Ababa University, and Jimma University
Kenya - Kenya Agricultural and Livestock Research Organization, and Kenya Agricultural Value Chain Enterprises (KAVES) in Kenya
Tanzania - Sokoine University, University of Dar es Salaam, Agricultural Research Institute, and National Biological Control Programme

Achievements: Biology of *Helicoverpa armigera* on various host plants completed. Effect of *Trichoderma* spp. on Fusarium wilt of chickpea evaluated. Push-pull technique for control of stemborer and fall armyworm in maize has been introduced. Baseline surveys in Kenya and Tanzania completed.

Capacity Building: Four PhD students and three MS students are supported by this project.

Lessons Learned: There is a high demand for field days demonstrating IPM technologies for grain crops. Recent invasion of fall armyworm requires immediate attention.

Presentations and Publications:

- Tefera, T. 2017. Rice, maize, and Chickpea project highlights to icipe management. Feb.8, 2017.
- Tefera, T. 2016. Progress report on rice, maize, and chickpea project annual planning and review meeting, Nov. 3, 2016.
- Tefera, T. 2017. *Spodoptera* species in Africa. Fall Armyworm Workshop in Addis Ababa, July 2017.
- Several presentations were made by the collaborating scientists and students in the planning meetings.

8. Integrated Pest Management for Vegetables in East Africa

Principal Investigator: John Cardina, Ohio State University

Location: Ethiopia, Kenya, and Tanzania

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

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

Achievements: Baseline survey was completed in all three countries. In Tanzania, grafting experiments were conducted with tomato and cucurbit crops to manage soil borne pathogens. Neem cake proved effective in controlling nematodes. In Ethiopia, protecting pepper seedling with nylon net reduced the incidence of virus diseases.

Capacity Building: Two PhD students and 10 MS students are supported by this project.

Lessons Learned: Development of relationships among researchers and research groups within and among the three countries are essential for successful implementation of the project. Tanzania and Ethiopia are developing technologies for IPM components while Kenya is active in the technology transfer mode.

Presentations and Publications:

- Sseruwagi, P., J. Ndunguru, M. Njelekela and D. Kalekayo. 2017. Major viral diseases of tomato and their management in Tanzania. Station Report. 4p.
- Several presentations were made at the Workshop on Sustainable Horticultural Production in the Tropics. Nov. 28 to Dec. 2, 2016.

VI. Associate Awards

None for this reporting period.

VII. Human and Institutional Capacity Development

a. Short-Term Training

Strengthening Production and Export of Vietnamese Fruit Crops Through Innovative and Market-Orientated IPM					
Country of Training	**Brief Purpose of Training**	**Who was Trained**	**Number Trained**		
			M	**F**	**Total**
	Biotechnology Methods	Scientists from Can Tho University and SOFRI	1	4	5
Vietnam	An overview of trapping crops	SOFRI staff	6	7	13
Vietnam	An Overview of Virus Diseases	SOFRI staff	9	13	22
Vietnam	IPM dragon fruit technological protocol	Farmers and local extension staffs of IPM sites	30	10	40
Vietnam	IPM dragon fruit technological protocol	Farmers and local extension staffs of IPM sites	38	2	40
Vietnam	Dragon fruit production protocol according to VietGAP standard	Farmers and local extension staffs of IPM sites	31	9	40
Vietnam	Training and transferring IPM longan technological protocol	Farmers and local extension staffs of IPM sites	34	10	44
Vietnam	Longan production protocol according to VietGAP standard	Farmers and local extension staffs of IPM sites	24	6	30
Vietnam	Longan production protocol according to VietGAP standard	Farmers and local extension staffs of IPM sites	40	5	45
Vietnam	Using safe and effective pesticides according to VietGAP	Farmers and local extension staffs of IPM sites	41	4	45
Vietnam	Training and transferring IPM longan technological protocol	Farmers and local extension staffs of IPM sites	24	6	30
Vietnam	IPM longan technological protocol	Farmers and local extension staffs of IPM sites	41	4	45
Vietnam	Longan production protocol according to VietGAP standard	Farmers and local extension staffs of IPM sites	36	8	44
Vietnam	Training and transferring IPM longan technological protocol	Local technician, local government officers and famers	42	8	50
Vietnam	Training and transferring IPM and VietGAP technologies	Local technician and famers who participated in the VietGAP model	21	9	30
Vietnam	Canopy and branch pruning for pest and disease management	Farmers and local extension staffs of IPM sites	38	2	40
Vietnam	Training and transferring IPM mango technological protocol	Farmers and local extension staffs of IPM sites	36	4	40
Vietnam	Mango production protocol according to VietGAP standard	Farmers and local extension staffs of IPM sites	36	4	40
Vietnam	Using safe and effective pesticides according to VietGAP standard	Farmers and local extension staffs of IPM sites	37	3	40
Vietnam	Training and transferring IPM lychee technological protocol	Farmers and local extension staffs of IPM sites	33	17	50
Vietnam	Training and transferring IPM and VietGAP protocols	Farmers and local extension staffs of IPM sites	25	7	32

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	Oct 16 – Mar 17	Under graduate Students	4	6	10
Nepal	Participate in Climate Change Conference	Scientist from Bangladesh (BARI)	1		1
Nepal	*Tuta absoluta* Orientation Workshop (national level)	Stakeholders of different project, GoN staff, Private sectors	28	9	37
Nepal	*Tuta absoluta*: Identification and Management Training (Regional level)	Stakeholders of different project, GoN staff, Private sectors, CBFs	26	10	36
Nepal	*Tuta absoluta*: Identification and Management Training (Regionals level)	Stakeholders of different project, GoN staff, Private sectors, CBFs	29	9	38
Ethiopia	Fall Army Workshop	IPM Nepal coordinator: Mr. Lalit Sah	1	0	1
Nepal	2 days Intensive IPM training	Farmers, CBFs, Private sectors	28	16	44
Nepal	Capacity building training to private enterprises, producer organizations, women groups	Farmers Groups, Private sector entrepreneurs	66	277	343
Nepal	Mobile Training on IPM (Issue based)	Community farmers	46	114	160
Cambodia	Several training workshops on use of beneficial fungus *Trichoderma*, virus disease diagnostics, nematode, and *Tuta absoluta*	Scientists, students, frames, extension agents, RUA faculty and staff, GIZ staff, Univ. Battambang faculty and staff, GDA staff, PDA staff, iDE staff, CARITAS staff, ADDA staff, AGRISUD staff, GRET staff, CRADI staff.	94	28	122
Cambodia	IPM package trials	undergraduate students, RUA	3	4	7
Nepal	Climate change conference	BARI scientist, Bangladesh	1	0	1
Nepal	*Tuta absoluta* Orientation Workshop (national level)	Scientists, project staff, extension agents, farmers, policy makers, agrovets, biopesticide manufacturers.	28	9	37
Nepal	*Tuta absoluta*: Identification and Management Training (Regional level	Scientists, project staff, extension agents, farmers, policy makers, agrovets, biopesticide manufacturers.	29	9	38

Participatory Biodiversity and Climate Change Assessment for Integrated Pest Management in the Annapurna-Chitwan Landscape, Nepal					
Country of Training	**Brief Purpose of Training**	**Who was Trained**	**Number Trained**		
			M	**F**	**Total**
Nepal	Training on MaxEnt software for ecological niche modeling	Students and researchers	6	6	12

Nepal	Review research progress and provide feedback to students and faculty on research methods and plans	Students and researchers	24	13	37
Nepal	Press meeting at international conference to raise national awareness of conference about USAID and project work	Media people	20	10	30
Nepal	Share research, build national capacity, raise awareness of biodiversity, and climate issues at international conference	Students, researchers, policymakers	231	124	355
Nepal	Methods for modeling climate impacts on biodiversity	Students & researchers	7	11	18
Nepal	International Conference of Biodiversity	Students, researchers, policymakers	231	124	355
Nepal	Interaction with farmers	Farmers	27	12	39
Nepal	Interaction with farmers	Farmers	28	12	40

Development of Ecologically-based Participatory Integrated Pest Management (IPM) Package for Rice in Cambodia (EPIC)					
Country of Training	**Brief Purpose of Training**	**Who was Trained**	**Number Trained**		
			M	**F**	**Total**
Cambodia	Adaptive research planning meeting – discussing and adapting intervention options	Lead farmers	16	4	20
Cambodia	Adaptive research planning meeting – discussing and adapting intervention options	Lead farmers	17	5	22
Cambodia	Adaptive research planning meeting – discussing and adapting intervention options	Lead farmers	19	3	22
Cambodia	Adaptive research planning meeting – discussing and adapting intervention options	Lead farmers	16	3	19
Cambodia	Rodent management	Lead farmers			28
Cambodia	Training on insect identification	Scientists and extension agents from CARDI, GDA, RUA	11	3	14
Cambodia	Farmer reflection meeting – Rodent management	Farmers	10	3	13
Philippines	Training on experimental design	Students (RUPP, GDA, PDA)	3	0	3
Cambodia	Training of interns	Students	2	0	2
Cambodia	Rodent management	Farmers	21	8	29
Cambodia	Weed and insect management	Farmers	11	4	15
Cambodia	Weed and disease management	Farmers	24	3	27
Cambodia	Biocontrol agents	Law makers (Department of Agricultural Legislation), GDA, PDA, CARDI, farmers, private sector, farmer groups.	100	42	142
Thailand	Mass rearing and production of biocontrol agents	GDA (National agricultural laboratories)	0	1	1
Cambodia	Farmer field visit – weed and disease management	Farmers	25	3	28
Cambodia	CE SAIN lecture: Designing pest resilient rice ecosystem	RUA students, GDA	8	4	12
Cambodia	Farmer reflection meeting – weed and disease management (different village)	Farmers	26	4	30

Cambodia	Farmer field visit – weed and insect management	Farmers	20	4	24
Cambodia	Farmer field visit – weed management	Farmers	21	4	25
Cambodia	Farmer field visit – weed and insect management	Farmers	29	1	30
Cambodia	Farmer field visit – rodent management	Framers	20	10	30
Cambodia	CE SAIN lecture: Why farmers do not adopt: Rethinking adoption	RUA students	5	5	10
Cambodia	Farmer field visit – weed an disease management	Farmers	12	7	19
Cambodia	Farmer reflection meeting – weed and insect management	Farmers	8	3	11
Cambodia	Field visit (AMRU rice and MODE – Local NGO and rice exporter)	Local NGOs and rice exporter organizations	37	8	45
Cambodia	Farmer field visit – Rodent management	Farmers	13	16	29
Cambodia	Farmer field visit – Rodent management (different village)	Farmers	27	2	29
Cambodia	Farmer reflection meeting – weed and insect management	Farmers	16	1	17
Cambodia	Farmer field visit – Rodent management	Farmers	24	7	31

Biological Control of the Invasive Weed *Parthenium hysterophorus* in East Africa					
Country of Training	**Brief Purpose of Training**	**Who was Trained**	**Number Trained**		
			M	**F**	**Total**
Ethiopia	Visit parthenium biocontrol mass-rearing facilities, field release sites and provide technical recommendations	Staff at AU's Guder bioagent facility	2	3	5
Ethiopia	Evaluate current status of parthenium biocontrol effort in eastern and southern Africa	Workshop participants from Ethiopia, Israel, South Africa, Uganda and USA	12	4	16
Ethiopia	Visit mass-rearing facilities at AU's Guder campus and field release site to make technical recommendations	Workshop participants	10	5	15
Ethiopia	Visit mass-rearing facilities at Wollenchiti and release sites to make technical recommendations	Workshop participants	10	5	15
Ethiopia	Visit parthenium biocontrol mass-rearing facilities, field release sites and provide technical recommendations	Staff at Wollenchiti Bioagent Mass Rearing Site	2	3	5
Tanzania	Biocontrol workshop	ECHO East Africa and CABI	46	34	80

Rice, Maize, and Chickpea IPM for East Africa					
Country of Training	**Brief Purpose of Training**	**Who was Trained**	**Number Trained**		
			M	**F**	**Total**
Ethiopia	Training of Researchers and extension agents on IPM technologies	Researchers and extension agents	34	1	35
Ethiopia	Training of Researchers and extension agents on IPM technologies	Researchers and extension agents	21	6	27
Ethiopia	Awareness creation on fall armyworm	Scientists, farmers, extension agents, policy makers			117
Kenya	Awareness creation on fall armyworm	Scientists, farmers, extension agents, policy makers	7	81	87
Kenya	Farmers sensitization on the push-pull technology for the control of stem borers in maize	Farmers	66	55	121
Kenya	Training of extension service providers on push-pull technology and its benefits.	Extension agents	18	6	24
Kenya	Farmers Field day on IPM technologies	Farmers	70	30	100
Tanzania	Rice IPM in Mvomero District	Agricultural officers and farmers	16	15	31
Tanzania	Training on Integrated Management of Maize Stemborers and Striga weed using Push-Pull Technology in Morogoro To introduce the PPT and to build the capacity of extension officers	Scientists, farmers, extension agents	20	10	30

Integrated Pest Management for Vegetables in East Africa					
Country of Training	**Brief Purpose of Training**	**Who was Trained**	**Number Trained**		
			M	**F**	**Total**
Tanzania	Seedling Health Workshop: 3-day practical demonstration of IPM technologies, e.g. seeds, soil, water, protection, biocontrols, fertility, & quality assessment, for seedling production	Trainers, extension officers, educators, students, farmers, male and female entrepreneurs	49	14	63
Tanzania	Virus vector identification and management.	Research assistants	2	1	3
Tanzania	On – farm training on onion IPM technologies: Principles of IPM; rationale of IPM, pests identification; damage and symptoms; IPM in onion – insect pests, diseases and weeds; seed selection; variety resistance, nursery establishment; transplanting; onion crop field management	Farmers, extension officers	37	43	80
Tanzania	IPM methods for tomato and Chinese cabbage.	Farmers, extension officers	67	23	90
Tanzania	Vegetable seedling health and crops production IPM practices and GAP. Training included use of WhatsApp to inquire, share and communicate pest and disease problems.	Farmers, extension officers, local leaders at Kerege, Bagamoyo	42	32	74
Tanzania	Hands-on training in vegetable viral disease IPM. Objectives:	Farmers, Local leaders, Extension officers; Journalists from Kerege, Matega, Zinga, and Chambezi	155	91	246

	• Understand cause, symptoms, spread, effect and control of viral diseases and insect vectors • Viral disease IPM • Good agricultural practices (GAP) for vegetable crops				
Kenya	IPM systems and technologies (i.e., site selection, solarization, insect proof netting, pathogen-free seeds/seedlings, scouting, identification of main diseases, establishment of seedlings in sterile media in germination trays).	Farmers from Nthambo, Mbuiru-Mwanjati, and Mbogoni Farmer Groups, and extension officers	33	40	73
Kenya	Use of WhatsApp for disease diagnostics and IPM communication. Those with good smart-phones are participating in the network by sending images and questions.	Farmers from Nthambo, Mbuiru-Mwanjati, and Mbogoni Farmer Groups	30	39	69
Kenya	To define solarisation and its application for management of soil borne pests, pathogens and weeds in the nursery bed	Farmers, extension officers	32	22	54
Kenya	Use of resistant varieties tomato (Var. Kilele) and Cabbage (Var. Queen) for management of bacterial wilt and black rot respectively	Farmers, extension officers	32	22	54
Kenya	Pest exclusion by use of insect proof netting in the nursery bed	Farmers, extension officers	32	22	54
Kenya	Identification and integrated management of Tomato pests and diseases	Farmers, extension officers	43	53	96
Kenya	Identification and integrated management of French bean pests and diseases	Farmers, extension officers	43	53	96
Kenya	Identification and integrated management of Brassica pests and diseases	Farmers, extension officers	48	59	107
Kenya	Use of *Trichoderma* for management of seedling damping off, *Fusarium* wilt and seedling rots	Farmers, extension officers	18	27	45
Kenya	Vegetable seedling health management	Farmers, extension officers	14	16	30
Kenya	Use of Smart phone for disease Diagnostics	Farmers, extension officers	38	39	77
Kenya	Use of social media for pest diagnosis and information sharing	Farmers, extension officers	38	39	77
Kenya	Use of lime to increase soil pH for phosphorous availability	Farmers, extension officers	9	13	22
Kenya	Identification and management of nematodes in French beans	Farmers, extension officers	9	20	29
Kenya	Use of biopesticides in vegetable production	Farmers, extension officers	34	35	69
Kenya	Propagation of seedlings in coco peat and germination trays	Farmers, extension officers	34	35	69
Kenya	Use of lime to increase soil pH	Farmers, extension officers	9	13	22
Ethiopia	Seed management, seed bed management, solarisation, protective covering, fertilization, safe use of pesticides, reduced insecticide use.	Farmers	91	12	103

b. Long-Term Training

i) Students and post-docs being trained

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
Farhanaz Sharma	F	Virginia Tech	PhD	Economics	December 2017	Y	Bangladesh
Mafruha Afroz	F	BSMRAU-Bangabandhu Sheikh Mujibur Rahman Agricultural University	PhD	Plant Pathology	December 2017	Y	Bangladesh
Sadique Rahman	M	Tribbuvan University and Virginia Tech	PhD	Economics	December 2017	N	Bangladesh
Chhum Chanda	F	Royal University of Agriculture	BS	Agronomy/ Plant Pathology	July 2018	N	Cambodia
Huong Nontarak		Royal University of Agriculture	BS	Agronomy/ Entomology	July 2018	N	Cambodia
Huot Chhunleng	F	Royal University of Agriculture	BS	Agronomy/ Entomology	July 2018	N	Cambodia
Koy Chakriya	F	Royal University of Agriculture	BS	Agronomy/ Plant Pathology	December 2016	Y	Cambodia
Lor Saorith	F	Royal University of Agriculture	BS	Agronomy/ Plant Pathology	June 2017	Y	Cambodia
Nak Lida	M	Royal University of Agriculture	BS	Agronomy/ Entomology	June 2017	Y	Cambodia

Nha Puthy	F	Royal University of Agriculture	BS	Agronomy/ Plant Pathology		N	Cambodia
Ren Vuthy	M	Royal University of Agriculture	BS	Agronomy/ Entomology	June 2017	Y	Cambodia
Roum Virak	M	Royal University of Agriculture	BS	Agronomy/ Plant Pathology	July 2018	N	Cambodia
Sngoun Saiya	F	Royal University of Agriculture	BS	Agronomy/ Plant Pathology	June 2017	Y	Cambodia
Tout Moykea	F	Royal University of Agriculture	BS	Agronomy/ Plant Pathology	July 2018	N	Cambodia
Arjun Khanel	M	Virginia Tech	PhD	Economics	July 2018	N	Nepal
Ram Khadka	M	Ohio State University	PhD	Plant Pathology	May 2020	N	Nepal
Sulav Paudel	M	Pennsylvania State University	PhD	Entomology	May 2020	N	Nepal
Kaitlyn Spangler	F	Virginia Tech	MS	Geography (Gender Studies)	June 2018	N	USA

Participatory Biodiversity and Climate Change Assessment for Integrated Pest Management in the Annapurna-Chitwan Landscape, Nepal							
Name (first, last)	Gender	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Anju Sharma	F	Tribhuvan University	PhD	Botany	2019	N	Nepal
Bidya Maya Shrestha	F	Tribhuvan University	MSc	Environmental Science	2018	N	Nepal
Bivekananda Mahat	M	Agriculture and Forestry University	MSc	Entomology	2018	N	Nepal
Bivekananda Mahat	M	Agriculture Forestry University	MS	Entomology	2018	N	Nepal
Dol Raj Luitel	M	Tribhuvan University	PhD	Botany	2019	N	Nepal
Ganga Shah	M	Tribhuvan University	MSc	Zoology	2017	Y	Nepal
Ghanashyam Bhandari	M	Agriculture and Forestry University	PhD	Entomology	2019	N	Nepal
Hom Nath Giri	M	Agriculture and Forestry University	PhD	Agronomy	2019	N	Nepal

Madhu Sudhan Ghimire	M	Agriculture and Forestry University	MSc	Entomology	2018	N	Nepal
Pratiksha Sharma	F	Agriculture and Forestry University	MSc	Agronomy	2018	N	Nepal
Pristi Dangol	F	Tribhuvan University	MSc	Botany	2018	N	Nepal
Ram Asheshwar Mandal	M	Tribhuvan University	Postdoc	Climate change	2018	N	Nepal
Ramesh Upreti	M	Agriculture and Forestry University	MSc	Agronomy	2018	N	Nepal
Sagar Khadka	M	Tribhuvan University	MSc	Botany	2017	N	Nepal
Sagar Khadka	M	Tribhuvan University	MS	Botany	2017	N	Nepal
Sanjeeb Bhandari	M	Tribhuvan University	MSc	Botany	2018	N	Nepal
Sarita Sapkota	F	Agriculture and Forestry University	MSc	Entomology	2018	N	Nepal
Seerjana Maharjan	F	Tribhuvan University	PhD	Botany	2019	N	Nepal
Vishubha Thapa	F	Tribhuvan University	MSc	Zoology	2017	Y	Nepal
Vishuva Thapa	F	Tribhuvan University	MS	Zoology	2017	Y	Nepal
Yashoda Panthy	F	Agriculture and Forestry University	MSc	Agronomy	2018	N	Nepal
Alexis Brewer	F	City Unversity of New York	PhD	Biology (ecology)	2020	N	USA
Arun Ravindranath	M	City Unversity of New York	PhD	Civil Engineering	2018	N	USA
Tenzing Doleck	F	City Unversity of New York	PhD	Biology (ecology)	2018	N	USA

Development of Ecologically-based Participatory Integrated Pest Management (IPM) Package for Rice in Cambodia (EPIC)							
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 Cheythyrith	M	Nagoya University	PhD	Plant Pathology	July 2019	N	Cambodia

Ong Socheath	F	Royal University of Agriculture	MS	Plant Pathology	July 2020	N	Cambodia
Sek Pisey	M	Royal University of Phnom Penh	MS	Conservation Biology	December 2017	N	Cambodia
Rica Joy Flor	F	IRRI	Postdoc	Agricultural Economics	September 2019	NA	Philippines
Corey Riedel	M	Virginia Tech	MS	Entomology	September 2018	N	USA
Sydni Jackson	F	Virginia Tech	MS	Agricultural Economics	June 2017	Y	USA

A High-resolution Interaction Based Approach to Modeling the Spread of Agricultural Invasive Species							
Name (first, last)	Gender	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Sichao Wu	M	Virginia Tech	PhD	Computer Science	May-17	Y	China
Mateus Ribeiro de Campos	M	Institut National de la Recherche Agronomique INRA	Postdoc	Research Engineer level 1	Feb-17	NA	France
Amleshwar Kumar	M	Virginia Tech	BS	Mathematics	May-17	Y	India
Issa Awal	M	CIRAD-BIOPASS	MS	Statistics	Jul-17	Y	Niger
Ahmadou Sow	M	CIRAD-BIOPASS	PhD	Entomology	Apr-18	N	Senegal
Arame Ndiaye	F	CIRAD-BIOPASS	Postdoc	Molecular biologist	NA	NA	Senegal
Mame Diarra Bousso	M	CIRAD-BIOPASS	MS	Entomology	Dec-16	Y	Senegal
Oumar Seydi	M	CIRAD-BIOPASS	MS	Horticultural crops	Dec-16	Y	Senegal
Serigne Sylla	M	CIRAD-BIOPASS	PhD	Horticultural crops	Feb-17	Y	Senegal
Bryan Kaperick	M	Virginia Tech	BS	Computation Modeling & Data Analytics	May-18	N	USA

Biological Control of the Invasive Weed *Parthenium hysterophorus* in East Africa							
Name (first, last)	Gender	University	Degree	Major	Program End Date (month/year)	Degree Granted (Y/N)	Home Country
Belaynesh Assema	F	Haramaya University	MS	Rural Development	Apr-17	Y	Ethiopia
Gizachew Girma	M	Ambo University	MS	Crop Protection	Jun-17	Y	Ethiopia

Ethel Xolile Magoso	F	Tshwane University of Technology	B Tech	Agriculture (Crop Production)	Apr-18	N	South Africa
Hamis Wambura	M	Sokoine University	MS	Ecosystem Sciences and Management			Tanzania
Joyce Christopher	F	Sokoine University	MS	Ecosystem Sciences and Management			Tanzania
Leticia Musese	F	Sokoine Univeristy	MS	Ecosystem Sciences and Management	Jun-17	Y	Tanzania

Rice, Maize, and Chickpea IPM for East Africa							
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
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
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
Josphat Korir	M	University of Nairobi	PhD	Agricultural Economics	June 2019	N	Kenya
Bonaventure January	M	Sokoine University of Agriculture	PhD	Agricultural entomology	June 2019	N	Tanzania
Ibrahim Hashim	M	Sokoine University of Agriculture	PhD	Plant Pathology	June 2019	N	Tanzania

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
Muntasir Hasan	M	Virginia Tech	MS	Agricultural Economics	August 2017	Y	Bangladesh
Feyisa Bekele	M	Hawassa University	MS	Weed Science	December 2018	N	Ethiopia

Habtom Hagos	M	Ohio State University	MS	Horticulture	January 2019	N	Ethiopia
Kumsa Did	M	Hawassa University	MS	Entomology	December 2018	N	Ethiopia
Kumsa Dida	F	Hawassa University	MS	Entomology	September 2018	N	Ethiopia
Yosef Beriun	M	Hawassa University	MS	Plant Pathology	December 2018	N	Ethiopia
Cecilia Ngugi	F	University of Nairobi	PhD	Entomology	June 2018	N	Kenya
Charity Gahambini	F	University of Nairobi	PhD	Plant Pathology	June 2019	N	Kenya
Denis Nyamu	M	Ohio State University	MS	Entomology	June 2019	N	Kenya
Joshua Kinene	M	Chuka University	MS	Entomology	December 2018	N	Kenya
Ester Rehema Matendo	F	SUA	MS	Entomology	December 2017	N	Tanzania
Happiness Christopher	F	SUA	MS	Plant Protection	December 2017	N	Tanzania
Hellen Kanyagha	F	Ohio State University	PhD	Plant Pathology	December 2019	N	Tanzania
Peter A. Maerere	M	SUA	MS	Entomology	December 2017	N	Tanzania
Tumsifu Samwel	M	SUA	MS	Plant Protection	December 2017	N	Tanzania

ii) Students who completed their degree and their employment details

Student name	Degree	Employer	Employed in field	Home Country
Mr. Ganga Shah	MS	Mid west University, Kanchanpur, Nepal	Yes	Nepal
Ms Vishubha Thapa	MS	Mechi Multiple College, Nepal	Yes	Nepal
Ms. Mafruha Afroz	PhD	Bangladesh Agricultural Research Institute, Gazipur, Bangladesh	Yes	Bangladesh
Ms. Belaynesh Assema	MS	Department of Rural Development, Wollo University, Ethiopia	Yes	Ethiopia

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.
Ethiopia: A candidate from --- University received her MS degree.
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 NAFAKA 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.
- Mass production of egg and larval parasitoids.
- 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)

- Prepared PERSUAPs for pesticides to be used for management of *Tuta absoluta* and fall armyworm.
- 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 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.
- Attended joint meeting of the IPM Regional Centers in Washington, DC.
- Organized a meeting for the Technical Advisory Committee and the Program Coordinating Committee in Ethiopia in July 2017.
- Attended the Innovations Lab Council Meeting is Washington DC in September 2017.
- 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.

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.

Achievements: The larval parasitoid, *Habrobracon hebetor* has been produced in the Labs at Niamey and Maradi and provided to the farmers cooperatives for mass production and field release in the fields for control of pearl millet headminer. An egg parasitoid, *Trichogrammatoidea armigera* collected on pearl millet headminer in the field is also multiplied in the lab for field release. This parasitoid has been found to parasitize eggs of pearl millet stem borer in the lab.

Capacity Building: Two PhD and two MS students are currently supported by this project. One project-supported MS student graduated.

Lessons Learned: Several steps involved in mass rearing of the egg parasitoid have been worked out. The facility at ICRISAT, Niamey could be developed into a lab for providing regional training.

Presentations and Publications:

Guerci, M.L., G.W. Norton, M.N. Ba, I. Baoua, J. Alwang, L. Amadou, O. Moumouni, L. Karimoune, and R. Muniappan. 2018. Economic feasibility of an augmentative biological control industry in Niger. Crop Protection (Submitted for publication).

Ba, N., I. Baoua, A. Kabore, L. Amadou, L. Karimoune, H. Salha, L. Dabire, and R. Muniappan. 2016. Towards development of a parasitoid cottage industry in the Sahel for biological control of the millet head miner. International Congress of Entomology, Orlando, Florida.

XIII. Issues

- 40% budget cut in the FY 2017 impeded several planned activities. Not releasing funds in time 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. 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*, *Beauvaria*, *Metarhizium*, *Bacillus thuringiensis*, and nucleopolyhedrosis viruses.

Obtain permits and establish natural enemies of *Parthenium* in Uganda and Kenya. Spread and establish natural enemies *Zygogramma hysterophorus* and *Listronotus setosipennis* throughout Ethiopia. Model spread of *Tuta absoluta* and other invasive species.

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

Appendices

Appendix A: List of awards given to U.S. partners (University, USDA, Private Sector, etc.)

Integrated Pest Management Innovation Lab 2014-2019			
U.S. Partner Awards			
Institution	**Project Name**	**FY 2017 Funding**	**Total Funding to date**
Ohio State University	Vegetable crops and mango IPM in Asia	26,623.00	81,706.00
Ohio State University	East Africa IPM Innovation Lab: Research and Technology Transfer for Vegetable Crops	386,286.00	766,654.00
Pennsylvania State University	Vegetable crops and mango IPM in Asia	10,000.00	64,380.00
Washington State University	Vegetable crops and mango IPM in Asia	4,725.00	11,970.00
Washington State University	Strengthening production and export of Vietnamese fruit crops through innovative and market-oriented IPM	-	21,958.00
International Development Enterprises	Vegetable crops and mango IPM in Asia	175,657.00	328,888.00
City University of New York	Participatory biodiversity and climate change assessment for integrated pest management in the Chitwan-Annapurna Landscape, Nepal	111,640.00	340,969.00
Mizellidae, LLC	Strengthening production and export of Vietnamese fruit crops through innovative and market-oriented IPM	-	13,751.00
Virginia State University	Biological Control of the Invasive Weed *Parthenium hysterophorus* in East Africa	87,646.00	229,312.00
North Carolina State University	A High-resolution Interaction Based Approach to Modeling the Spread of Agricultural Invasive Species	41,918.00	41,918.00
TOTAL		$ 844,495.00	$ 1,901,506.00

Appendix B: Success Story on Biocontrol of Parthenium hysterophorus Weed in Ethiopia

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

USAID
FROM THE AMERICAN PEOPLE

Innovation Lab for Integrated Pest Management

Leveling the playing field in the fight against *Parthenium*

Two biological agents are damaging the invasive weed parthenium in the Amhara Region of Ethiopia. Large tracts of farmlands and pastures in Ethiopia are infested by the invasive weed *Parthenium* (*Parthenium hysterophorus*). *Parthenium* reduces yields of major crops and replaces valuable pasture species, decreasing livestock productivity. *Parthenium* also makes people sick, causing both skin and respiratory allergies, and displaces native plant species, damaging the region's biodiversity.

In order to combat this weed, a project led by Virginia State University and funded by USAID through the Feed the Future Innovation Lab for Integrated Pest Management at Virginia Tech has released two bioagents, the leaf-feeding beetle (*Zygogramma bicolorata*) and stem-boring weevil (*Listronotus setosipennis*). On June 20, 2017, thousands of adult *Zygogramma* and hundreds of *Listronotus* were released at several parthenium-infested sites around the town of Finote Selam.

By mid-August 2017, the bioagents were thriving and damaging *Parthenium*. The *Zygogramma* kills *Parthenium* by defoliating its leaves while *Listronotus* inflicts damage to the weed from inside by burrowing its stem. In addition, native vegetation is starting to make a comeback as Parthenium is weakened.

Zygogramma has also moved from the release site to nearby *Parthenium*-infested fields to feed on the weed. *Listronotus* also started to damage nearby *Parthenium* plants. At the new sites, staff observed larva and newly emerged adults of *Zygogramma*, indicating that the bioagent is reproducing and new generations are in action against the invasive weed.

The effect of *Zygogramma* on *Parthenium* seen at Finote Selam (altitude 6000 ft) are similar to what was observed in Wollenchiti (altitude 4700 ft) after the release of this bioagent in 2016. In Wollenchiti, *Zygogramma* fed on parthenium on the spot it was released near a railway track and then moved to nearby bean and teff fields that were infested by the weed. *Zygogramma* defoliated *Parthenium* without touching the bean and teff crops, showing it only attacks the weed and it is safe to other plants.

However, this is just the beginning of the effort to manage *Parthenium* using natural enemies in Amhara and other regions of Ethiopia. It will require releasing large number of adults of the bioagents at multiple sites in different parts of the country over several years. This biocontrol program will require patience and effort over several years to be successful, but the potential for sustained control of *Parthenium* in Ethiopia is very promising.

The leaf-eating beetle, *Zygogramma*, on a *Parthenium* leaf.

A technician at the biocontrol rearing site in Wollenchiti, Ethiopia with a *Parthenium* plant

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Appendix C: Success Story on Management of Canker Disease of Dragon fruit on Vietnam

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

USAID
FROM THE AMERICAN PEOPLE

Innovation Lab for Integrated Pest Management

A simple solution to Vietnam's big dragon fruit problem

The dragon fruit is one of Vietnam's principal fruit crops, growing on approximately 36,000 hectares with 140,000 tons of production each year. It plays an important role in the country's economy because of its high export value compared to other locally grown fruits. It is one of the four crops that the Feed the Future Innovation Lab for Integrated Pest Management works on in its Exportable Fruit Crops in Vietnam project due to its economic importance.

However, this high value crop is threatened by a number of pests and diseases, the most serious being canker (*Neoscytalidium dimidiatum*), a fungal disease. The canker disease was first recorded in Vietnam in 2009 and by 2013 it had spread to over 10,000 hectares causing losses of dragon fruit ranging from 30-70 percent in individual fields. The disease is most severe during the wet season when infected fruits are not even suitable for sale in the domestic market. Farmers' attempts to manage this disease have resulted in high pesticide use and residues, making the fruit unacceptable for sale and export due to the market restrictions and demands.

The IPM Innovation Lab and its Vietnamese collaborator, the Southern Horticulture Research Institute, began working on a way to solve this problem. What they developed was a plastic sleeve to manage the canker along with other pests. Fruit bagging is a relatively common method for controlling pests on a variety of fruit crops, but not all bags are created equal given the specific farming practices of dragon fruit in Vietnam.

Dragon fruit in one of the IPM Innovation Lab plastic bags.

The project ran a study to evaluate the effectiveness of different types of fruit bags, looking at both the issues of fruit quality and cost to the farmers. They found a plastic sleeve made in Vietnam the resolved both the issues of cost as well as farming methods. The plastic sleeve cost only 300 VND a piece (roughly one cent) whereas the next cheapest option cost 800 VND, more than double the price, and others cost up to 5000 VND per bag.

In addition, in order to adhere to the Chinese import standards, a foliar spray must be applied to the fruit five to six times per growing cycle (which is 52-55 days). Some of the other bags had to be discarded after being opened for the spraying, raising the price. The plastic bags were able to keep their shape, so the farmers could easily spray and continue using the same bag. Furthermore, the plastic bag is transparent, allowing farmers to monitor the fruit's growth and quality.

Testing showed that canker disease incidence and severity in the IPM test areas using the plastic sleeves were significantly lower than those that did not use the sleeves. Moreover, the dragon fruits in the plastic sleeves also showed lower populations of insect pests such as green stink bugs and fruit flies. Based on these promising results, Vietnamese farmers are now using the plastic sleeves as one component in an integrated approach for the management of dragon fruit diseases and pests.

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Appendix D: Success Story on "Push-Pull" Technology for Management of Maize Pests

Maize is one of the most important crops in East Africa, but it is seriously challenged by many diseases and pests, such as the stemborer insect and the invasive weed striga. The IPM Innovation Lab Grains IPM for East Africa, which works on maize along with rice and chickpea in Ethiopia, Kenya, and Tanzania, is implementing technologies to improve maize yield.

One such technology is the push-pull method, developed by scientists at the International Centre of Insect Physiology and Ecology in Kenya, the same center that is currently leading the IPM Innovation Lab project. Push-pull is an environmentally friendly and drought resistant technology that helps protect maize by controlling against the stemborer and striga.

The push-pull technology is an intercropping system, meaning that it works by growing other plants along with maize in the same field. These plants have functions that help protect the maize from pests. The push-pull system works in two ways. The "push" comes from planting species, such as *Desmodium*, that emit chemicals that repel stemborer moths to drive them away from the maize. These plants are intercropped among the maize. *Desmodium* is a low-growing plant so it does not interfere with the maize's growth and additionally, it helps contribute to soil stability and fertility. And beyond repelling the stemborer, it also suppresses striga weeds.

The "pull" comes from planting border crop for the maize, such as the grass, Brachiaria. This protects the crop and also attracts the stemborers. This grass is planted around the border of the field. The adult stemborer moths become attracted to this grass instead of the maize and do not enter the main growing area. In addition, these grasses are also excellent hosts to the stemborers' natural enemies.

Currently, the IPM Innovation Lab and ICIPE project are implementing push-pull in the three program countries. In the Oromia and Southern Nations and Nationalities and Peoples Regional States of Ethiopia there are more than 200 demonstration farms, three farmer training centers, and two schools all focused on spreading this vital technology. In Kenya, over 40 farmers are being trained in the Kericho, Nakuru, and Naivasha counties. And in the Motombo Village in the Morogro Region of Tanzania, the project is already working with 11 farmers.

Adopting the push-pull technology has already had a very positive effect on maize production and productivity, women's empowerment, nutrition, and farmer income. For example, in Tanzania alone, crop yield increased by nearly 25 percent.

By using push-pull technology, along with other IPM practices, the Grains IPM in East Africa project is increasing crop productivity, yield, soil fertility, and farmer income and empowerment in the three target countries.

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