

FINAL REPORT

External Evaluation Team of the Feed the Future Innovation Lab for Integrated Pest Management

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Table of Contents

List of Acronyms	ii
List of Tables	iv
List of Figures	v
Executive Summary	vi
Acknowledgements	ix
Chapter 1: Introduction	10
Chapter 2: Management and Implementation	18
Chapter 3: Technology Development	37
Chapter 4: Stakeholder Collaboration for Enabling Environments	63
Chapter 6: Program Future.....	111
Chapter 7: List of Recommendations from the External Evaluation Team.....	117
References	120
Appendix 1: Credentials of the External Evaluation Team Members	121
Appendix 2: Scope of Work for the External Evaluation Team	137
Appendix 3: Summary of IPM IL Collaborator Survey	143
Appendix 4: IPM IL Publications provided by IPM IL ME to the External Evaluation Committee.....	169
Appendix 5: Trip Report of S. Shanmugasundaram (Sundar) and Jacob Ricker-Gilbert to Virginia Tech; Blacksburg, VA	219
Appendix 6: Report of S. Shanmugasundaram (Sundar), Team Leader, External Review of IPM IL to East Africa (Ethiopia and Tanzania).....	Error! Bookmark not defined.

List of Acronyms

AGRA	Alliance for a Green Revolution in Africa
AO	Agreement Officer
AOR	Agreement Officer's Representative
APHIS	Animal and Plant Health Inspection Service
APSA	Asia Pacific Seed Association
ASD	Anaerobic Soil Disinfestation
AVRDC	Asian Vegetable Research and Development Center
BARI	Bangladesh Agricultural Research Institute
BFS	Bureau of Food Security
BIFAD	Board for International Agricultural Development
CABI	The Centre for Agriculture and Bioscience International
CARDI	Cambodian Agricultural Research and Development Institute
CBF	Community Business Facilitators
CGIAR	Consultative Group for International Agricultural Research
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo
CIP	Centro Internacional de la Papa
CIRAD	Centre de Cooperartion Internationale en Recherche Agronomique
CIRED	Center for International Research, Education and Development
CN	Concept Note
CRS IL	Climate Resilient Sorghum Innovation Lab
CRSP	Collaborative Research Support Program
CS	Consumer Surplus
CTBS	Community Trap Barrier System
CUNY	City University of New York
DAE	Department of Agricultural Extension
DFID	Department for International Development
EA	Extension Agent
ECBEE	Economic Crop Based Ecological Engineering
EFSB	Eggplant Fruit and Shoo Borer
EPIC	Ecologically-Based Participatory IPM Package for Rice in Cambodia
EU	European Union
FAMEWS	Fall Army Worm Early Warning System
FAO	Food and Agriculture Organization
FAW	Fall Army Worm
FC	Financial Coordinator
FGD	Farmer Group Discussion
FP	Full Proposal
FPPHH IL	Food Processing and Post-Harvest Handling Innovation Lab
FtF	Feed the Future
GAP	Good Agricultural Practice
GDAC	General Directorate of Agriculture in Cambodia
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GKSS	Grameen Kalyan Sangharsh Samiti

GMO	Genetically Modified Organism
GTFFAW	Global Task Force for Fall Army Worm
Hort IL	Horticulture Innovation Lab
HQ	Head quarters
HUA	Hawassa University of Agriculture
IAPPS	International Association of Plant Protection Sciences
IARC	International Agricultural Research Center
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
icipe	International Center for Insect Physiology and Ecology
ICRISAT	International Crop Research Institute for Semi-Arid Tropics
ICT	Information and Communication Technology
iDE	International Development Enterprise
IITA	International Institute for Tropical Agriculture
INGENAES	Integrating Gender and Nutrition within Agricultural Extension Services
INRA	Institut National de la Recherche Agronomique
IPM	Integrated Pest Management
IPM IL	Integrated Pest Management Innovation Lab
IPW	Inverse Probability Weighting
IPWRA	Inverse Probability Weighted Regression Adjustment
IRR	Internal Rate of Return
IRRI	International Rice Research Institute
LS IL	Livestock Innovation Lab
LTBS	Linear Trap Barrier System
MAFF	Ministry of Agriculture Fisheries and Forestry
ME	Management Entity
MHM	Millet Head Miner
MCC	Mennonite Central Committee
NAFAKA	Cereals Marketing System Development Project in Tanzania
NAPDN	National Plant Diagnostic Network
NGO	Non-Government Officer
NARCs	National Agricultural Research Centers
NARS	National Agricultural Research System
NPV	Net Present Value
OSP	Office of Sponsor Programs
OSU	Ohio State University
PCC	Program Coordinating Committee
PERSUAP	Pesticide Evaluation Report and Safe Use Action Plan
PI	Principal Investigator
POPS	Policies and Operating Procedures Manual
PPT	Push-Pull Technique
PS	Producer Surplus
PSM	Propensity Score Matching
RCBD	Randomized Complete Block Design
RFA	Request for Applications
RGD	Rapid Gender Assessment

RUA	Royal University of Agriculture
RYMV	<i>Rice yellow mosaic virus</i>
SI IL	Sustainable Intensification Innovation Lab
SM IL	Sorghum and Millet Innovation Lab
SOFRI	Southern Horticultural Research Institute
SPSS	Statistical package for Social Sciences
SUA	Sokoine University of Agriculture
TAC	Technical Advisory Committee
TLM	Tomato Leaf Miner
TNAU	Tamil Nadu Agricultural University
VND	Vietnam Dong
VSU	Virginia State University
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
UN DESA	United Nations Department of Economic and Social Affairs
UVA	University of Virginia
VIAMO	Via Mobile
VT	Virginia Tech
WBS	Witches Broom Syndrome

List of Tables

Table 1: Current projects and Principal Investigators for the IPM IL	23
Table 2: List of consultations with the mission in each country and participating institutions....	26
Table 3: Associate awards and grants secured by the administration for IPM IL Phase V	32
Table 4: IPM IL Phase V Budget Breakdown	35
Table 5: Number of <i>Zygogramma bicolorata</i> and <i>Listronotus setosipennis</i> released from 2016-2018.....	45
Table 6. Different meetings organized by IPL IL, 2014-2018	65
Table 7: Meetings conducted by IPM IL groped according to subject matter.....	65
Table 8: Different groups of participants in IPM IL organized meetings.....	66
Table 9. IPM IL Long-term training by country and by gender from 2014-2018	78

Table 10. Number of people receiving long-term training on the IMP IL 2014-2018, by sub-grant, degree, and gender	78
Table 11. Number of people receiving short-term training on the IMP IL 2014-2018, by sub-grant, and gender	82
Table 12: Studies assessing net benefits of IPM technologies and practices	97
Table 13: Net Present Value (NPV) and Internal Rate of Return (IRR) for Vegetable IPM in Bangladesh.....	98
Table 14: Progressive increases in number of demonstration trials in Ethiopia, Kenya and Tanzania 2016-2018	98
Table 15: Yield increases in maize due to PPT over control in Ethiopia, 2016-2018.....	98
Table 16: Achievements against initial target indicators for rice, maize and chickpea in Ethiopia, Tanzania and Kenya (Aggregate number)	99
Table 17: Collaborator Survey, If USAID renews the IPM IL for a new phase, please rank what you view as priorities for the project	117

List of Figures

Figure 1: The original structure of IPM IL	20
Figure 2: Recommended revised structure of IPM IL ME	20
Figure 3: Dragon fruit, longan, lychee, and mango (from left to right).....	38
Figure 4: 1) Mango fruits with wax paper bags, 2) mesh plastic bags for longan fruit clusters, 3) light trap for longan with mesh bag, 4) plastic sleeves for dragon fruit buds, 5) Plastic sleeves for dragon fruit flower	39

Figure 5: <i>Trichoderma</i> , pheromone trap, Neem seed extract sold in the market.....	43
Figure 6: <i>Zygogramma bicolorata</i> , B. <i>Epiblemma strenuana</i> C. <i>Listronotus setosipennis</i> D. <i>Carmentis nr. Ithaca</i>	46
Figure 7: IPM IL engaged with the mission, mission project, private sector and farmers	67
Figure 8. Distribution of publications by project from IPM IL Phase V	81
Figure 9: Multiple benefits of Push Pull Technology that is used to control maize stem borer, FAW, and Striga	100

Executive Summary

Integrated Pest Management Innovation Lab's origin (IPM IL) dates back to 1993 when it was known as the IPM Collaborative Research Support Program (CRSP). The project began with institutionalization, then regionalization and globalization. The current (fifth) phase includes invasive species monitoring, forecasting and management. In the past 25 years the IPM IL has made significant advances in combating pest problems through IPM and reducing the use of pesticides. The success of the the IPM IL has increased the income of poor small-scale farmers in the Feed the Future (FtF) countries. For example, in Bangladesh, the benefit due to adoption of IPM in tomato (cultural practices) is estimated at US\$21-24 million; the net benefit for cucurbits due to IPM (Pheromone traps) is estimated at USD\$3-6 million; for eggplant and cabbage pest control using IPM (cultural practices), the net benefit is estimated at US\$26-29 million (Fayad, 2013). The largest estimated impact is due to papaya mealybug control using IPM (biocontrol agent). The net benefit is estimated to be between US\$500 million to 1,340 million over five years (Myrick, et. al., 2014). IPM IL's budget for the past 20 years is US\$50 million. Given these estimated net benefits, the benefit: cost ratio for USAID's investment in the IPM IL is between 15-35:1 (Fayad, 2013).

A two-member External Evaluation Team was commissioned to review the IPM IL phase V from December 1, 2018 to January 31, 2019 and provide the management entity (ME) and USAID with a constructive report on the progress, performance, conclusions and recommendations of basic, applied and adaptive research, along with extension, impact assessment, gender and scale-up based on evidence. Also, offer an assessment of rationale for extending the IPM IL for another 5 years.

The team met with the ME, two technical advisory committee members (TAC) and some team members at Virginia Tech (VT) for one and half days to gather information. The team leader also visited Ethiopia and Tanzania, for 10 days, where the project members briefed him on the progress of their activities and interacted with farmers during field visits. This report is the outcome of EET's extensive and in-depth review of documents (provided by ME), surveys, personal contacts and literature review. A survey of the host country collaborators was conducted and the results were used in the assessment.

The EET commends the VT ME for freely providing all the information and data throughout the evaluation period. In general, the administration and fiscal management is smooth for the eight-project program. However, it is important to note that following the approval of the project, the protocol to have consultation with the missions in the seven countries took time before Request for Applications (RFAs) were released. In spite of careful planning, one of the projects with CUNY was terminated due to poor performance and one of the scientists had to be dropped and a PI had to be changed. The ME was able to identify the problem while reviewing the first-year progress and the decision was approved by the TAC and AOR. Furthermore, funding cuts necessitated the termination of the Asia and Africa manager positions. This is the second time in the life of IPM IL funding has been reduced. Delays in receiving funding have constrained most of the partner activities, which is beyond the control of AOR and ME. The ME should be commended for managing to strengthen the program through Associate awards, buy-ins, grants and leverage funds in the amount of US\$349,017.

The TAC has critically reviewed the proposals and progress and has given its suggestions and recommendations for the ME and AOR. AOR is constantly in touch with the ME and monitors the progress through participation in the annual review and visiting the sites.

The following technologies are reaching a stage where they are ready to be scaled-up:

- Various types of bagging exportable fruit crops to protect them from pests and diseases in Vietnam
- Use of *Trichoderma*, Coco-peat, pheromone traps, bio-pesticides (*Beauveria*), and raising seedlings under nylon net in Bangladesh, Cambodia, and Nepal, and grafting, Bt eggplant, and bagging mango fruits to control insects and diseases in Bangladesh.
- PPT to control maize stem borer, *Striga* and potentially FAW in East Africa
- Control of invasive weed *Parthenium* using biocontrol agents
- Improved rice varieties in Cambodia (CAR 14) and Tanzania (SARO and KUMBOKO) to combat rice blast and RYMV; and use of *Trichoderma* and *Bacillus subtilis* to control rice blast.
- Improved maize hybrids and chickpea varieties, Arerti and Habru to combat blight and wilt.
- Participatory IPM of vegetables in East Africa.

The use of plastic sleeves, plastic mesh bags or wax paper bags to protect the exportable fruit crops has been well received by fruit growers in Vietnam. It is labor-intensive, and bagging fruits in crops like mango, longan and lychee are cumbersome due to height. Labor is also in short supply. Therefore, a socio-economic analysis of the technology is warranted. IPM of vegetable and mango in Asia, PPT for maize stem borer control and control of *Parthenium* are projects continuing from phase IV, and impact studies are recommended for them. Two modeling projects, one from Biocomplexity institute at VT and another at Tribhuvan University in Nepal are primarily basic research to forecast and predict the invasive pests. USAID has established a FAW taskforce. FAO has recently established a global task force for FAW monitoring and Early Warning System (FAWM&ES) with CABI (<http://www.fao.org/fall-armyworm/en/>) provides information in real time on a global level. However, IPM IL, using limited data set, was able to predict correctly the movement of FAW eastwards from Sudan to Yemen. Furthermore, the modeling project has successfully provided a Risk Assessment of FAW to USAID mission in Egypt. More importantly, IPM IL is the only one carrying out modeling on *Tuta absoluta* around the world.

IPM IL, in consultation with the Missions in the participating countries and other stakeholders identifies the demands and addresses the problems using IPM technology. For

example, at the request of USAID mission in Egypt IPM IL undertook a study on the spread of and food security risk due to FAW. Again, IPM IL in collaboration with ICRISAT-Niger responded to an RFA issued by SM IL and secured the sub-award for control of pearl millet head miner. In order to foster such inter-Innovation lab collaboration, efforts should be made in the program formative stage, through consultation with concerned parties with the help of AOR and the Mission staff. Such consultations should also encourage the mission value chain and the private contractors to strengthen their collaboration with IPM IL using their resources and the expertise from IPM IL. It will be a win-win situation for both.

IPM IL has brought together the stakeholders through training workshops, farmer field days, planning meetings, annual review meetings, consultations and seminars. The number of participants in these meetings are impressive and nearly 40% of the total are women:

• Number of farmers and EA in training workshop from 7 countries	9,096
• Number of farmers participating in Farmer Field Days	7,859
• PPT meeting	1,399
• <i>Tuta absoluta</i> meeting	1,188

IPM IL has established collaborative linkage with a number of NGOs, Mission value chains, private contractors and to a certain extent invited private sector in Asia and Africa to participate to achieve their objectives. IPM IL prepares the Pesticide Evaluation Report and Safer Use Action Plan (PERSUAP) and it is approved by the USAID Environmental Officer, AOR and Director of BFS.

The program has remarkable accomplishment in terms of long-term and short-term training. A total of 88 men (48) and women (40) were enrolled for M.S. or Ph.D. training. Around 14,492 people received short-term training. In terms of publications both the project members and the ME were very prolific in bringing out a remarkable 651 publications of different kinds (ME with 165 and all projects with 486). EET commends their aggressive effort to publish quality papers in reputed journals. Recommendations are given to encourage the graduate students to be creative and innovative.

Impact analysis of IPM for six vegetables in Bangladesh showed a net present value (NPV) of \$768,625 and an IRR for eggplant 42%, for tomato, 39% and for cucumber 30%. Detailed impact analysis needs to be conducted in the next phase for other countries. For example, the number of PPT conducted in 2016 in Ethiopia, Kenya and Tanzania was 33 and in 2018 it increased to 930. The project is planning to extend the technology to 24 Kebeles and each Kebeles has 8000 farmers; that is a total of 192,000 farmers. The Rice, Maize and chickpea project has set targets for each activity and report the achievements so that one can easily see the accomplishment. For example, farm households practicing IPM in Ethiopia achieved 110% of the target while the women's group practicing IPM reached 370% of the target. EET hopes that the ME insists on other projects to follow the example of Rice, maize and chickpea project in reporting their progress. As shown in the case of PPT in maize, impact has multi-dimension—farmers, children, health, animals, cost reduction, reduced pesticide use, improved income soil health and sustainability and such benefits need to be uncovered from impact studies. Based on the successful outcome of the ongoing project recommendations are made for scaling up and impact studies.

The two modeling projects have a number of graduate students who are expected to complete their studies and degree by the end of the project. These two projects have impact on policy by Governments to take timely action to institute pest management to avert disaster. They also help in prompt awareness creation.

When using biocontrol agents to control the pests, the impact depends on the ease with

which the biocontrol agents can be mass multiplied and released in strategic locations and how fast the biocontrol agents spread and their adaptation. For example, mealybug spread 50 to 100km per year within the country but with unintended human assistance it can cross oceans and move from one continent to the other. Since 2000, papaya mealy bug has spread from its native place in Mexico to all over the world. After the control, there was no resurgence of mealybug which helped in the control of mealybug. Continued research is the driving force to achieve sustainable results. Continuity of investigation is extremely important to sustain the momentum of activities conducted in Phase V. Experience of IPM IL enables them to ensure continued successful implementation of the project and produce significant achievements. EET strongly recommends that the IPM IL be continued for another term. Priorities for the next phase have been provided in the following pages.

Acknowledgements

The external evaluation team would like to thank the members of the IPM IL Management Entity: Rangaswamy Muniappan, Amer Fayad, Zara Shortt and Sara Hendery, for their support willingness to share information as we completed this report, and for hosting us during our visit to Blacksburg in December, 2018. We are also grateful to John Bowman from USAID for providing us the opportunity to engage in this evaluation. We also appreciate Tadele Tefera and the rest of the IPM IL collaborators and farmers in East Africa who hosted S. Shanmugasundaram on this site visit during December, 2018. We also thankful to all of the other collaborators on the IPM IL who took time to complete the collaborator survey and provided us with additional information for the report. In addition, we appreciate Rajeswaran Shanmugasundaram design for the cover page. All views expressed in this report are those of the external evaluation team and we take responsibility for any errors.

Chapter 1: Introduction

The world's current population of 7.5 billion is projected to reach 9.7 billion by 2050. Asia has the largest share of the world's population at 60% while Africa's share currently stands at 15%. While the population will increase on both continents, Africa's population growth rate is accelerating and demographers expect that the continent will hold 25% of the world's population in 2050 and 54% in 2100. Conversely, Asia's population will fall to 54% in 2050 and 44% in 2100 (UN DESA Report). These population growth scenarios, along with rising incomes on both continents will most certainly cause demand for food to increase. At the same time, threats to production such as climate change, increased pest and disease pressure and volatile prices of agricultural inputs and outputs put tremendous pressure on the food system to produce enough food to meet this growing demand. The current situation dictates that governments in Africa and Asia along with the private sector and donor community make strategic investments to enhance agricultural land and labor productivity in order to improve food security on both continents.

Smallholder farmers in both Asia and Africa grow a wide variety of crops for home consumption and marketing. The major staple food crops in Asia are rice, wheat and millets and grain legumes. In Africa they are maize, sorghum, cassava, millets and grain legumes. Grain legumes (also called pulses), such as common bean, cowpea, groundnut, pigeon pea, mung bean, chickpea and soybean, fix nitrogen in the soil providing productivity benefits. In addition, grain legumes along with vegetable and fruit crops compliment the calorie-rich, staple crops and play an important role in providing a balanced nutrition with plant proteins, vitamins, minerals, antioxidants, and plant fiber.

The yields of many crops are improving, thanks to the dedicated work of National Agricultural Research Centers (NARCs) in Asia and Africa, local universities, along with the

CGIAR and other International Agricultural Research Centers. However, pests, pathogens and weeds are a constant threat that often damage a considerable portion of the crops produced by poor, smallholder, and subsistence farmers. The annual crop production loss due to arthropods worldwide is estimated to be around 18-26% valued at \$470 billion (Culliney, 2014), with the majority of these losses occurring in Asia and Africa. However, accurate figures are hard to come by for these regions due to paucity of data. Farmers in these regions largely depend on inorganic pesticides (e.g.: insecticides, fungicides herbicides, and rodenticides) sold by commercial dealers to manage pest and disease problems. Clearly, pesticide dealers' incentives are to sell pesticides, so a common scenario is that when a farmer contacts a pesticide dealer, he or she often receives a recommendation, mixture of pesticides, simply based on his or her crops' symptoms rather than any visit or diagnosis of the farmer's field. Thus, inappropriate or indiscriminate use of pesticides increases the cost of production to the farmers, reduces their income, and more importantly exposure to pesticides poses a serious threat to human and animal health. In addition, pesticides pollute the environment and natural resources like rivers, streams and wells.

In an effort to reduce pesticide use to a sustainable, and profit maximizing level, stakeholders including researchers, extension services and farmers themselves have worked together to develop a strategy called integrated pest management (IPM) in 1959 (<https://www.cabi.org/BNI/FullTextPDF/2018/20183174927.pdf>). IPM is a broad-based ecosystem approach that focuses on long-term prevention of pests (including insects, diseases and weeds) or their damage through a combination of techniques such as biological, habitat manipulation, modification of cultural practices and the use of resistant varieties. IPM also allows for the judicious use of chemical pesticides or a combination of one or more of them. The main objective of IPM is to suppress pest populations below the threshold economic injury level, by

tailoring packages of recommendations and practices to meet the needs of specific locations, seasons and crops. Ultimately, IPM seeks to avoid pesticide residue, while improving farmers' incomes and protecting the environment in a sustainable manner.

Since existing pests are continually adapting and new pests are always emerging in different locations, it is essential to invest in IPM research that can identify problems and provide potential solutions that are appropriate, environmentally friendly, and economical for farmers, while at the same time considering nutrition, health and concern for biodiversity. Successfully diffusing and scaling-up IPM technologies and practices that researchers develop, will help improve the income of smallholder farmers in the developing world who have limited resources and help to ensure food and nutritional security for a growing population. In addition, IPM technologies and practices have the potential to benefit women and youth in the developing world, as invariably women and youth are involved in crop production, processing and marketing. Enabling these underserved groups with the research outputs will empower them to efficiently produce grains, vegetables and fruits and assure improved income, safe food and nutritional security aligning with the FtF Global Food Security Research Strategy.

The United States Agency for International Development (USAID) recognizes the need to help small-scale poor farmers in Africa and Asia adopt and implement IPM technologies and practices in a sustainable manner. As a result, beginning in 1993 USAID provided support for an IPM Collaborative Research Support Program (CRSP), based at Virginia Tech (VT). The IPM CRSP ran for ten years in two five-year phases. Based on the performance of the first ten years and Virginia Tech's successful recompetition, the project was extended to another ten years in 2005, which again occurred in two five-year phases. During the second of the two phases (phase IV), between 2009-2014, the CRSP evolved into one of 22 Feed the Future (FtF) Innovation Labs,

President's initiative - IPM Innovation Lab (IPM IL).

During the 2009-14 phase, 52 staff members from 15 US universities along with partners from 16 countries in six geographical regions collaborated with the IPM IL. Governmental and non-governmental institutions in East Africa and South Asia have had a long-standing relationship with the IPM IL dating back to its inception as a CRSP in 1993. In the past 25 years, the IPM IL has adapted and evolved, using basic and applied research, along with input from farmers and extension personnel in focus countries to develop and deliver effective IPM packages for smallholder farmers. The IPM IL has used lessons learned from these experiences to refine their strategies. One successful model for collaboration developed and used by the IPM IL is the “mature partners as mentors” system where researchers and implementers from experienced partner institutions and countries train and support partners from new institutions and countries. For example, researchers from Tamil Nadu Agricultural University (TNAU) in Coimbatore, India who were successful partners of IPM IL in earlier phases with *Trichoderma spp.* production and use to control soil borne pathogens are recruited to serve as mentors to train the partners of IPM IL in Cambodia, Ethiopia and Tanzania in the current phase. This model has worked very well. In addition, the IPM IL has many other documented success stories. Perhaps the best example of quantitative impact from the IPM IL is the identification and documentation of the papaya mealybug, *Paracoccus marginatus* in India in 2008 by IPM IL director Rangaswamy Muniappan. Muniappan recognized the white cottony mass on papayas in Tamil Nadu, India was due to papaya mealybug, and alerted the local authorities about the threat. The IPM IL was able to work with scientists in the US, along with the government in India and scientists there to introduce biological control in the form of three parasitoids, *Acerophagus papayae*, *Pseudleptomastix mexicana*, and *Anagyrus loecki* that attack the mealybug. Within five months of introducing the parasitoids the

mealybug was under control, pesticide use went down, and farmers' incomes went up. The lessons learned from this example is that 1) timely intervention is extremely important to control the pest problem with classical biological control program with aggressive parasitoids, 2) commitment by the Government agencies, and 3) a massive effort by the researchers, extension agents and farmers (they released about 57 million parasitoids). With only \$500,000 investment for four years the net present value of benefits of this IPM innovation over five years was estimated to be between U.S \$500 million-\$1.34 billion in India alone (Myrick et al., 2014). The return per dollar invested in ecologically-based biocontrol and cultural control of pests had been estimated to vary from \$30 to \$300 which is significantly higher than the \$4 estimated for the control achieved by the use of synthetic pesticides (Culliney, 2014). The magnitude of these benefits shows that IPM strategies have the potential for extremely high return on investment, justifying expenditure on IPM research, extension and scale-up.

In 2014, IPM IL recompleted and USAID renewed the project for a phase V, because of the project's success over the prior 20 years, and the continual threats that invasive pests pose to smallholder farmers in Asia and Africa. Phase V is the current phase of the project that is set to run until the end of November 15, 2019, and is a continuation of the collaboration between US universities, and partner institutions, along with international Agricultural Research Centers (IARCs) and selected host country institutions. The goals of the IPM IL in phase V are as follows:

1. measurably reduce crop losses due to pests
2. increase farmer income
3. reduce chemical pesticide use
4. reduce pesticide residue on export crops
5. improve IPM research, extension, and education program capabilities

6. improve ability to monitor and manage pests
7. improve ability to monitor, forecast, and manage invasive pest species and
8. increase the ability of women in IPM decision-making and program design

These objectives relate to research (both basic and applied), extension (in the form of communication and education of farmers) and scale-up (e.g.: developing and engaging private sector partners to market IPM innovations). The overall goal is to induce behavioral change that encourages farmers to adopt IPM. In addition, the IPM IL works with host country scientists, extension personnel and policy makers to build institutional capacity, promote policy and institutional reform, and engage and/or develop sustainable local enterprises.

The management entity (ME) of the IPM IL remains at Virginia Tech in phase V, and there are eight sub-grantees in this phase of the project. Four of the sub-grant projects focus on Asia, three focus on Africa and one focuses globally. These sub-grants focus on IPM issues in one or more of the following seven countries: Ethiopia, Kenya, and Tanzania in Africa, along with Bangladesh, Cambodia, Nepal, and Vietnam in Asia. Their project titles are as follows:

1. Strengthening production and export of Vietnamese fruit crops through innovative market-oriented IPM
2. Innovative scientific research and technology transfer to develop and implement IPM strategies for vegetable and mango pests in Asia
3. Participatory biodiversity and climate change assessment for integrated pest management in the Annapurna-Chitwan landscape, Nepal
4. Development of ecologically based participatory IPM package for rice in Cambodia
5. A high-resolution interaction based approach to modeling the spread of agricultural invasive species

6. Biological control of the invasive *Parthenium hysterophorus* in East Africa
7. Rice, maize and chickpea IPM for East Africa
8. IPM for vegetables in East Africa

At the end of 2018 and early 2019, the ME of IPM IL and the USAID (AOR) commissioned the performance evaluation of the IPM IL to evaluate the following:

1. Assess progress on activities and outcomes
2. Improve effectiveness of on-going activities
3. Provide robust evidence-based findings, conclusions and recommendations, assessing needs and opportunities, for tackling outstanding key research questions connected to IPM in developing countries and
4. Provide and assess as to the rationale for extending the IPM IL for another 5-years vs. undergoing a re-competition for 6-10 years. What critical aspects of momentum, impact and success might be lost if a decision is made to re-compete the lab instead of granting a 5-year extension

The primary audience and intended users of the EET report are the IPM IL ME, Bureau of Food Security (BFS)/USAID Program for Research, USAID Missions in countries and implementing partners and universities.

The EET consists of Dr. Subramanyam Shanmugasundaram (Team Leader), with 40 years of experience in international experience in research, administration, and development and Dr. Jacob Ricker-Gilbert, Associate Professor in the Department of Agricultural Economics at Purdue University with more than 10 years-experience (see EET CVs in Appendix 1).

The scope of work for the EET is given in appendix 2.

The EET used the following resources in preparing this report:

1. Document reviews: Project proposals, annual technical work plans, annual and semi-annual progress reports, project publications including research publications (Appendix 4), success stories, indicator outputs, pamphlets, books, posters, slide sets and other published materials provided by the ME
2. Key informant interviews: IPM IL researchers, IPM IL ME, selected country coordinators (Appendix 3)
3. Group discussions: Both EET team members visited VT from December 10-11, 2018 and met with IPM IL ME, some of the PIs and two Technical Advisory Committee (TAC) members (one in person and another over conference call), (a detailed trip report is provided in appendix 5).
4. Field visits to project sites in the participating regions: Dr. Shanmugasundaram visited East Africa (Ethiopia and Tanzania) from December 15-25, 2018 (a detailed trip report is provided in appendix 6).
5. Conference call: Communicated with some of the PIs with conference call
6. Email communication and interaction: The EET has communicated extensively with the ME, TAC members and other collaborators via email
7. Resources from Internet.
8. Conducted an email questionnaire survey, with 28 questions developed by the EET, of more than 100 collaborators in Asia, Africa and the US using Qualtrics software licensed to Purdue University.

Chapter 2: Management and Implementation

1. *Integrated Pest Management Innovation Lab (IPM IL) research themes*

The research themes for phase V of IPM IL focus on encouraging smallholder farmers in Asia and Africa to adopt IPM in order to i) reduce crop losses, ii) conserve ecosystems, iii) preserve biodiversity and iv) avoid pollution and contamination of natural resources. The eight sub-grant projects were chosen based on their teams' past successes, the need to continue some of the ongoing projects from phase IV, and their potential to make impact in specific crops and for specific pests or groups of pests. Two of these projects are region and globally based modeling projects that were instituted based on RFA issued by USAID for the current phase of IPM IL. Their forecasts can help avert disastrous damage to crops which would have negative implications for smallholder farmers, communities and countries. In general, modeling efforts require a massive amount of diverse data including crops, pests, weather, soil, trade, commodity prices, and other economic data from different geographical regions, for different seasons for several years. However, IPM IL has developed a model for spread of *Tuta absoluta* with minimal datasets.

IPM IL develops science-based IPM technology packages for specific crops, through basic and applied research. The IPM IL identifies new invasive pest species, makes government and other stakeholders in focus countries aware of the invasive pest problem, tests the proven technologies in specific locations in different seasons for a few years to confirm its dependability and transfers technologies to farmers and extension personnel through training, demonstrations and farmer field days. In addition to the national partners, IPM IL has reached out to NGOs and private sector to disseminate and scale-up IPM technologies.

The IPM IL also includes monitoring and evaluation of how well their technologies and practices have been disseminated in subsequent years. In addition, the impacts of IPM practices

and technologies are assessed against the targets planned at the beginning of the project. IPM IL is committed to capacity building by providing long-term and short-term training to national staff to strengthen the institutions. Emphasis is given to empower the women at all levels to strengthen their role in decision making when IPM is used to protect the crop and improve income and ensure the health and better nutrition for their children and family. IPM IL has organized a large number of workshops, symposia and conferences to bring together all collaborators with special emphasis on women as well as those who are not from USAID-assigned FtF countries to share their experiences and learn from each other. In addition, the ME and selected PIs, host country collaborators, technicians, and students from IPM IL have participated in International symposia and conferences and disseminated the IPM IL's success stories for the benefit of people around the world. The scientists from IPM IL and the communications office have been very productive in publishing scientific and popular articles for scientific community and for the farmers, NGOs, private sector, administrators and donors.

2. Organization, Structure, and Function of the ME

The original structure of IPM IL shown in Figure 1 includes the ME, sub-grant projects and miscellaneous items.

Figure 1: The original structure of IPM IL in the project proposal

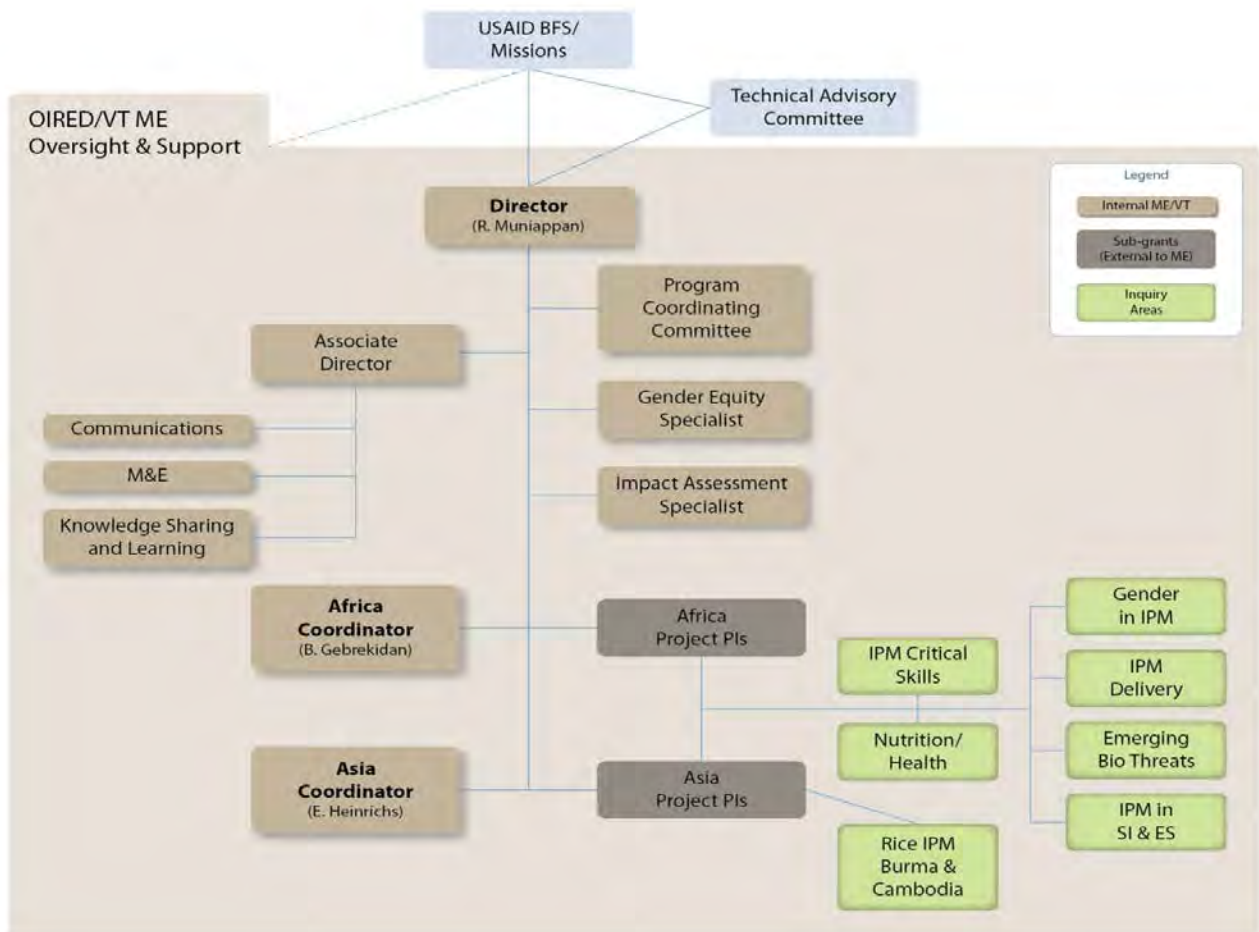
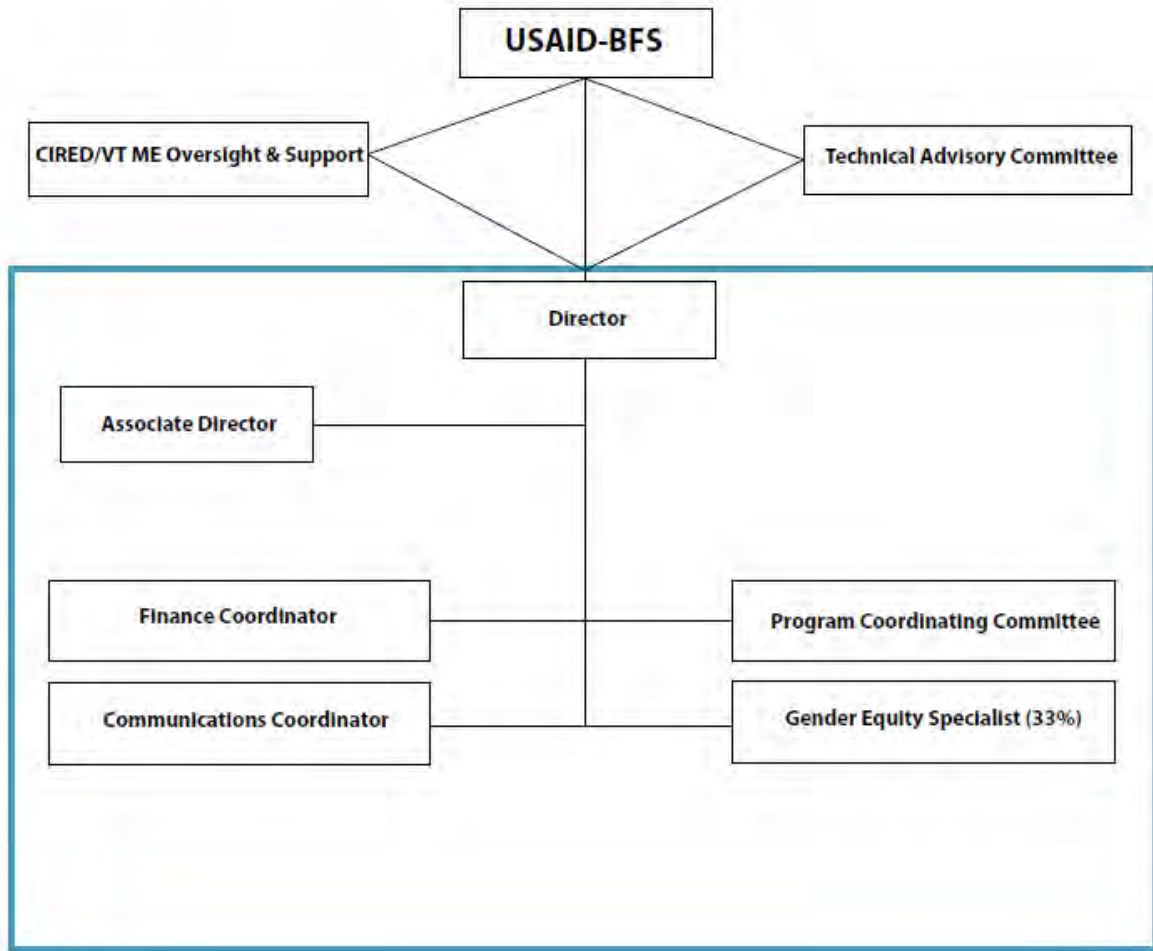


Figure 2: Current structure of IPM IL ME



Currently, the ME team of IPM IL at Virginia Tech consists of the Director (Dr. Rangaswamy Muniappan), Associate Director (Dr. Amer Fayad), Ms. Zara Shortt (Finance Coordinator), Ms. Sara Hendery (Communications Coordinator), and Mr. Daniel Sumner (Gender Coordinator). The ME role and function is discussed and evaluated in more detail in section 3 of this chapter. Dr. John Bowman serves as the Agreement Officer's Representative (AOR) for Bureau of Food Security (BFS)/USAID) and is constantly in touch with the Director of IPM IL, reviewing, monitoring, advising, and assisting in the progress as well as the smooth operation of the IPM IL.

USAID proposed in its RFA the crops and countries, in consultation with the missions and the national partners and other stakeholders in the region, for the IPM IL to focus on. If the ME needs to change crops or countries then they have to discuss with AOR and get his/her approval. The IPM IL addresses IPM for the following crops: Maize, rice, chickpea, (grain crops), tomato, onion, eggplant, cabbage, cauliflower, cucurbits, chilies, and beans (vegetable crops), dragon fruit, mango, longan and lychee (fruit crops).

Table 1 presents the eight current projects in the IPM IL. Three projects are focused in Africa and four projects are focused in Asia and one project is global. The following four Principal Investigators (PI) are from U.S institutions: Wondi Mersie from Virginia State University, George Norton from Virginia Tech, Abhijin Adiga from University of Virginia, and Luis Cañas from The Ohio State University who replaced John Cardina from the same university. Two PIs from International institutions are: Buyung Hadi, International Rice Research Institute (IRRI) and Tadele Tefera, International Center for Insect Physiology and Ecology (*icipe*). Two PIs are from the partner country institutions: Hoa Nguyen Van, Southern Horticultural Research Institute (SOFRI) in Vietnam and Pramod K. Jha, Tribhuvan University, Nepal. Each of the projects have sub-awardees in the USA as well as in collaborating countries with Co PIs and collaborators. The eight PIs, the Director of IPM IL, and the Associate Director of the IPM IL form the Program Coordinating Committee (PCC) (Paige Selvey, CRA personal communication). The AOR is a member of TAC. The PIs are responsible for planning, implementing, reviewing, evaluating and monitoring the projects with sub-awardees and reporting to ME. The PCC reviews the sub-award workplans along with TAC and provide their recommendations for final approval by the Director of IPM IL and AOR. Recommendations for modifying, revising or terminating project or personnel come from TAC and it is finally approved by AOR.

Two projects (#3 and #5 in table 1) focus on participatory biodiversity and climate change assessment for IPM in Nepal and invasive species modeling for South American Tomato leaf miner and groundnut leaf miner. The other projects have specific crop and country focuses with both research and extension components in the focus countries. To date, the modeling projects are research focused without extension.

Table 1: Current projects and Principal Investigators for the IPM IL

<u>Projects</u>	<u>Principal Investigators</u>
1. Exportable fruit crops IPM-Vietnam	Hoa Nguyen Van
2. Parthenium biocontrol-East Africa	Wondi Mersie
3. Biodiversity and climate change-Nepal	Pramod Jha
4. Vegetable crops and mango IPM-Asia	George Norton
5. Modeling of invasive species dispersal	Abhijin Adiga
6. Rice IPM-Cambodia	Buyung Hadi
7. Vegetable crops IPM-East Africa	Luis Cañas
8. Rice, maize and chickpea IPM-East Africa	Tadele Tefera

The IPM IL also has a Technical Advisory Committee (TAC) that consists of five members with diverse expertise and from diverse institutions. The current TAC members are:

- 1.) Dr. Lawrence Datnoff, Chair
- 2.) Dr. Dely Gapasin,
- 3.) Dr. Glen Hartman,
- 4.) Dr. Sunday Ekasi

5.) Dr. Ramaswamy Srinivasan.

The TAC serves as external advisors to the IPM IL. The task of the TAC is to provide clear guidance and direction for the research and development activities based on the goals and objectives of the project. They help the ME by i) reviewing work plans, 2) reviewing awards, 3) reviewing and recommending project proposals from various collaborators for potential sub-awards, 4) reviewing ongoing projects, 5) participating in annual meetings, and 6) reviewing the progress of the projects in different regions and providing suggestions to improve the implementation of the projects to achieve their objectives.

Based on the qualifications, experience and geographical representation, the ME and the AOR are generally happy and pleased with the current group of TAC members and their contribution to the success of the IPM IL. Some of the members of the TAC are quite enthusiastic about the IPM IL while others appear to have reservations about the proposals review process and transparency. However, majority of them are satisfied with the review process. One of the members is brand new to the program (Dr. Sunday Ekasi from *icipe*). Some of the TAC members are from US universities and others are from IARCs. The US universities and the IARCs can compete for the awards from IPM IL. Therefore, being members from these institutions and also serving as reviewers for the proposals is a potential conflict of interest. EET recognizes that this issue has been stated in the Policies and Operating Procedures Manual (POPS) and requests the TAC members to be considerate and excuse themselves if they feel that they have conflict of interest.

3. Management of IPM IL

The IPM IL team consists of the ME, AOR, PCC, and TAC. The ME's VT team includes the Director, Associate Director, Financial coordinator, communications coordinator and the gender coordinator. The team works under the leadership of the Director. The Associate Director handles planning, reviewing, monitoring, evaluation and preparation of various publications. When the Director is away from the HQ, the Associate Director handles everything at the HQ. The ME along with TAC and the PCC meets once a year to review the workplans, progress and make recommendations on the project and budget. These are taken into consideration by the Director of IPM IL and AOR to make final decisions.

Based on recommendations from the TAC, and the AOR, the IPM IL ME has made several important decisions in phase V to adjust the size of the program based on peoples' performance and the IL's evolving needs. For example, the original Request for Applications (RFA) for the IPM IL included positions for an Africa Manager and an Asia Manager to be part of the ME. However, the Africa Manager position was terminated in 2016, and the Asia Manager position was terminated in 2017, due to budgetary reasons and the lack of clear roles and responsibilities for the positions. The IPM IL has also terminated a sub-award to the City University of New York (CUNY) in September 2017 due to non-performance. IPM IL terminated a collaborating retired scientist from University of Florida in 2017 since he was not familiar with the subject matter. They also terminated another collaborating scientist from University of Minnesota, in 2018, who was too busy to find the time to get involved in the project.

The EET noted that after following the normal protocol the IPM IL ME terminated CUNY sub-award, and a retired Florida university scientist.

The sub-grant approval process for the IPM IL follows a formal structure. The ME has a format for concept notes (CN), which are first submitted by potential sub-grantees. The ME and

TAC members review the CN. The sub-grantees who have their CN approved are invited to submit a full proposal (FP). The FP then undergoes a more thorough review again by the ME, TAC, and if necessary, additional external reviewers. Successful sub-grantees are notified by the ME and they begin establishing a sub-grant.

It takes anywhere from four to five months from the time CN is requested until the final awards are made. In phase V of the IPM IL, the request for CN commenced in December 2014 and continued, in stages, until June 2015. The final awards were given from May 2015 until September 2015 in stages. The RFA for CN was sent out in stages mainly because the Director of IPM IL and AOR have to meet with the Missions in each of the countries and the local staffs and stakeholders for consultation concerning the choice of locations, crops and priority problems to be addressed prior to making decisions. The schedule of countries visited and the diversity of institutions participated in the consultation is given in Table 2 The Mission, value chain staffs, IARCs and the local staffs are all represented in the consultation. This consultation may be the opportunity for IPM IL to look for synergy and collaboration with those who are present at the meeting including value chain group. The sub-awards follow the same procedure.

Table 2: List of consultations with the mission in each country and participating institutions

Bangladesh	R. Muniappan and E. Heinrichs	March 7-10, 2015	USAID	5
			Government	2
			Value chain	5
			Private	2
			Total	14
Cambodia	J. Bowman and R. Muniappan	December 7-13, 2014	USAID	6
			Government	6
			Universities	10
			Private	7
			Value chain	2
			Total	31
Ethiopia	R. Muniappan and B. Gebrekidan	February 14-22, 2015	Government	8
			CIP	1
			ICARDA	3
			Value chain	3
			Total	15

Kenya	J. Bowman and R. Muniappan	February 7-13, 2015	USAID	2
			CYMMIT	1
			ICIPE	8
			Government	8
			Value chain	3
			Total	22
Nepal	R. Muniappan and E. Heinrichs	March 11-13, 2015	USAID	2
			NGO	2
			Total	4
Tanzania	J. Bowman, R. Muniappan, and B. Gebrekidan	May 9-17, 2015	USAID	2
			AVRDC	7
			Government	2
			University	5
			Value chain	6
			Private	6
			Total	28
Vietnam	J. Bowman and R. Muniappan	November 26 to December 6, 2014	USAID	8
			USDA	3
			Government	18
			Universities	10
			Total	39

A template is provided for submitting the CN and FP to the prospective collaborators. Even though the CN and FP are reviewed and recommended by TAC members, the final decision on the approval is made by the AOR in consultation with the IPM IL Director. The justifications for project selection are based on BFS/USAID and its missions' priorities for crops, technologies, regions, countries and technical merit of the project to contribute to the FtF objectives.

IPM IL has an annual program review and it gives an opportunity for all the sub-grantees to exchange information and encourage collaboration among them. The IL holds frequent technical workshops with extension agents, short-term training, farmer field schools and field demonstrations to promote and strengthen capacity and outreach.

The IPM IL has an efficient system for information collection and sharing among collaborators using the *IPM IL web portal v2.0* (for subscribers only). The portal is organized to have i) program information, ii) proposals, iii) sub-proposals, iv) trip reports, v) travel requests,

vi) approvals, vii) annual reports, and viii) data set submission and sharing. Each location has a maximum space allocation. Collaborators can submit documents in word, Excel and pdf.

The web portal system is useful for collecting and archiving project documents such as the annual and semi-annual reports. Semi-annual reports are due in April and annual reports are due in October. The project PI's write their reports and submit to the ME through the portal. The ME then collects and combines the PI reports and submits them to the AOR/USAID. The TAC members also review these reports before they are stored in the portal and published in the IPM IL website. Any data collected and deposited into the portal also goes to USAID's online repository of research data. Furthermore, the portal is useful for collecting and storing information on travel. All collaborators who travel on IPM IL funds are required to submit a trip report, within 30 days after the travel, to the web portal. These trip reports are publicly available in the IPM IL website. It is important to recognize that the development of this portal was funded by IPM IL project funds at a cost of US\$200,000 initial funding in 2014 and yearly operational expenses of US\$30,000.

4. Technical leadership

Under the current management structure, the technical leadership for the IPM IL is provided by the Director, the Associate Director and as needed by the gender coordinator. The ME is constantly looking for any new invasive species that is a threat either in the U.S or Feed the Future (FtF) countries. One such invasive pest that is currently entering the portfolio is fall armyworm (FAW), *Spodoptera frugiperda*. The team is also always looking for specific biocontrol agents or IPM technology packages that can be adopted by smallholder farmers to more efficiently control pests that are currently in their portfolio of concern. The IPM IL is quite responsive and willing to listen

and offer technical assistance to USAID HQ and Missions, and request from host country institutions are handled on a case by case basis depending on USAID's priorities.

Fortunately, the IPM IL program is quite flexible when there are new invasive species that need urgent response. The AOR is willing to approve requests from the IPM IL to bring awareness to and address the invasive species problem through technology or other practices. For example, at the request of USAID Mission in Egypt the IPM IL team has prepared a risk assessment of FAW. The model developed by the IPM IL team predicted that the pest would spread into Yemen via wind currents from Sudan, which later occurred.

USAID is very much interested in cutting edge emerging technologies that can be used advantageously for the benefit of IPM IL. One of them is modeling, and the IPM IL has VT and Tribhuvan University in Nepal working on two different projects to model invasive species and bio-diversity, along with climate change assessment for IPM in Nepal respectively.

IPM IL has also brought awareness of pests such as the South American tomato leaf miner, *Tuta absoluta*, Parthenium weed, papaya mealybug, groundnut leaf miner, and witches' broom of longan through workshops and trained the local people the IPM packages to manage the above pests. Awareness was also created through national, regional and international workshops and symposia on the threat of invasive species such as Parthenium and Fall Armyworm (FAW) and the need to address the IPM solution to these threats before it is too late. The IPM IL has also held webinars on these topics. By organizing various workshops, national, regional and international conferences IPM IL has brought awareness, usually at the appropriate time in order to take proper action to address the serious problem of invasive pests, diseases, and weeds that may endanger global food security.

In order to have checks and balances IPM IL has developed a built-in evaluation system in its program and project implementation that begins in the initial planning stage. Each project and activity has a target against which the progress is reviewed and evaluated. The projects are reviewed annually and the reason(s) for not achieving the target are critically evaluated. Necessary remedial measures are then taken as appropriate. In cases where the reasons for not achieving the target is beyond the control of the collaborator then the ME makes necessary adjustments in the work plan. The Director takes initiative and encourages and assists researchers from developing countries to write and publish their research output in international journals. For example, the Co-PI from Vietnam, Dr. Hanh, was given English training at Virginia Tech in 2018, in order to improve entomology skills along with her English communication and writing ability. Dr. Hanh returned to Vietnam and applied her skills to write about a new mite species as the responsible culprit that causes Witches' Broom disease in longan fruit. In another example, the Sorghum Millet Innovation Lab (SM IL) recognizing the expertise of IPM IL on the pest millet head miner (MHM) *Heliocheilus albipunctella* in Niger and Senegal. SM IL provided a sub-award to IPM IL to address the problem. The sub-grant project of IPM IL with local partners successfully mass produced *Habrobracon hebetor*, a larval parasite from Niger for field release as effective IPM control for the head miner. IPM IL is now working together with Niger partners towards the development of a cottage industry to mass produce and release *H. hebetor* to combat the MHM (Guerci, et.al. 2018).

5. Administration

IPM IL ME handles the administration of the program efficiently. The Director and Associate Director are supported by the Financial Coordinator and Communications Coordinator. Financial

office and administration staff from CIRED provide backstopping whenever needed. The flow of information and communication is seemingly smooth. The ME has developed a policy manual as a guide for all the PIs and sub-awardees as well as all the collaborators. The guide explains all of the procedures and instructions to follow in submitting the progress and financial reports. Almost all the collaborators surveyed concur that the administrative procedures are very clear and there is no problem (Appendix 3).

As mentioned earlier, the project administration flows from the BFS/USAID AOR through the Director of IPM IL and down. Semi-annual and annual reports are required from all the projects. In the annual meeting, the team reviews progress on the different sub-grants and measures are taken by the ME to correct or resolve issues. Based on the progress made, new annual work plans are prepared and approved for the following year.

The EET feels that review of progress once a year through semi-annual and annual reports can be more critical and stringent but constructive and helpful. It is true that we cannot expect a perfect score or performance from all collaborators. However, there are opportunities both at the time of the annual review meeting, and during the site visits to scrutinize and support the sub-awardees who are lagging behind in making progress or those who are not using proper IPM technologies. The EET recommends that the ME make extraordinary efforts to speed up the “slow-runners” among the PIs, who may be encouraged and provided with additional information or resources in terms of technical support to catch up with the best ones. This is an opportunity for ME to demonstrate their ability for institution building.

Recognizing the competence and expertise of the IPM IL the USAID mission in Egypt provided a buy-in of \$50,000 to assess the food security risk due to FAW. Similarly, administration

was able to secure a sub-award from SM IL to investigate the millet head miner in pearl millet and to identify appropriate biocontrol agents. The Vice President for Outreach and International Affairs at Virginia Tech provided \$50,000 to work on *Trichoderma* and Coconut Peat in Bangladesh, India and Nepal. The President of Haramaya University in Ethiopia provided \$5,000 towards construction of a plastic rearing house for *Parthenium* biocontrol agents. Several other grants were secured as shown in Table 3 for a total leverage sum of \$351,517.

Table 3: Associate awards and grants secured by the administration for IPM IL Phase V

IPM Innovation Lab 2014-19

Associate Awards/Buy-ins

Award	Source	Amount	Dates	Purpose
Buy-in	USAID Mission Egypt	\$50,000	September-December 2018	Conduct a spread and food security risk assessment of the fall armyworm, <i>Spodoptera frugiperda</i> in Egypt
Sub-award	Sorghum and Millet Innovation Lab	\$207,017	April1, 2014-July 22, 2019	Biocontrol of pearl millet pests in Niger
Grant	President of Haramaya University	\$5,000	2018-2019	Biocontrol of <i>Parthenium</i>

Leverage

Award	Source	Amount	Dates	Purpose
Grant	Outreach and International affairs, Virginia Tech	\$50,000	January 2018-January 2019	Conduct impact assessment for <i>Trichoderma</i> and coco peat in Bangladesh, Cambodia, and Nepal
Consultancy	FAO	\$10,000	March 27-31, 2018	Consultations fees for Muniappan to assess Red Palm Weevil situation
Consultancy	Biocontrol Lab, Ministry of Agriculture, Saudi Arabia	\$10,000	Nov 6-12, 2016	Assessment of biocontrol capacity in Saudi Arabia

Travel	FAO	\$5,000	2017	Support attendance of Wondi Mersie at the Parthenium meeting in Algeria
Travel	Horticulture Innovation Lab	\$3,000	June 7-12, 2015	Support Munniapan to participate in the Horticulture IL planning meeting in Zambia
Travel	Arab Society for Plant Protection	\$2,500	November 5-10, 2017	Support attendance of Muniappan at the Arab Society for Plant Protection Meeting in Hurgada, Egypt
Travel	FAO	\$2,500	October 19-22, 2015	Support attendance of Muniappan at the Arab Society for Biological Control meeting in Cairo, Egypt
Travel	Organizers of the meeting	\$2,500	October 22-27, 2017	Support attendance of Muniappan at the Sudan African Entomologist Meeting
Travel	Swiss Government	\$2,000	August 26-30, 2018	Support attendance of Muniappan at the International Symposium on Biological Control of Weeds; Switzerland
Travel	Ivory Coast Government	\$1,000	January 2019	Support attendance of Eric Kwadjo at the FAW biocontrol workshop in Kenya
Travel	AVRDC	\$500	September 2-9, 2016	Support Muniappan's participation at the AVRDC Horticulture review meeting
Travel	Western IPM Center, USDA	\$500	January 23-24, 2018	Support participation of Muniappan at the review of Western IPM Center, Washington DC

6. *Financial management*

The Office of Sponsored Programs (OSP) at Virginia Tech handles restricted and non-restricted contracts, including Federal and non-Federal awards. There is a contracts team that is responsible for overseeing the negotiation of awards between the donor and the University. There are also pre-award and post award teams who manage budgeting guidelines and ensure those are clarified and

followed. After an award has been made to VT there is a review and set up phase after which the accounting system and budget is set up so that the project can begin.

The Financial Coordinator (FC) of IPM IL works closely with CIRED and OSP at VT. She is very knowledgeable about the system and enables the project's finances to run smoothly. VT has an overhead rate of 26% on modified total direct costs for off-campus projects that applies to the IPM IL. The cooperating national and international partners who do not have an official negotiated indirect rate can elect to charge a de minimis rate of 10%.

IPM IL has invoicing templates for sub-grantees, but the documentation required varies depending on the type of institution. For example, travel is pre-approved by the ME and USAID, but receipts are only required for reimbursement of expenses from host country subawardees. For all international travel, approval is required from USAID for each specific country. Federal guidelines based on global security must be followed.

The FC handles the sub-grantee receipts and invoices. Once finalized she submits them to CIRED for approval and then passes them on to the OSP administrator at VT. OSP reviews and raises issues if they exist. In this system two people review and audit each invoice. Rules for hiring consultants and purchasing equipment are based on the terms of each contract. FC provides quarterly expense break down report by country to John Brown (AOR) and Charles Jackson (Agreement Officer, AO) at USAID. Expenditures on the project are incurred on a cost-reimbursable basis for VT and the sub-awardees. OSP and IPM IL provides guidelines for all the partners specifying expenditure categories, allowable and acceptable receipts. Receipts from host country partners must have dates, and description of the expenditure. For countries in Asia and Africa where the language is different the subawardees provide receipts with translation to English.

In cases where necessary, VT provides a one-time working capital advance to IPM IL subawardees. The system works well as long as USAID allocates the funds in a timely fashion to VT. This year there are delays which has complicated the partners' research plans and affected the timely implementation of activities.

The EET congratulates and appreciates the efficient financial management of IPM IL with the help of experienced people at OSP at VT and excellent coordination from Zara Shortt at IPM IL. This is one of the important areas of strength for the IPM IL.

The budget flow is from USAID to OSP and then to IPM IL. There is a total of 22 sub-awards and 11 sub-funds at VT. The budget is disaggregated in table 4.

Table 4: IPM IL Phase V Budget Breakdown.

Section B - Budget Categories					
6. Object Class Categories	Grant Program, Function or Activity				Total (5)
	ME	Competitive Prgm Asia & Africa	Competitive Prgm Rice Project	Additional Research Prgrms	
a. Personnel	\$ 2,489,121.00	\$ -	\$ -	\$ -	\$ 2,489,121.00
b. Fringe Benefits	\$ 897,622.00	\$ -	\$ -	\$ -	\$ 897,622.00
c. Travel	\$ 734,658.50	\$ -	\$ -	\$ -	\$ 734,658.50
d. Equipment	\$ -	\$ -	\$ -	\$ -	\$ -
e. Supplies	\$ 58,278.00	\$ -	\$ -	\$ -	\$ 58,278.00
f. Contractual	\$ 38,857.50	\$ -	\$ -	\$ -	\$ 38,857.50
g. Construction	\$ -	\$ -	\$ -	\$ -	\$ -
h. Other	\$ 376,698.00	\$ 7,711,000.00	\$ 2,353,500.00	\$ 2,059,865.00	\$ 12,501,063.00
I. Total Direct Charges (sum of 6a-6h)	\$ 4,595,235.00	\$ 7,711,000.00	\$ 2,353,500.00	\$ 2,059,865.00	\$ 16,719,600.00
j. Indirect Charges	\$ 1,194,765.00	\$ 39,000.00	\$ 6,500.00	\$ 40,135.00	\$ 1,280,400.00
k. TOTALS (sum of 6i and 6j)	\$ 5,790,000.00	\$ 7,750,000.00	\$ 2,360,000.00	\$ 2,100,000.00	\$ 18,000,000.00

USAID usually allocates the funds based on the proposed budget. The annual allocation is around US\$3.6 million. There was a deficit of around US\$1.2 million in 2014-2015 and around US\$1.5 million in 2016-2017. The program received US\$3,004,000 on February 2019 leaving a deficit of US\$649,872. For phases I and IV of IPM IL (CRSP) the budget cut from USAID was around US\$900,000. For phase II the cut was US\$1.5 million. Phase III was the perfect one without any budget cut. Budget cuts cause uncertainty at the ME level, while at the partner and host country level, without funding the season is lost for planting the crops and conducting trials.

Due to a delay in funding from USAID until March, sub-grantees in Ethiopia and Tanzania cut their activities but salaries were not cut. In Nepal, sub-grantees have to let workers know two months in advance whether or not they will be paid. Regardless of these impacts, USAID wants the work done with or without funding.

When the budget is cut and funds from USAID are delayed, travel and other activities are reduced in order to keep people employed and cover the cost of the cuts. As mentioned earlier the Asia and Africa manager positions were cut, which allowed the IPM IL to recover some of the money from the cuts. Also, since budgets are linked to the work plan and aligned every year, adjustments are made within projects to redistribute and reallocate money based on needs, with the approval of AOR. EET congratulates the IPM IL ME for their effective and efficient management of the funds.

The EET recognizes the difficulties encountered by the IPM IL due to the delay in receipt of the budget. As a result, the program activities unduly suffered. Even under the difficult circumstances the IPM IL and its partners implemented the activities and made significant progress and impact in Asia and Africa. The EET recommends that BFS/USAID AOR appreciate the situation and make whatever efforts that are necessary to avoid uncertainties in funding. One recommendation to keep activities funded during funding cuts or delays is to require sub-grantees to cut salaries and activities in equal proportions. ME and the PIs should use their judgement to keep the trained staff as much as possible. It is a delicate balancing act and EET appreciates the ability of the ME taking necessary and appropriate action

Chapter 3: Technology Development

To what extent did the IPM IL generate quality research technologies/outputs using systems and gender-sensitive approaches and appropriate metrics for productivity, sustainability and resilience?

IPM aims to reduce crop losses through eco-friendly means by conserving natural resources. The IPM IL encourages PIs and project collaborators to conduct quality research to identify appropriate IPM technologies for specific crops to control insect pests, diseases and weeds. The technologies and practices identified by the IPM IL include i) use of resistant varieties, ii) identification, testing, multiplication, demonstration and widespread use of parasites that attack invasive pests, iii) use of predators, iv) promoting cultural practice for pest reduction, v) avoiding the pests, vi) trapping or repelling pests, vii) using protective covers to shield crops from pests and diseases, viii) use of protective cultivation practices (such as growing high-value crops under net houses) and ix) promoting good agricultural practices (GAP).

In the past 20 years the IPM IL has identified, refined, and modified some of the already widely used IPM technologies by conducting location-specific research applicable to specific countries, geographic regions, and seasons. Fortunately for the IPM IL, identification of new parasitoids and predators is a priority for FtF countries. This makes it potentially easy to convince local policy makers to approve the use of natural enemies in their countries to manage pests.

In the current phase, there are eight projects. The following sub-sections discuss these projects and the IPM technologies that each has developed and promoted.

1. Project: Exportable fruit crops IPM-Vietnam. PI: Hoa Nguyen Van



Figure 3: Dragon fruit, longan, lychee, and mango (from left to right)

In Vietnam, dragon fruit, *Hylocereus undatus*, longan, *Dimocarpus longan*, lychee, *Litchi chinensis* and mango, *Mangifera indica* (Fig. 3) are very important export oriented fruit crops.

Dragon fruit area increased from 12,000 ha in 2008 to about 36,000 ha in 2017, with total production reaching nearly 14,000 t/year. Canker, *Neocyttallium dimiachatium* is the most important wet season fungal disease that affects dragon fruit. The disease was first identified in Vietnam in 2009 and it has spread to nearly 10,000 ha in 2013. The disease causes an estimated loss of about 30 to 70% of potential harvest. China is the major importer of Dragon fruit from Vietnam, and sanitary and phytosanitary regulations require dragon fruit to receive six foliar sprays in a 52 to 55-day window. Although dragon fruit farmers have used chemical pesticides to combat the canker they were not effective at reducing the canker. After evaluating different types of bags IPM IL identified plastic sleeves as a potentially effective canker control. Research by the IPM IL suggested that the sleeves gave a 30% more marketable yield than the control treatment without the bag. The farmers who used plastic sleeves sprayed 60% less pesticides. Evidence suggests that the plastic sleeves are cost-effective, priced around US \$0.01/bag, while better quality bags costs between US \$0.03-\$0.12/bag. Most of the Vietnamese farmers are small farmers with 0.5 to 2.0 ha land and they find the new technology useful. The bags also protect the crop from stink bugs

and fruit flies. Currently the project provides sleeves to the participating farmers. The women are employed in handling, cleaning and export of dragon fruit.

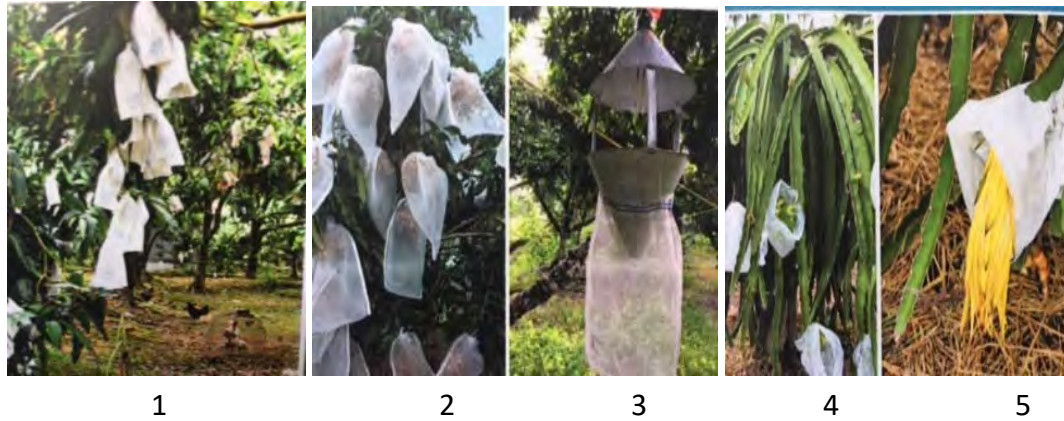


Figure 4: 1) Mango fruits with wax paper bags, 2) mesh plastic bags for longan fruit clusters, 3) light trap for longan pest monitoring, 4) plastic sleeves for dragon fruit buds, 5) Plastic sleeves for dragon fruit flower.

In 2015, Vietnam earned US\$100 million from longan export (second only to dragon fruit) the share that was exported to the United States was worth US\$ 1.5 million. Longan is susceptible to fruit borer, stink bugs and fruit flies. Southern Horticultural Research Institute (SOFRI) in Vietnam, the PI for the project, developed the one gallon mesh plastic bags (best compared to non-oven bags and cloth bags) to cover the fruit clusters 15 days after fruits set. The mesh bag provides the right moisture, temperature and light transmission for healthy fruit development protects them from pests. The light trap attached to plastic bag attracts the pests in the trap for monitoring. Researchers found that the mesh bag increased the profit by 7% and pesticide use is considerably reduced.

Recently, another disease, Witches' Broom Syndrome (WBS) became a serious problem in longan. The IPM IL team was the first to identify that the disease was caused by an eriophyid (*Eriophyes dimocarpi*) mite which feeds on the growing bud of young shoots. This is supported

by the absence of phytoplasma and viral sequences from high-throughput sequence analysis of longan samples showing the symptoms. WBS is estimated to cause up to 90% yield loss in longan. The IPM IL team has also identified two natural predators. The research is on-going.

Mango is also an important export crop for Vietnam. Fruit flies, leaf hoppers, fruit borer, and thrips are the devastating pests for mango. The most important disease is anthracnose. IPM IL evaluated various technologies, and found that bagging the fruits with wax paper bags prevents pest damage, and also reduces anthracnose infection. Seventy to 100 bags are used per tree and it costs about US \$0.025/bag. Although bagging the mango fruits is labor-intensive, it reduces the cost and labor of insecticide spray and enhances the fruits commercial value since it is pesticide free. Exporters prefer bagged fruit over pesticide sprayed fruit.

Based on the observations in Vietnam and other countries there are a number of private sector agents such as seed dealers, pesticide companies, fertilizer distributors and even lead farmers that are becoming small entrepreneurs in undertaking the multiplication and distribution of IPM components. Empowering the private-sector including enterprising farmers (many of whom are women farmers) to take the leadership and ownership in extending the appropriate IPM technology will speed up adoption and lead to sustainability. **Therefore, the review team recommends that the IPM IL continue to serve as a catalyst to encourage and facilitate bio-pesticide business development with lead farmers, NGOs and private entrepreneurs in other countries in Asia and Africa as it has done with Bangladesh, India and Nepal to ensure sustainability.**

The EET recommends that the IPM IL encourage the Vietnamese National Agricultural Research System (NARS) to stimulate the private-sector or lead farmers to pick up the sale of plastic sleeves, plastic mesh bags and wax bags marketing to the fruit farmers so that

sustainability and scaling-up of the technology will be assured.

2. Project: Vegetable crops and mango IPM-Asia. PI: George Norton

This project promotes IPM strategies for vegetable and mango in Asia. It is run from Virginia Tech, and it implements ecologically based participatory IPM in Cambodia, Nepal and Bangladesh. Different technologies that have been developed and promoted by this project over the years, including, i) *Trichoderma*, ii) pheromone traps, iii) neem seed oil extract or azadiractin, and iv) microbial pesticides are now privately marketed to farmers in these countries.

In Cambodia 24 farmers' field trials were completed with yard long bean. Twelve trials on cucumber were also completed. Biological control of *Maruca vitrata* in yard long bean and *Bactrocera cucurbitae* in cucumber pests were achieved effectively with *B. thuringiensis*, *B. subtilis*, *Beauveria bassiana*, *Trichoderma* and orange oil. IPM trials were conducted at Royal University of Agriculture (RUA) in Cambodia using *T. harzianum*, *T. viride* and *T. koningii* to control damping off. The team learned that field experiments in the rainy season should be avoided, but if necessary then raised beds should be used to have good drainage. Root stocks were evaluated to control bacterial wilt (*Ralstonia solanacearum*) of tomato, eggplant and chili under field conditions. However, the root stock trials suffered badly with *Tomato yellow leaf curl virus*-like symptoms. By screening different wild *Solanum* species three stocks were found to be resistant to bacterial wilt, among them WSS002 (*S. sysimbriifolium*) and WSMO5- BARI Brinjal-8 were highly compatible as root stocks for summer tomato.

Bt eggplant (GMO), from multi-location trials in Bangladesh, demonstrated 90.3% reduction in eggplant fruit and shoot borer (EFSB) damage over non-Bt eggplant.

To control mango leaf hopper in Bangladesh, the team developed and recommended that

farmers spray a powder formulation of *B. bassiana* @5.0g/L of water three times (one at flower initiation, the second prior to flower open stage and the third at pea stage). In addition, the IPM IL team found that using a double layer brown paper bag is recommended to cover the fruits to protect them from fruit fly, *Bactrocera dorsalis* in high rainfall hilly areas. The team's evaluation suggested that mango's marketable yield from bagged trees increased 102.8% over the control. Even though bags are used to protect the fruits of different fruit crops, type of bags vary with location and season (as seen in Vietnam).

The IPM IL recommends that farmers combine Coco-peat with *Trichoderma* to raise healthy seedlings of various vegetables in Bangladesh and Nepal. Farmers should spray *T. viride* 75 days after transplanting to reduce anthracnose and *Cercospora leaf spot* compared to control plots. Based on numerous trials in different countries *Trichoderma* either alone or combined with compost is recommended and included as one of the components in IPM packages.

Mustard cake as the carbon source has been identified as the best for Anaerobic Soil Disinfestation (ASD) in Nepal. Light trap, sticky trap and tomato leaf miner (TLM) pheromone trap are all used to trap *Tuta absoluta*. Neem oil and Bt were found to be the best at controlling *Tuta* in two locations in Nepal. Light traps also trapped other nocturnal pests such as *Spodoptera sp.* and *Helicoverpa sp.*

In Cambodia, it is a challenge for the investigators to monitor the effect of the IPM treatments. The IPM IL team found that farmers continued to use chemicals to protect their crop since they are unsure of the IPM's results, when the investigators were not there.



Figure 5: From Left, Trichoderma, pheromone trap, Neem seed extract sold in the market.

3. Project: *Parthenium* biocontrol-East Africa. PI: Wondi Mersie

Biocontrol of the invasive weed *Parthenium* in East Africa is a project that has continued from the previous phase of the IPM IL (phase IV). *Parthenium* is a serious weed that affects maize, and sorghum yields in wild life parks, farmers' fields and in homestead gardens in the countries of Ethiopia, Kenya, Tanzania, Uganda and South Africa. The weed releases toxic chemicals which causes mutagenicity and has an allelopathy effect on crops that it contacts. The cattle that feed on *Parthenium* produce off-flavor milk which fetches a poor price, and their meat is also of poor quality. Traditionally people hand weed to remove *Parthenium*, but hand weeding is labor intensive and labor is often scarce for limited resource households. Furthermore, many people are also allergic to the weed, causing them to suffer from respiratory problems when hand weeding.

South Africa has done a lot of work and used biocontrol agents to effectively control *Parthenium*. The IPM IL has identified two biocontrol agents including *Zygogramma bicolorata*, a beetle from Mexico that lays eggs underneath the leaves of the *Parthenium*. The larvae then feed on the leaves, defoliating the plants. The second biocontrol agent for *Parthenium* is *Listronotus setosipennis*. It lays eggs on the flower buds and the larvae bore through the stem and the whole plant wilts and dies.

Biocontrol rearing facilities have been established and run by IPM IL in Wollenchiti and in Ambo University at Ambo-Guder, Ethiopia. Although *Parthenium* is a noxious weed and it produces nearly 28,000 small seeds per plant which can travel by wind, water, animals and other

means, growing healthy plants of Parthenium in the screen houses is not easy. To produce the weed, the medium should be a mixture of 25% sand, 25% humus and 50% clay loam soil. Pots need to be kept clean by wiping them with dilute (2%) sodium hypochlorite solution and the soil should be sprayed with the same solution to prevent pathogen build up. The plants should be free of mites, mealybugs and lizards. Similarly, the biocontrol agents also need to be handled tenderly. For multiplication at all stages careful attention is paid to their requirements. Cleanliness with 2% sodium hypochlorite solution is a must at all stages of handling the pots and the biocontrol agents. The biocontrol agents are susceptible to ants and spiders and therefore, care should be given to see they are free of these pests.

The biocontrol agent *Zygogramma bicolorata* prefers lush young growing plants while the other agent, *Listronotus setosipennis* requires thick stemmed plants with lots of young flowers. *Zygogramma* is suitable for high rainfall areas while *Listronotus* is adapted to harsh conditions. Each *Zygogramma* beetle can eat about four to five leaves a day and in one month cycle it can devour the whole plant. In Ethiopia, the biocontrol agents have been released in four regions. Monitoring and evaluation is being conducted in the release areas. One setback is that it appears that a fungus attacks the *Zygogramma* which needs to be carefully examined.

Initial studies have shown that the biocontrol agents have moved 100 meters from the release site. Over the years there is steady progress in the number of biocontrol agents released in farmers' fields (Table 5). It definitely shows the vast potential to manage Parthenium. Experience in countries like India, Australia and South Africa, where they started to control Parthenium using biocontrol agents much earlier than IPM IL, shows that it will be a slow process since the biocontrol agents are not that aggressive and it takes time for them to build a critical mass to have complete destruction of the weed. Furthermore, the biocontrol agents are sensitive to seasonal

fluctuations. It is necessary to mass produce the biocontrol agents and release them at appropriate times in various locations around the country to get rid of Parthenium. Since the farmers in Africa are subsistence poor farmers (not commercial farmers) they cannot afford to pay for the biocontrol agents. Sometimes farmers and the public may pick up the biocontrol agents from an established place and release them in their fields or properties in another place.

Table 5. Number of *Zygogramma bicolorata* and *Listronotus setosipennis* released from 2016-2018

Year Released	No. of <i>Zygogramma</i>	No. of <i>Listronotus</i>
2016	10,000	0
2017	15,800	2,300
2018	32,500	8,000
Total No. released	58,800	10,300

Drought reduces the larval production. The biocontrol agents do not completely destroy the weed. Instead the biocontrol agents and the weed co-exist keeping a balance and the weeds are kept at a very low level to cause any significant economic loss.

Furthermore, the EET observed the sincerity with which Dr. Wondi Mersie brought plastic pots, which are preferred and convenient for raising Parthenium, from the USA and he also brought filter paper and plastic trays from USA for handling the adults and eggs of the biocontrol agents. It is commendable and he also distributes these inputs to smallholder farmers in Ethiopia who collaborate on the project. Importing these inputs from the U.S is okay for the purposes of small-scale testing in the context of the project. However, in order for the biocontrol agents to be propagated sustainably, the IPM IL should explore the feasibility of using local materials for

raising *Parthenium* and also for biocontrol agent rearing and multiplication. The project should establish rearing sites close to release sites. From these sites, the biocontrol agents can be redistributed to other sites. This project has an excellent team as the five technicians at Wollenchiti have three to seven years-experience each. They are highly dedicated, devoted, responsible, dependable, and knowledgeable and were also able to teach and demonstrate others very clearly. They should be commended for their devotion to duty. IPM IL is lucky to have such talented people.

The Minister for Agriculture in Ethiopia strongly supports the *Parthenium* biocontrol program, and would like to see Ethiopia to be the hub for sub-Saharan Africa region for *Parthenium* biocontrol research, training and development. Kenya and Uganda have diverse ecological zones. Diversity in biocontrol agents have yet to be studied, but biocontrol rearing nurseries need to be established close to the problem areas. There are still outstanding challenges with biocontrol agents. For example, six weeks after the release of the biocontrol agents in homesteads, *Parthenium* returns within only a few weeks. Further study of this issue is needed.

IPM IL is also considering evaluation of the following biocontrol agents as potential ones for future use: *Smicronyz lutulentus*, (a seed feeding weevil), *Carmenta* sp. (a day flying clear-winged moth), *Epiblemma strenuana* (a stem galling insect), (Fig. 6) and *Conotrachelus* sp.

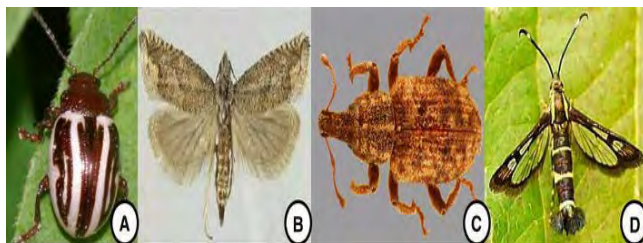


Figure 6 A: *Zygogramma bicolorata*, B. *Epiblemma strenuana* C. *Listronotus setosipennis* D. *Carmenta* nr. *Ithaca*

Based on literature review, among the four biocontrol agents, *Epiblemma strenuana* was found to be unsuitable since it also attacks niger (*Guizotia abyssinica*), an important oilseed crop in Africa. Therefore, it was not considered.

The EET recommends that the IPM IL encourage and provide training to rear the biocontrol agents using locally available materials so that the sustainability is ensured. IPM IL should also conduct further research to examine the diversity in biocontrol agents since *Zygogramma bicolorata* is suitable for high rainfall areas and *Listronotus setosipennis* to harsh drought stricken areas, but *Parthenium* is adapted to both situations. Once the biocontrol agents are established in the field, they will sustain and spread themselves. The enemies of biocontrol agents also need to be studied so that the agents are not decimated by their enemies. Since Ethiopia has successfully introduced, tested and evaluated the release of biocontrol agents in farmers' field EET recommends that Ethiopia should serve as a hub for disseminating the technology to other neighboring countries.

4. *Project: Vegetable crops IPM-East Africa. PI: Luis Cañas*

Integrated pest management of vegetables in East Africa is implemented by The Ohio State University and the project has also been continued from the previous phase (phase IV). In the last phase, the project emphasized developing diagnostic technologies and materials so that pests, disease and weed problems could be properly identified, and suitable IPM measures could be undertaken to address these problems. In the current phase, IPM packages have been developed with emphasis on judicious use of pesticides. The major crops addressed are tomato, cabbage,

Chinese cabbage, kale, cucurbits, onion, and chili. IPM IL is focused on managing viral, bacterial and fungal diseases for the aforementioned crops. The project has developed a detailed, pictorial, pamphlet in Swahili and English providing information on various diseases and insects. The research is conducted at Mikocheni Agricultural Research Institute (MARI) in Dar es Salaam, Tanzania, Sokoine University of Agriculture (SUA), also in Tanzania, Hawassa University of Agriculture (HUA) located in Ethiopia and Kenya Agricultural & Livestock Research Organization (KALRO). The field trials and demonstrations are conducted in farmers' fields close to Mikocheni, rift valley and close to SUA. In order to control the vectors and virus diseases, emphasis was given to producing disease free clean, healthy seedlings. The project recommends good quality improved seeds of specific crops to farmers. Raised beds and solarization of soil are also recommended to control soil borne diseases and to have good drainage in the soil. Protective plastic covering of seed beds is recommended to avoid early virus infection by vectors. Predominantly, the team uses various cultural practices from the IPM package as a priority technology before embarking on the use of biocontrol or judicious insecticide spray as a recommendation. Farmers in this area are mostly commercial farmers, so they are used to spraying insecticides to protect their crop (and they can afford to do so). Therefore, unless the IPM technology is attractive, convincing and economical they are not inclined to adopt. Therefore, the researchers are careful not to make indiscriminate recommendations. Farmers use numerous techniques for clean cultivation, such as, i) making ridges and furrows to enable ease of irrigation and weed control, ii) mulching to conserve soil moisture and to suppress the weeds and also control diseases, iii) staking to avoid plants touching the soil and becoming susceptible to diseases, iv) pruning and getting rid of insect-affected leaves and branches, and v) protective cultivation with

netting. Such protected cultivation shields the crop and prevents the entry of pests and also vectors of disease.

In the Rift valley, IPM IL team recommends reducing pesticide use by i) scouting pests and diseases, ii) identifying them, iii) managing them by treating seeds with either hot water or with a diluted (2%) sodium hypochlorite solution. Seedlings are also meant to be raised in low tunnels. The IPM IL also recommends *Trichoderma*, mulching, staking, raised beds, and use of resistant varieties and GAP. All of these practices help farmers maintain healthy seedlings that are free of pests and diseases.

4. Project: Rice, maize and chickpea IPM-East Africa. PI: Tadele Tefera

The rice, maize and chickpea in East Africa project is implemented by the International Center for Insect Physiology and Ecology (*icipe*). Rice is an important crop in Tanzania, and rice blast disease caused by *Pyricularia oryzae* is a serious problem, causing yield losses of 10 to 30%. Other rice diseases include yellow mottle virus disease caused by *Rice yellow mottle virus* (RYMV; Genus *Sobemovirus*) and transmitted by *Chaetocnema pulla* and *C. varicornis* (flea beetles), as well as by grasshoppers. The RYMV can cause 90 to 100% yield loss, while the rice bacterial blight disease incited by *Xanthomonas oryzae* is very serious and can cause a yield loss of about 70 to 80%.

Fortunately, two improved rice varieties SARO 5 (TXD 306) and KOMBOKA are resistant to all three diseases mentioned above. They have long translucent slender grains with a soft texture after cooking that remains soft during overnight storage, which is preferred by consumers. Both have excellent aroma, and grain quality meets the need of the farmers and consumers.

After evaluating 22 different rice varieties, IPM IL recommended SARO 5 and KUMBOKA to farmers through demonstration trials. Out of 260 farmers who enthusiastically participated in the demonstration trials, 66% were women. They expressed the opinion that the KUMBOKO is resistant to diseases and gave almost double the yield of the local variety. However, the grain size is small, so it is difficult to market and the local variety fetches a significantly better price than KUMBOKO. **The EET noted the enthusiasm of the rice farmers during the field visit and recommends that IPM IL pay attention to the marketing problem for improved rice varieties that they are promoting. We also suggest the team conducts a socio-economic analysis of the situation to determine the adoption potential for the improved varieties before proceeding further. Farmers also need market information and awareness to successfully grow and market these disease resistant, high yielding rice varieties that the project is promoting.**

Maize is a major crop in Tanzania and is produced by 80% of smallholder farmers and 65% of maize production is consumed domestically while 35% enters the export market. Therefore, it is a subsistence and cash crop for smallholder farmers. As mentioned earlier the major yield-limiting pests are stem borers, and *Striga*. The yield loss due to stem borers can be from 20 to 50% while yield losses due to *Striga* can range from 20 to 90%. The IPM IL is promoting the Push Pull Technology (PPT), using Napier grass, *Pennisetum purpureum* or *Brachiaria* sp. as a border around maize plots along with green leaf *Desmodium intortum* as an intercrop, to manage both stem borers and *Striga*. The dense ground cover of the *Desmodium* effectively smothers the *Striga*. In addition, since *Desmodium* is a legume it fixes atmospheric nitrogen that enhances soil fertility. *Desmodium* leaves produce volatile chemicals that repel stem borer moths (PUSH). *Desmodium*

roots also produce chemicals which stimulate the germination of *Striga* seeds (Suicidal) and premature germination of the *Striga* prevents it from attaching to the maize plants. Both Napier grass and *Brachiaria* attract the female stem borer to lay eggs on the leaves (PULL), while Napier grass produces a gum-like material that kills the first instar larvae of the stem borer. Results showed that when farmers use the PPT package, maize yields increased by 30% and the *Striga* infestation was reduced by about 25%.

During conversations with lead farmers for maize, they enumerated the benefits of PPT as follows:

1. PPT is very helpful
2. Productivity of maize and income increased
3. They were able to reduce the cost of fertilizer (use less fertilizer) since *Desmodium* fixes nitrogen
4. They were able to reduce the use of insecticides and other inputs
5. *Brachiaria* and *Desmodium* in maize is healthier and greener
6. *Brachiaria* attracts pests (Pull) and reduces pest incidence
7. *Desmodium* repels pest (Push) and serves as a mulch
8. *Brachiaria* and *Desmodium* are used to feed goats and cattle. The animals have a preference for eating them.
9. The goats and cows fed with the border and intercrop plants increased their milk production, and milk and butter quality is better than before.
10. Weed problem is reduced during the current year and in subsequent years
11. Farmers cannot grow maize in areas with *Striga*, but after one season of *Desmodium* covered ground, it smothers the *Striga* and farmers can grow maize on those fields.
12. Farmers prefer the hybrid maize variety Silico, with two ears. The variety is from SEEDCO in Zambia.

13. Lead farmers would like to take a tour of successful areas in Kenya and Tanzania

The EET appreciates that excellent PPT is readily accepted by the enthusiastic farmers and congratulates all those team members involved in the work. The EET recommends that a mechanism be instituted for *Desmodium* and *Brachiaria* seed availability. Since the lead farmers have keen interest in PPT and other farmers are eager to adopt there is great potential for scaling-up within a short time. Therefore, there is a need to continue this effort for one more phase, with a focus on extension and scale-up.

5. Project: Rice IPM-Cambodia. PI: Buyung Hadi

Rice IPM in Cambodia is a new project for IPM IL and the implementing agency, International Rice Research Institute (IRRI) is a new partner. Rice is an important staple food crop in Cambodia occupying nearly 90% of the cultivated area. Considerable effort has been made to conduct field-level surveys across the country for the pests, diseases, weeds, rats and other problems in order to determine smallholder Cambodian farmers' level of knowledge and the control measures that they practice. Such information is necessary to design appropriate and ecologically based participatory IPM packages to manage these problems. For example, different kinds of rodent trap barriers have been evaluated combined with catch and kill, electric fences and rodenticide, ecological engineering using wild flowers, or sesame or mung bean on the rice bunds to encourage beneficial insects to fight against pests, local strains of *Trichoderma* and entomopathogenic fungi are being identified for inclusion in the recommended IPM package. Several graduate students are working on the project in Cambodia and in the US. The EET has no information on any new technology

developed from this project, nor any information about the adoption of any IPM technologies or packages by smallholder farmers in Cambodia as a result of this project.

6. *Project: Modeling of invasive species dispersal. PI: Abhijin Adiga*

There are two projects which are new to IPM IL in Phase V, and are outside the traditional frontiers of farmer-level IPM technology development and dissemination that the IL has been conducting for the past 25 years. The first one, "A High-resolution Interaction-based Approach to Modeling the Spread of Agricultural Invasive Species," focuses on two important invasive insect pests: *Tuta absoluta* and groundnut leaf miner (*Aproaerema modicella*). This project was implemented by the Biocomplexity Institute at Virginia Tech and now moved to the University of Virginia. It aims to produce a high resolution, interaction based approach to modeling which includes diverse environmental and biological interactions. The model is expected to provide reasons for pest spread, early detection, early warning, informing prevention and mitigation efforts, crisis options in near real time, risk assessment and economic impact. The economic impact as part of this project will focus on direct and indirect loss, consumer surplus, producer surplus, and social cost. The goal of the modeling effort is to help identify "hot spots" for pest and disease outbreaks that will hopefully inform and influence policies, awareness creation and control measures.

The team has multi-disciplinary expertise and has sought the cooperation of and data from French National Institute for Agricultural Research (INRA), CIRAD (France), ICAR (India), and North Carolina State University. They have published a number of quality papers in reputed journals which will be valuable for the scientific community. It will be interesting and valuable if the modeling effort can eventually predict the movement of pests, and forecast their arrival so that countries can be forewarned and prepare to take necessary actions to prevent catastrophic damage

to the crops. A large volume of data, from various agro-ecological zones, on weather, pest dynamics, hosts' presence, alternative hosts, predators and parasites of the pests, pesticide use, are all needed to make accurate predictions. These data are not easily available and currently they are not available for many of the necessary parameter for the model. Therefore, the computer modeling has to make many assumptions, which causes the robustness and value of the model into question.

One of the EET's key questions is whether or not the team has and can obtain the required amount of data to develop a meaningful model which can provide reliable and predictable information on pest movement and "hot spots." The team stated that is a common problem in this type of study. In spite of these problems, the team used minimum dataset and correctly forecasted the eastward movement of FAW from Sudan to Yemen and also provided a Risk Assessment of FAW in Egypt. It appears that the modeling team may be able to build on their initial successes. The *Tuta absoluta* project partly involves the USDA APHIS and therefore may be considered important information to the US in the long-run.

7. *Project: Biodiversity and climate change-Nepal. PI: Pramod Jha*

The second modeling project, Participatory biodiversity and climate change assessment for IPM in Annapurna-Chitwan Landscape in Nepal was originally implemented by City University of New York (CUNY). The sub-awardee, Tribhuvan University in Nepal recruited 20 graduate students and they are working on modeling to identify the distribution of three invasive weed species, (*Lantana camara*, *Parthenium hysterophorus* and *Ageratina adenophora*). They have also worked on finger millet, maize, cauliflower and others. The general concept of this project is that its results can be used as a useful model to measure changes in biodiversity due to climate change. There are

several dissertations and publications currently in the pipeline from this project. The students are currently transposing distribution of the above mentioned invasive weeds into the images, produced by remote sensing satellites, which will be sent to the scientists at Biocomplexity Insititute for machine learning, which is a technique developed and started around 1995. This study is expected to provide distribution and spreading patterns of these weeds from 1990 onwards in the Himalayas. They are also working on the distribution of *Zygogramma* in Nepal, which will give IPM IL information on climate ranges of *Parthenium* and *Zygogramma*. Therefore, the outcome of this project has several spin-offs

The two modeling projects discussed above have made some significant contributions to science and art of modeling and forecasting and the effect of climate change on biodiversity. The need for such research that enables us to understand the biocontrol agents and their interaction with the host and the environment was mentioned as being important in the collaborator survey. Therefore, the EET is convinced that the above two modeling projects should be continued in the next phase.

Additional Projects: Potential food security risk of FAW in Egypt (USAID mission in Egypt associate award), and Biocontrol of millet head miner (sub-award).

The EET recognizes and congratulates the proactive initiative taken by ME in assessing the potential food security risk of FAW in Egypt with buy-in from USAID mission in Egypt. Similarly, IPM IL was awarded a sub-award from Kansas State University's Sorghum and Millet IL (SM IL) to work on biocontrol of millet head miner. IPM IL and its partners in Niger were able to mass produce the natural enemy, *Habrobracon hebetor*, a parasitic wasp, for augmentative control of

head miner, *Heliocheilus albipunctella* (Guerci, et. al., 2018). Collaborators and the ME have also identified egg parasitoids, *Trichogrammatoidea* sp. (Trichogrammatidae), *Trichogramma* sp. (Trichogrammatidae) and *Telenomus* sp. (Platygastridae); egg-larval parasitoid, *Chelonus* sp. (Braconidae); and larval parasitoids, *Cotesia* sp. (Braconidae), *Charops* sp. (Ichneumonidae) on FAW (Amadou, et. al., 2018). The same parasitoids have already been identified in Ethiopia, Kenya and Tanzania. Further research and development efforts on these will ensure food security for the vulnerable groups in this region.

The EET recommends that exciting technology identification as has been done in Niger and other countries in the Sahel should be encouraged and promoted with other NARS so that new technologies are constantly feeding the pipeline for testing and adoption by the farmers.

2. Are the outputs relevant and appropriate for a demand-driven research-for-development (e.g., did they generate/develop new technologies of relevance to FtF countries that practitioners and/or small holder farmers are likely to use).

Consumers are becoming concerned about the pesticide residue. The policy makers and host country governments are beginning to recognize consumers' concerns about food safety. Smallholder farmers are also realizing that it is becoming increasingly difficult, if not impossible, to indiscriminately use pesticides to control the pests, diseases and weeds. They need alternative technologies and practices, which will reduce pesticide use and lower their production cost, for food crop (including vegetables and fruits) production and marketing. Communities are worried about their bio-diversity, pollution to land, water and environmental resources, and most importantly human and animal health. Many pesticide dealers are now even concerned that the

days of reckless advice to the farmers on pesticide use are over. Based on all the above issues IPM offers an attractive alternative to pesticide use.

IPM IL has identified a number of biocontrol agents as mentioned earlier and they clearly meet the demand by the FtF country practitioners and smallholder farmers. For example, different types of bagging technology developed by IPM IL, the ease with which they can be used and the economic viability of the technology, makes it easy for the farmers to adopt the technology in Vietnam, Nepal and Bangladesh for fruit crops.

Although many farmers see the potential benefits of releasing a large number of leaf-eating beetles and stem-boring weevils to control the invasive weed *Parthenium*, most of the farmers are poor so they cannot afford to pay for the release of the biocontrol agents. In this case, national research and extension services in host countries have to come up with some innovative means to mass produce the biocontrol agents at strategic locations and release them in the farmers' fields to combat the weed.

The control of maize stem borer without pesticide is extremely important for smallholder farmers. The PPT developed and used in demonstration plots in Tanzania have shown the multi-dimensional benefits of the technology. The technology is very attractive to the FtF country farmers. In addition, improved rice varieties are attractive to increase the yield with reduced or no pesticide.

Raising healthy, vigorous seedlings using raised beds and protective cover prevent early infection by virus diseases in vegetable crops. Smallholder vegetable farmers in Tanzania follow GAP, including an IPM package that includes solarization, use of local strains of *Trichoderma*, staking, pruning, grafting and use of protective cover or net houses to cultivate vegetables.

Bringing awareness to smallholder farmers of the pests, diseases and weeds is a crucial activity for the IPM IL to promote. Farmers are often not aware of the exact problem that is causing their crop to fail. Their only source of information is often pesticide dealers, whose incentives are to sell pesticides. IPM IL and its partners have developed diagnostic tools with pictures of pests and diseases, and they have trained farmers to recognize them. Farmers welcome this development and they would like to learn more about the real source of their pest problems and how to cost-effectively manage them.

3. Describe and highlight which research efforts have been most effective and which technologies have greatest potential impact. What opportunities are there to improve on-going IPM IL research (in terms of both increasing quality and generating appropriate outputs for FtF countries)

Among the research efforts undertaken during the current phase, for millet head miner, *Heliocheilus albipunctella*, the natural enemy, *Habrobracon hebetor*, a parasitic wasp has been mass produced and released in farmers fields in Niger, and an augmentative biocontrol using the parasitoid has already been instituted. Mass multiplication and marketing of parasitoid to farmers has been undertaken by private sector partners in the country. In addition, a recent study by Amadou, et. al., (2018) identifies eight local parasites for the FAW. These findings open up the potential to make an impact by releasing these biocontrol agents in areas affected by FAW. Similar research efforts should be strongly encouraged and promoted. The keys are moving from identification and trials to large-scale awareness building and adoption by farmers, along with building a sustainable supply-chain so that IPM technologies and practices can be scaled-up.

icipe's PPT is also very attractive to the farmers in Ethiopia and Kenya because of its multiple benefits. There is an excellent chance that FtF country smallholder farmers adopt the PPT because it is yield enhancing, and cost-reducing making it a cost-effective alternative to the status quo. Many women are involved in maize production and they love this technology due to its potential to improve income and health of their families and communities. The economist at *icipe* is a co-PI for this project and therefore, considerable amount of survey and cost-benefit analysis have been done. This lends robustness and credibility to the field-level studies and observations that have been undertaken.

Vegetables and mango IPM in Asia is evaluating a number of IPM packages in farmer's fields in Cambodia, Bangladesh, and Nepal in a participatory approach. Since the PI is an economist, there is a built-in impact assessment component in this project. The use of coconut pith dust either alone or with *Trichoderma* for raising seedlings, pheromone and sticky traps to control *Helicoverpa* and *Spodoptera*, neem seed oil and microbial pesticides such as *Metarhizium* and *Beauveria* are some of the promising technologies in the IPM components for vegetables in Cambodia, Bangladesh and Nepal. In addition, since many farmers have attended training and demonstrations there is potential for adoption if they believe that the selected IPM components are better for them compared to what they are using now. The project has learned some lessons and encountered challenges working with farmers. For example, the team learned that when they are not around, farmers spray their trials with pesticides to protect the crop from losses in case the IPM treatments fail. As a result, the data obtained are unreliable and final recommendations are not easy to make.

Parthenium weed control project has identified new biocontrol agents in addition to *Zygogramma bicolorata* and *Listronotus setosipennis*. IPM IL is also collaborating with South Africa and Australia where they are fairly successful in managing Parthenium.

Improved rice varieties, SARO-5 and KUMBOKO, identified in Tanzania can take off if the seed availability and marketing problems associated with promoting them can be resolved. Farmers would like to see further quality and marketing improvements such as a larger kernel bred into these varieties so that their grain fetches higher prices and retains their yield improving and disease resistant traits. This is a promising area for further research and the project should examine already available improved varieties that meet these traits requested by farmers.

4. Building on IPM results, what general opportunities and priorities exist for future national and regional research for IPM in Africa and Asia

The Parthenium project is in the second phase. Expertise in mass rearing of biocontrol agents has been transferred to a number of researchers in strategic locations in Ethiopia. A large number of biocontrol agents are currently being multiplied and released in three different sites in Ethiopia. Ugandan Government has already issued permits. *Zygogramma bicolorata* and *Listronotus setosipennis* have been already introduced to Uganda. The staffs from Kenya are hopeful that they can get a permit from their government to introduce the biocontrol agents into the country where Parthenium is threatening crop lands and wildlife parks. IPM IL has also identified additional biocontrol agents and they will start to mass rear, multiply, release and evaluate compared to *Zygogramma bicolorata* and *Listronotus setosipennis*. At the same time, the impact of biocontrol agents in already released areas needs to be assessed. The IPM IL in Ethiopia can serve as a hub for all the other neighboring countries to manage the weed.

The Asia vegetable and mango project has developed and extended IPM packages for tomato, country bean, cucurbits and okra to vegetable growing areas in Jessore and Bogra and the FtF districts in Kulna and Barisal in Bangladesh. Bt eggplant is almost completely free from EFSB and pest damage in Bangladesh. Bagging mango fruits and use of bio-pesticides (*Beauveria bassiana*) significantly reduced the damage due to fruit flies. In addition, Trichoderma compost, leachate and powder are recommended to control soil borne diseases; pheromone traps are recommended for control of insects in eggplant and bitter melon. In Nepal, the emphasis is on the control of the invasive tomato leaf miner, *Tuta absoluta*, with the help of IPM packages such as pheromone traps, biopesticides and growing seedlings under nylon nets. Some people also use *Tuta* free-seedlings. In Cambodia, with the help of IPM IL a local company is producing and marketing *Trichoderma* for use in tomato and beans. India is an old partner for the IPM IL and TNAU in India now it serves as a “mentor” and have been participating in conducting *Trichoderma* workshops in Cambodia, Ethiopia, Nepal and Tanzania. It is a south-south tech transfer.

In Vietnam, use of different types of bagging has shown significant promise for dragon fruit, longan and mango farmers. It reduces the use of pesticides, protects the environment, and improves fruit quality. As a result, small-scale fruit growers, along with fruit processors and exporters all derive tangible benefits from the technology, while consumers in China, USA and other fruit importing countries also benefit. Since the fruits are commercial crops, a sustainable model for promoting the technology should have processors and exporters take the lead in promoting the technology to farmers.

Push Pull Technology (PPT) has a lot of benefits and farmers are very eager to adopt them. The seeds and planting material for *Desmodium* and *Brachiaria* should be produced and made available for the farmers who are interested in adopting the technology. Private seed companies

and lead farmers can take initiative by producing and marketing the seeds. The team has already conducted benefit-cost analyses of the PPT, but further efforts should lead to highlight the multiple benefits in terms health, income, animal (both cattle and poultry) health and productivity, quality of milk and butter, consumer benefits, soil productivity and women's empowerment. Measurement of these impacts will help document the project's alignment and contribution towards USAID's FtF objectives.

Furthermore, adoption of improved varieties of rice and other crops with pest and disease resistance can play a major role both in Asia and Africa as it does in Tanzania, Bangladesh, Cambodia and Nepal. This is an important part of a successful IPM package that should not be ignored. In addition, attention should not only focus on the yield gains, diseases and/or pest resistance but also on quality and consumer acceptance of the crops' traits.

Finally, cultural practices as a component of IPM along with the use of selected bio-pesticides, biocontrol agents, microbial pesticides and botanical pesticides can play a major role in reducing the use of synthetic chemical pesticides, while at the same time reducing yield loss due to pests, diseases and weeds. These measures can also help to conserve the environment and protect human and animal health. Future research should focus on innovative, cost-effective and labor efficient technologies using modern tools and locally available materials.

Chapter 4: Stakeholder Collaboration for Enabling Environments

The stakeholders of IPM IL in the current phase are predominantly in USA, East Africa and South and Southeast Asia. However, interest in the work of the IPM IL goes beyond the borders of these regions, and is in fact, global. For example, requests for collaboration with the IL have come from Egypt, Niger and other countries in East Africa such as Uganda. The IPM IL has engaged partners in these countries and addressed their requests successfully. In addition, the Biocomplexity Institute at Virginia Tech has collaborated with partners in Senegal, France, Australia and India for their modeling project. In addition, the Director of IPM IL has been invited to give special lectures in various international conferences on invasive species and their management.

1. In what ways are relevant partners, including USAID missions and projects, FtF, IARCs, NGOs, host country governmental and academic institutions, private sector and community stakeholders

(if applicable) being informed and engaged (as appropriate) in target countries and regions, and at IPM IL level?

After the IPM IL's fifth phase (2014-2019) was approved, the director and the AOR arranged consultations with the missions, national partners (both academics and government), IARCs, NGOs, along with private-sector and other stakeholders in each of the seven target countries. The consultation helped to refine the goals and objectives of the IPM IL so that it aligned with the priorities in those countries and helped identify strategic locations for research and development. The consultation was participatory, interactive and informative. The engagement with USAID missions and other stakeholders provided an opportunity for the IPM IL to address their needs, and come up with an understanding to share responsibilities so that the outcome aligned with FtF objectives.

Whenever the IPM IL ME visits a region or country they try to meet with the missions and keep them informed about the progress being made by the IPM IL projects. The mission staff also participated in the field visits to observe the progress.

Research planning workshops and annual review meetings are two of the important occasions when collaborators come together to share and exchange information. It also provides an opportunity to discuss mutual collaboration either within the country or countries within the region or even between regions. The majority of the collaborators in the survey feel that they are extremely or very well engaged in setting the research priorities and objectives while a minority of them would like to have more support for participation in such exercises (Appendix 3).

The majority of collaborators (85%) also say that they have played some role in the research outputs of the project (Appendix 3). The EET observes that there is active participation of collaborators in the annual meetings and workshops. However, for capacity building and

sustainability reasons it is extremely important to increase the research leadership of scientists in host countries.

IPM IL organized meetings and the number of participating countries in each meeting and the total number of participants are given in Table 6. IPM IL organized a total 39 meetings and a total of 13,065 collaborators and stakeholders participated, and women were well represented (40%).

Table 6. Different meetings organized by IPM IL, 2014-2018

Type of Meeting	No. of countries	No. of Participants		
		Male	Female	Total
Planning	6	302	149	451
Training	14	3223	2263	5486
Field days	7	3202	2310	5512
International Conference	8	1055	424	1479
Seminar	2	36	59	95
Consultation Meeting	2	30	12	42
Total	39	7848	5217	13,065

The meetings were grouped according to topics to understand the focus of IPM IL (Table 7).

Table 7: Meetings conducted by IPM IL grouped according to subject matter.

Subject	No. of countries	Number of Participants		
		Male	Female	Total
Diagnostic Techniques	5	419	236	655
PPT	2	1127	272	1399
Farmer's Field Day	7	4521	3338	7859
Gender	8	36	47	83
Biocontrol of weeds	3	361	164	525
Trichoderma	4	113	27	140
Plant virus	6	329	116	445
<i>Tuta absoluta</i>	11	898	290	1188
FAW	2	116	38	154
Nematode	2	127	50	177
Total	50	8047	4578	12625

Of the meetings organized by IPM IL, *Tuta absoluta* attracted the most number of countries and

second most number of participants (10%). All the projects organized FFD and nearly 62% of the total participants joined the FFD showing the importance and interest of the farmers.

If we look at who is the majority participating in the meetings, nearly 74%, were farmers and extension agents from 7 participating FtF countries out of the total of 12,337 (Table 8). About 27% were students, government officials, scientists and NGOs from 15 countries. Only from 2 countries the private sector has participated (Table 8). IPM IL should encourage private sector from more countries to join the meetings.

Table 8: Different groups of participants in IPM IL organized meetings

Group	No. of countries	No. of Participants		
		Male	Female	Total
Farmers and extension agents	7	5,266	3,830	9,096
Students, Govt. Scientists, NGOs	15	2,156	1,188	3,344
Private sector	2	88	38	126
Researcher	1	85	14	99
Total	1	7,595	5,070	12,337

Note: The women participants are around 40% of the total participants. There is discrepancy between three tables and the error happened during compiling but one can see the trend.

Various types of publications are another mode by which the collaborators are kept informed and share the research and development outputs (Appendix 4). According to the collaborator survey lack of engagement with collaborators while preparing the reports for publications appears to create some tension among the researchers as to who gets the credit for the work (Appendix 3).

In Bangladesh, NGOs such as the Mennonite Central Committee (MCC), Grameen Kalyan

Sangharsh, Samiti (GKSS), Practical Action and Department of Agricultural Extension (DAE) personnel and the private-sector partners like Ispahani have been trained on vegetable IPM by the IL. All these people in turn train a large number of farmers. The private sector also sells IPM products such as pheromone traps and beneficial insects. In Nepal, IPM IL has collaborated with NGO, international Development Enterprise (iDE). iDE has established learning centers, for farmers and extension agents that provide IPM Know-how to scale up technologies. A number of community business facilitators (CBF) have also promoted IPM packages and products in *Tuta*-affected tomato growing areas and helped the farmers identify the problem and select suitable IPM solutions such as pheromone traps, bio-pesticides and growing seedlings under nets. In addition, Agricare, a private firm is engaged in marketing bio-pesticides.

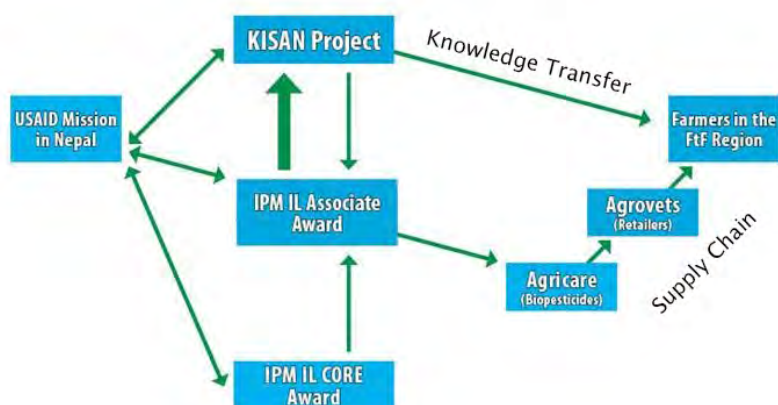


Figure 7: IPM IL engaged with the mission, mission project, private sector and farmers

In Cambodia, private sector firms such as Eco-Agri Center, Angkor Green Co are producing and marketing *Trichoderma* and other biocontrol products to vegetable farmers.

The EET recommends that the IPM IL ME and collaborators make efforts to track how many IPM trainings are held by partner organizations that they have trained and also how many technologies have been sold by private-sector partners. This is important leverage and

impact for the project's success that should be documented.

2. How do the host-country stakeholders perceive the IPM IL initiatives? What extent do they share ownership and share a common vision of foci, approaches and process (What, why and how)?

Southern Horticultural Research Institute (SOFRI) in Vietnam is a new partner for IPM IL in Asia. Their major concern for smallholder farmers in their country is loss of export fruit crops such as dragon fruit, longan, lychee and mango due to pests, diseases and pesticide residue. The Vietnamese government and other local stakeholders appreciate the initiative taken by the IPM IL to address the fruit growers' problems so that they minimize loss due to pests and diseases responsibly and economically, while at the same time reducing or eliminating pesticide residues. Currently, the US government requires all fruit exporters in Vietnam to irradiate their fruits prior to exporting. The initiative taken by IPM IL along with its national partners is to develop different kinds of bags and other strategies (e.g.: plastic sleeves for dragon fruit, mesh bags and light traps for longan, wax bags for mango, and grafting old mango trees). These improved technologies are simple to use, with easily available materials at a low cost. Producing and selling of these inputs can potentially provide employment opportunities for women and youth. The extent and speed of adoption rate of this technology needs to be monitored and evaluated. Different kinds of bags developed for adoption should be made easily available by encouraging the private-sector and/or the fruits exporters association to sell to smallholder farmers. The economic and social benefits of this technology need to be assessed rigorously.

Small-scale subsistence maize (and also sorghum) farmers in Ethiopia and Kenya are enthusiastic about the PPT initiated by *icipe* and promoted in cooperation with the IPM IL. As we can see in impact and scaling section, there is considerable interest in the PPT due to its multi-

dimensional benefits to the farmers. The challenges to adoption of PPT is mainly the availability of seeds of *Desmodium* and *Brachiaria*. However, some of the lead farmers overcome this challenge by taking the initiative to collect the seeds of the two crops and they are planning to sell them to neighboring farmers. The women and youth are involved in these activities. The potential for rapid expansion of this technology is great.

Various IPM technologies, such as bio-pesticides (*Trichoderma*, *Beauveria*), neem seed products (extracts and powders), pheromone traps, nylon nets, coconut pith (and compost), grafting (for tomato, eggplant and cucurbits), bagging (for mango), are initiatives of IPM IL for combating vegetables and mango insects and diseases in Bangladesh, Cambodia and Nepal. Young scientists are involved in evaluating and identifying the best technologies. Selected IPM components were found to be attractive to NGOs and private entrepreneurs, based on the interest and demand from the farmers. These entities have commenced with producing and marketing these technologies to small-scale farmers. Women entrepreneurs are actively involved in this venture enabling them to gain employment, empowerment and business management opportunities.

In addition to determining the impact in terms of internal rate of return (IRR), consumer surplus (CS), producer surplus (PS) it will be worthwhile to trace the sale of traditional chemical pesticides, prior to the introduction of IPM components and after the adoption of IPM and also determine the trend in sale of IPM components and its relationship to sale of chemical pesticides as well as pesticide residue.

Stakeholders in Kenya and Uganda are very much interested in adopting the biocontrol agents to manage the invasive weed *Parthenium*. Ugandan Government has already issued permits. *Zygogramma* and *Listronotus* have been already introduced to Uganda. IPM IL is taking

initiative to approach the government of Kenya and try to get permission (permit to import the biocontrol agents) to initiate the rearing facilities to multiply the biocontrol agents. Ethiopia is taking the lead in serving as the hub for *Parthenium* control. Recognizing the importance of controlling *Parthenium* and significance of IPM IL's initiatives the President of Haramaya University, Dr. Chemindsa Fininsa provided a grant of 100,000 Bir (US\$5000) to the IPM IL for the control of *Parthenium*.

The ambitious goal of the IPM IL's modeling invasive tomato leaf miner and groundnut leaf miner project is of great interest to APHIS/USDA in the US. The project is expected to develop models which can predict the potential invasion of unwanted, uninvited, invasive pests, diseases and weeds into the US. Using biological, physical, seasonal, behavioral, trade and other factors the project is aiming to develop models forecasting the potential movements of the pests which will be useful not only to US but also to other FtF countries. Nepal's President, Hon. Bidya Devi Bhandari, was keenly interested in the climate change and its implications on biodiversity changes in countries like Nepal. She inaugurated international conference on Biodiversity, climate change assessment, and impacts on livelihood in Nepal in 2017 that was organized by the IPM IL.

The IPM IL is a partner in the sub-award from SM IL for biological control of millet head miner in Niger and Senegal. IPM IL and its partners are working on mass multiplication of *H. hebetor* (a larval parasitoid) and *Trichogrammatoidea armigera* (an egg parasitoid) for field releases. They are also developing a business model by working with cooperatives and private organizations.

Fall armyworm (FAW), *Spodoptera frugiperda* is an invasive polyphagous pest that attacks more than 80 species of crops and other plants. In Africa FAW damages maize and other crops in at least 44 sub-Saharan African countries, threatening the food and nutritional security of more

than 300 million people. A number of FAW awareness workshops have been conducted by various institutions in Africa and Asia. *icipe* is one of the institutions working on FAW for the past 2 years and this year European Union (EU) has awarded them with a €7 million from 2018-2022 to combat FAW using biopesticides (https://www.the-star.co.ke/news/2018/02/22/eu-gives-icipe-grant-to-help-farmers-fight-armyworm_c1718404).

IPM IL has also collaborated with *icipe* to combat the maize stem borer using *icipe*'s PPT package, which also controls the FAW. *icipe* is currently focusing its research efforts on the compounds in *Desmodium*, *Brachiaria* and *Napier grass* which repels and attracts the FAW so that they can extract those chemicals to manage the pest. In addition, the IPM IL has taken the initiative to identify locally available biocontrol agents which can be used to combat and control the FAW. Since the FAW problem is enormous IPM IL's initiative will complement that of *icipe* and hopefully bring a faster and better resolution to the problem.

Furthermore, the USAID mission in Egypt recognized the expertise of IPM IL, so they provided at US \$50,000 buy-in to conduct a food security risk *assessment* of the FAW, *Spodoptera frugiperda*.

Recently in Niger, IPM IL along with the Niger collaborators have identified egg parasitoids, *Trichogrammatoidea* sp. (Trichogrammatidae), *Trichogramma* sp. (Trichogrammatidae) and *Telenomus* sp. (Platygastridae); egg-larval parasitoid, *Chelonus* sp. (Braconidae); and larval parasitoids, *Cotesia* sp. (Braconidae), *Charops* sp. (Ichneumonidae) on FAW (Amadou, et. al., 2018). IPM IL is the first to organize a training workshop in Kenya in February 2019 to train the partners in rearing some of the above parasitoids to control FAW.

The IPM IL provides its collaborators with two important sources of information. The first is IPM packages for individual crops. The packages are modified as more information is generated

through research. The second source of information provided by the IPM IL is a Pesticide Evaluation Report and Safer Use Action plan (PERSUAP). IPM IL works closely with USAID environmental officer at BFS/USAID to generate the PERSUAP, and prepares a list of pesticides and measures that are approved for use to fight a pest in a certain country. The PERSUAP has a list of safe pesticides that is updated periodically as more information becomes available. The PIs are fully aware of using pesticides that are in the PERSUAPs. They participate in the preparation of PERSUAPs. It is also discussed in the annual project planning and TAC meetings. Even to purchase pesticides listed in their PERSUAP, sub-awardees are required to obtain approval from the AO/USAID.

It is important to note that a judicious application is suggested if these approved pesticides are allowed as part of an IPM IL control strategy. In the current phase, IPM IL has obtained two PERSUAPs, one for *Tuta absoluta* in Nepal and one for *Spodoptera frugiperda* in East Africa. IPM IL has also prepared PERSUAPs for Vietnam, Cambodia, Bangladesh, and Nepal. The IPM packages and PERSUAPs are not universal and they need to be modified, even for the same crop, in different countries, and even within the country in different seasons or locations.

3. What potential is there for other partnerships and collaborations, including other FtF Innovation Labs and other USAID programs in the target countries?

In the past, the FtF ILs collaborated primarily with the US universities or US institutions. In the current phase, USAID has included the CGIAR centers and other IARCs and the NARS to submit the proposals in responses to the RFA and compete for the sub-awards. Expanding potential collaboration opportunities is a welcome development. Currently, IRRI, AVRDC, *icipe*, IITA, (CGIAR and IARCs) and SOFRI in Vietnam and Tribhuvan University in Nepal have been

awarded projects. The choice of selection of awardees should be based largely on the merit and value of their financial proposal, capability of their personnel, and their ability to perform and deliver. From a collaboration point of view, inclusion of diverse institutions is a healthy step in the right direction. When working with host country government institutions there are administrative issues that delay and frustrate. However, it is important to work with local institutions, since they are the ones with the most potential to engage and influence policymakers. For example, Nobel Laureate Norman Borlaug knocked on the doors of the Prime Minister, Indira Gandhi to bring about the green revolution in India. Therefore, patience, understanding and determination will definitely pay off when working with host country governments. However, in order for this to happen, local government institutions must be the beginning planning phases. Decision-making and ownership should be given to them so that they have a responsibility and obligation to accomplish the objectives that benefit their smallholder farmer populations.

Currently there are 22 FtF Innovation Labs. Based on the comparative advantage of IPM IL some of the projects from other Innovation Labs should be encouraged to collaborate with the IPM IL through sub-awards or otherwise. For, example, IPM IL and its partners in Niger were sub-awardee of SM IL to control pearl millet pests in Niger and Senegal. **The EET recommends that the ME and AOR encourage all the FtF ILs to consider synergies among the Innovation Labs. Among the FtF Innovation Labs, Hort IL, SM IL, CRS IL, LS IL, FPL IL, PHL IL and SI IL likely have compatibility and synergy with IPM IL to have collaboration that may be considered in the formative stages.**

In addition, the collaboration with *icipe* is generating important impacts. Also, AVRDC has developed a number of disease resistant vegetables for Africa and Asia, so the IPM IL may consider taking advantage of their resources and strengthening collaboration with them. Socio-

economists in the collaborating countries should be included in projects, many of which are ripe for impact assessment. Baseline information from representative smallholders in focus countries needs to be collected during project initiation in order to measure adoption of IPM technologies over the course of the project.

4. In what ways does the research capacity of U.S. universities, IARCs complement (not replicate) capacities of the national programs and their NGO partners in target countries.

The facilities at US universities and IARCs are much better and readily accessible to researchers and students. By utilizing their facilities and expertise, they are able to conduct in depth basic research to better understand the functionality of IPM technology packages. These can then be tested and used by the national programs. Some of the national programs, such as in India, have developed capabilities comparable to US. Over the years, majority of the national partners lack facilities, equipment, and resources to conduct basic research. However, national partners can conduct applied research and farmer field trials to select the best technology suitable for their locations. NGOs and government extension personnel can be trained to promote such technology to farmers in order to scale-up and quickly spread the technology to have an impact.

IARCs in collaboration with the national partners develop disease and insect resistant varieties of crops which are refined through testing to suit to specific locations and socio-economic situations. IPM IL has used the US and IARCs expertise to train the national partners and NGOs.

It is also important for US universities to train students from host countries in order to build local capacity. IPM IL in their long-term training for M.S. and Ph. D. degrees, the “sandwich” students who spend part of their time in the US universities and rest of the time in their home country to complete their Ph.D. They have the advantage of both the worlds. The US universities

get additional people to work on their projects and the students are able to use the facilities to do basic research and gain valuable experience. They will serve as future institution builders in their home country. IARCs also provide essential training and provide Ph.D. research training in their facilities for students in host countries.

In some instances, like the Parthenium project, the project leader has, with good intention, brought the research materials necessary for rearing the biocontrol agents from the US back to Ethiopia. He did this because biocontrol agents can be easily and efficiently reared and multiplied using the materials from the US. This is perfectly acceptable for experimental and trial purposes. However, from the practical and sustainability standpoint it is better to use the locally available materials for such purposes. The EET suggests that the IPM IL PIs encourage the local researchers and students working on the project to be innovative and creative in identifying locally available materials for use in adaptive research. For example, in rearing and multiplying the biocontrol agents, so that the adoption can be more efficient, cost-effective, and sustainable.

Importing biocontrol agents from other countries, creates issues of permits and international policy. Therefore, identifying and using locally available biocontrol agents, bypasses international government bureaucracies. As such, national research partners in the countries that collaborate with the IPM IL and IARCs are able to identify the locally present biocontrol agents. (For example, biocontrol agents for FAW in several countries). However, for most invasive pests like Parthenium importing parasitoids is the only option and in those cases the IPM IL follows the proper protocols and permits before importing them into the country.

The Biocomplexity Institute's basic modeling research conducted at Virginia Tech is expected to predict the spread of both South American tomato leaf miner in Africa and Asia and groundnut leaf miner in Africa. It is also expected to provide information on countries at high risk

of invasion by these invasive species in Africa, the Indian sub-continent, along with Central and North America. As mentioned earlier APHIS/USDA and USAID is interested in such forecasting techniques for US agriculture, so this project potentially has direct benefit to US farmers in addition to famers in other parts of the world.

Chapter 5: Human and Institutional Capacity Building

Human and institutional capacity building has always been an important component of IL projects and this certainly holds true for the IPM IL. Formal academic training for qualified staffs from host country strengthens the national institutional capability to sustain the research progress even after the project ends.

5. How relevant are the IPM IL identified academic and technical capacity building needs for the IPM host country and regional stakeholders?

Long-term training is for undergraduate and graduate students who are enrolled in a recognized university in their country and working towards their respective M.S. or Ph.D. degrees. Such training is extremely relevant for improving the capacity of the host country and regional stakeholders. Research topics are chosen in consultation with the IPM IL project staff who serves as one of the advisors for the students aligning with the needs of the country and the objectives of the IPM IL.

The following are examples of the types of research topics pursued under the long-term training component of the IPM IL: i) identification of appropriate biocontrol agents, ii) development of microbial pesticides, iii) mass production techniques for biocontrol agents, iv) host range studies, v) agronomic trials to evaluate disease resistant varieties, vi) socio-economic cost-benefit analysis studies to evaluate the benefits of IPM in vegetable crops, vii) cost-benefit analysis of different IPM techniques such as push/pull technologies (PPT) and their impact, viii) factors affecting and constraining IPM adoption, ix) gender empowerment, and women's involvement and contribution to IPM, x) developing invasive pest epidemic forecast models, xi) the speed with which the biocontrol agents spread in space and time and xii) climate change and biodiversity.

There are students who have a sandwich program where they are enrolled in a US university and complete the course work and conduct their thesis research in one of the participating home country universities. In addition, US students complete their course work in the US and undertake field research in an IPM IL host country. However, the majority of the students are enrolled in their home country university both for academic training as well as for their thesis research. Some of the students are also sent to neighboring countries such as Sokoine University of Agriculture in Tanzania, Makerere University in Uganda, or a South African University for their advanced degree.

6. How effectively has IPM IL addressed academic and technical capacity needs of stakeholders and how could IPM IL better serve and provide for the capacity needs of these stakeholders in the future

Long-term academic training is an important component of the IPM IL project. The EET is pleased to see IPM IL has enlisted 120 people from 16 countries for long-term training on the IPM IL

project between 2014-2018 (Table 9 and Table 10). The number of males (56%) and females (44%) receiving long-term training are relatively close to each other (Table 9). Out of the total of 120 people trained, the Vegetable IPM in Asia project and the Biodiversity/Climate change in Nepal project have each trained 22.5% of all the people who have received long-term training under this phase of the IPM IL. In addition, the Vegetable IPM in East Africa project has trained 15% of the total number. Around 48% worked toward their M.S. degree while 28% towards their Ph.D. degree (Table 10). Nearly 55% of the trainees are from Asia while 32% are from Africa and 12% are from USA. Nepal (24%), Cambodia (13%), USA (12%), Tanzania (12%), Vietnam (10%) and Ethiopia (8%) had the highest percentages of trained scholars (Table 10).

Table 9. IPM IL Long-term training by country and by gender from 2014-2018

Home Country	Male	Female	Total
Bangladesh	4	2	6
Ecuador	0	1	1
Nepal	19	10	29
USA	6	8	14
Vietnam	6	6	12
Ethiopia	6	4	10
Cambodia	7	9	16
China	1	0	1
India	1	0	1
Senegal	5	1	6
Tanzania	6	8	14
Kenya	4	2	6
Philippines	0	1	1
France	1	0	1
Niger	1	0	1
South Africa	0	1	1
Total	67	53	120

Table 10. Number of people receiving long-term training on the IMP IL 2014-2018, by sub-grant,

degree, and gender

Sub grant (PI)	Male				Female				Total
	BS	MS	PhD	Post Doc	BS	MS	PhD	Post Doc	
Vegetable IPM Asia (G. Norton)	4	1	8	0	7	4	3	0	27
Vietnam fruit crops IPM (N. Hoa)	6	0	0	0	3	2	1	0	12
Parthenium (W. Mersie)	0	2	0	0	1	4	0	0	7
Biodiversity/ Climate Change in Nepal (P. Jha)	0	10	4	1	0	8	4	0	27
Rice IPM Cambodia (B. Hadi)	0	3	1	0	0	3	0	1	8
Modeling Invasive Species (A. Adiga)	2	5	3	1	0	0	0	1	12
Grains IPM in East Africa (T. Tadele)	0	2	5	0	0	1	0	0	8
Vegetable IPM East Africa (L. Canas)	1	8	0	0	2	4	3	0	18
Students on other projects completing degree on no-cost extension from previous phase	0	0	0	0	0	1	0	0	1
Total	13	31	21	2	13	27	11	2	120

Source: IPM IL Management Entity

From collaborators' survey, long term training appears to be well integrated with the project. For example, the modeling project scholars' work on quantitative modes of disease and pest movement; rice and maize IPM scholars conduct research on the IPM of rice and maize pests respectively. The majority of the collaborators believe that specific funds are allocated for long-term training (Appendix 3). More early career scientists feel that they should get advanced training for M.S. and Ph.D. degrees and more funds should be allocated for long-term training. This is likely reflective of the fact that collaborators want themselves and their colleagues to have an opportunity to enhance their education and subsequent advantages it provides both for them personally and professionally to their country. The students are quite diligent, hard-working, sincere in collecting the data and knowledgeable in using modern technology in analyzing and interpreting the data and results. They have learned how to prepare journal papers of their research work and the importance of publishing them in peer refereed national or international journals. They have also learned how to effectively present their research work to the scientific audience

and defend their work. The research topics are relevant and appropriate for the IPM IL. The advisors from the university and also from the IPM IL staff assist and guide the students in the right direction. Prior to submitting their theses, many students have already published their research in several peer-reviewed journals; EET congratulates both the advisors and the students for their excellent job.

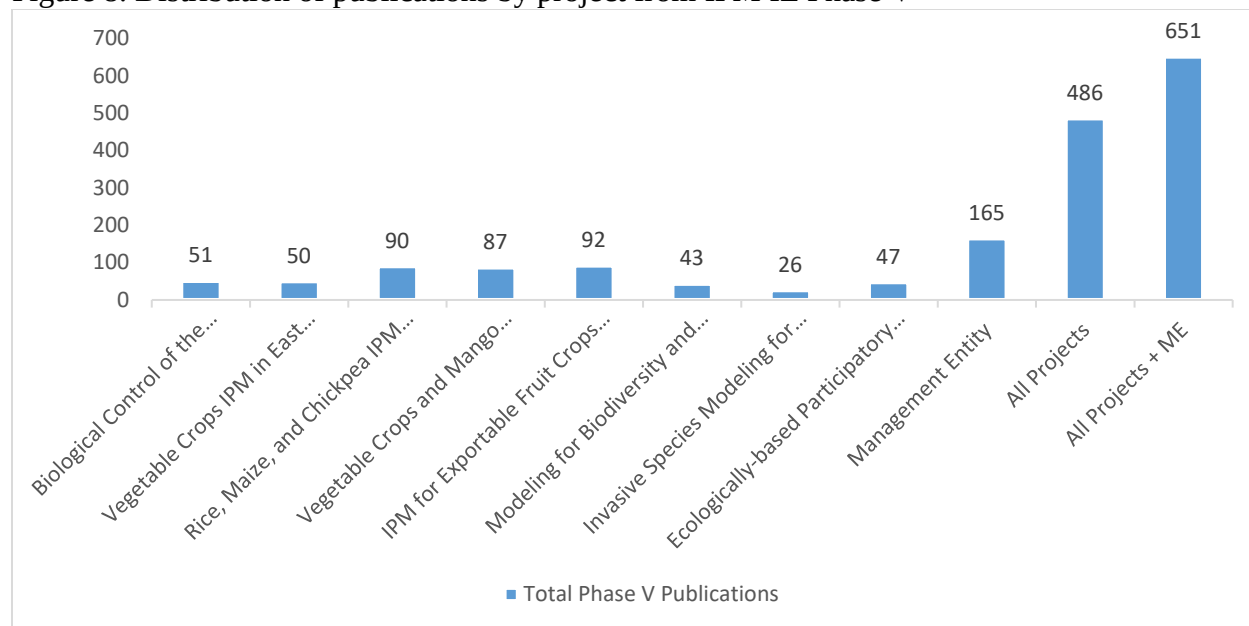
7. What improvements, if any, are needed in how academic and technical capacity strengthening activities are identified and implemented

In some instances, EET observed that several students begin their project with a survey, on the same topic, in the traditional way. The students explained that this gave them the opportunity to learn how to conduct the survey. With expanding information and communication technology (ICT), it is getting cheaper and easier to collect data cost-effectively and quickly. Many US universities have designed their own program to survey agriculture and livelihood related activities among smallholder farmers in focus countries, including impact assessment. Axio survey of Kansas State University is a survey software that is widely used by ILs. Qualtrics is another survey program that is used extensively in various fields. Therefore, gradually the graduate students have to be more creative in designing and conducting their surveys. They can either develop their own software or use the existing software to meet their needs. IPM IL may like to encourage them and make such software available to the collaborators.

The communication coordinator at VT and each of the eight projects have actively prepared their outputs (a total of 651) as quality publications of various kinds—research articles published in peer reviewed international and national journals, popular articles, pamphlets, bulletins, posters, newspapers, Agrilinks, BIFAD News and others. The distribution of publications by projects and

from ME are shown in Figure 8. The ME and the IPM IL team should be congratulated for their prolific communication to the scientific, farming and policy making community (Appendix 4).

Figure 8. Distribution of publications by project from IPM IL Phase V



EET commends the ME for focusing their attention in enhancing the knowledge base and strengthening the institutional capacity of the collaborators in Asia and Africa. Since there is a need for more trained personnel for Africa, EET recommends that in the future, more people from Africa should be given opportunity to earn advanced degrees using IPM IL funding. EET also recommends that the IPM IL advisors continue to serve as a catalyst to stimulate young minds to do original research creatively using their imagination and come up with new ideas, new tools, new technologies and new ways of doing research.

8. In what ways, if any, have the training programs contributed to strengthening organizational capacity, including fostering institutional innovation and learning cultures, and inter-organizational and inter-sectoral cooperation in target countries?

Short-term training/extension

Short-term training, on various IPM topics were given in each country, for farmers, extension staffs, NGOs and the private-sector to improve their technical IPM knowledge. The training included formal lectures with slide presentations, and hands-on exercises and demonstrations in the screen house or lab and fields, such as field day demonstrations. Scholars receive training materials in the form of posters, pamphlets and slide-sets so that they can refer them for future use. Experienced technical experts on specific subject matters, from the US, mature IPM IL partner countries, along with IPM IL staff and experts from host countries who are included as resource people for the training.

Of the total 14,492 who received short-term or extension training on the IPM between 2014-2018, 8,209 (57%) were men and 6,283 (43%) were women. In Bangladesh, Nepal and Cambodia more number of women received training than men indicating large number of women's participation in vegetable and fruit IPM. The Vegetable IPM project has trained 3,891 people, the Vegetable IPM East Africa has trained 3,185 people while the Rice IPM in Cambodia project has trained 2,619 people (Table 11).

Table 11. Number of people receiving short-term training on the IMP IL 2014-2018, by sub-grant, and gender

Sub grant (PI)	Male	Female	Total
Vegetable IPM Asia (G. Norton)	1,734	2,157	3,891
Vietnam fruit crops IPM (N. Hoa)	671	167	838
Parthenium (W. Mersie)	252	138	390
Biodiversity/ Climate Change in Nepal (P. Jha)	726	525	1,251
Rice IPM Cambodia (B. Hadi)	1,211	1,408	2,619
Modeling Invasive Species (A. Adiga)	43	40	83
Grains IPM in East Africa (T. Tadele)	1,368	496	1,864
Vegetable IPM East Africa (L. Canas)	1,906	1,279	3,185
IPM IL Management Entity-led	298	73	371
Total	8,209	6,283	14,492

Source: IPM IL Management Entity

Around 57% of the collaborators surveyed indicated that the short-term/extension training is either extremely or well integrated into their program (Appendix 3). About half of the collaborators are aware that specific funds are allocated for short-term/extension training. It is likely that the other half are either field staffs or students who won't have the budget details. It is significant to note that 58% of the collaborators confirm that the training had a positive impact on the production practices of farmers. Therefore, the training is effective in transferring the IPM technology and is crucial for the project (Appendix 3). As a continuation of training the farmers, extension agents, NGOs, private sector, university staffs and the IPM IL project staffs were also connected through a network of WhatsApp group to exchange information on pests and disease identification, IPM packages for specific crops and other information relevant for the farmers.

The training program on *Parthenium* utilized the seven screen houses that the IPM IL established in Wollenchiti for rearing and multiplying the two biocontrol agents. IPM IL scientists trained the Ethiopian NARS staff along with people from Uganda, and Kenya. The staff at Wollenchiti trained other collaborators on the art and science of meticulously raising the *Parthenium* plants for multiplying the two biocontrol agents in the screen houses, which they have mastered. The specialist from South Africa also gave special lectures and hands-on training to the visiting scholars. The training was interactive and participatory, which fostered collaboration between Ethiopia, Uganda, Kenya and South African scientists.

In the case of the Asia vegetable and mango IPM project, training of NGOs (MCC, GKSS, and Practical Action) resulted in these groups conducting their own follow-up training for a large number of farmers. In addition, training the Department of Agricultural Extension (DAE) personnel led to their agents training additional farmers on IPM. Similarly, training private-sector

companies such as Isphani, who sell pheromone trap and beneficial insects, on IPM causes them to go out and educate the farmers the benefit of IPM using their own resources. Women entrepreneurs have picked up production and marketing of *Trichoderma* compost, providing them with jobs and opportunities.

Therefore, one can see multiplication and spill-over effect, where partner organizations leverage the benefits of the IPM IL training programs. Several community business facilitators (CBF) have also helped farmers become better able to identify their pest problems and use IPM packages to address their problems. IPM IL has invited experienced scientists from TNAU in India to Nepal, Tanzania, and Ethiopia in order to provide training in the use of various *Trichoderma* products and the coconut pith for use in IPM packages. *Trichoderma* workshops conducted in Nepal resulted in the firm Agricare embarking on production and marketing of biopesticides. Similarly, in Cambodia private sector firms such as EcO-Agri Center and Angkor Green Co are producing and marketing *Trichoderma* and other biocontrol products to farmers. As a result, the demand for their products is increasing. Production of quality vegetables with low or no pesticides have encouraged collaboration between IPM IL and government contractor, iDE, for marketing of such vegetables in Nepal and in Cambodia.

As mentioned earlier, the Push/Pull Technology (PPT) promoted by IPM IL partner *icip*e is so attractive to farmers in Tanzania, Kenya and Ethiopia that there is great demand for extensive training. Farmers' field days attract a large number of interested participants, many of whom want to become demonstration farmers themselves after seeing the results of IPM packages. Some of the progressive farmers who are involved in the project are engaging other farmers who are interested in adopting PPT and collecting the seeds of *Desmodium* and *Brachiaria* so that they can sell these seeds to them the next season. The private company Real IPM, Debre Zeit Research, and

Bako research Centres (Ethiopia) Dakawa Research Centre and national Biological Control Program (Tanzania), Hawasa University, University of Nairobi, University of Dar Es Salam and KALRO have all partnered with *icipe* to promote PPT method to control Maize stem borer and Striga, and also potentially control FAW.

The pest control program in fruit crops in Vietnam is led by IPM IL partner SOFRI and has developed different kinds of bagging for different fruit crops, including dragon fruit, longan, lychee and mango. The bags are simple, easy to use and inexpensive. Establishing collaboration with the local fruit processors and exporters will be extremely beneficial in sustaining new IPM technology to control fruit crop pests and diseases after the project is completed. The training of the staff members has empowered them to become better communicators, not only to smallholder farmers but also to the scientific community. Their ability to write scientific articles have improved, and their initiative to inquire and explore new causal agents from the symptoms is commendable. For example, the Witches' broom disease of longan has been hitherto attributed to virus. However, Dr. Hanh the Co-PI in Vietnam in cooperation with IPM IL was able to identify the causative organism to be an eriophyid mite. As a result, the species of the mite will be named after Dr. Hanh. It is a great achievement indeed.

9. To what extent has capacity building enabled target country partner organizations to maintain IPM research activities after the completion of IPM IL?

Fruit crops exported in Vietnam is a big cash earner for the farmers. If farmers reduced their pesticide use on fruit crops due to IPM practices instituted by IPM IL and its training, it is attractive to exporters since the importing countries prefer low or no pesticide residue in their imported fruits. IPM IL has enabled the NARS partners to use the IPM technology on the fruit crop pests.

Therefore, it is in their own interest to sustain and strengthen these research activities to further refine and improve the technology after the completion of IPM IL. IPM IL can focus on the rate at which the scaling up is taking place and identify the hiccups in scaling-up process and how to overcome them to achieve the project's goals of farmers adopting IPM practices sustainably. The impact of these technologies can also be assessed to further strengthen the national program efforts.

In the case of Asia, IPM of vegetables and mango, the training program appears to have laid the foundation by training the IPM IL implementing partner iDE, NGOs, extension personnel, private sector and the USAID contractors such as iDE. They are undertaking further training of farmers. Assuming the technology is successful, as the initial marginal return from the IPM practice compared to control (farmers' practice) indicates, the trained personnel can continue additional training of farmers. This will be possible as long as funding is available from government or other donor sources. Since the private sector has been trained and they have vested interest in marketing the biocontrol and other IPM products they will continue to promote them through training and other popularization techniques such as mass media.

In the case of Parthenium control, to date a limited number of people have been trained. There is a need to increase the number of trainers who can train more people. The number of two biocontrol agents currently being released in the farmers' fields are progressively increasing and eventually the two biocontrol agents are expected to get established in these areas. Continuous monitoring of the released and neighboring fields will provide the information on impact. To complement the existing natural enemies, there is a need to push towards identifying additional biocontrol agents. IPM IL is working with Australia and South Africa and following their experiences and procedures.

In Niger, the national partners will be able to sustain the management of millet head miner

since they appear to have mastered the rearing and multiplication of the biocontrol agent through IPM IL and its Niger partners. Furthermore, IPM IL has catalyzed business model for local co-ops who are currently mass producing and marketing the agent to farmers. They are now moving to manage the FAW using this agent as well.

10. Building on IPM IL achievements, what general opportunities and priorities exist for future national and regional capacity development for sustainable intensification in Africa and Asia?

Based on the IPM IL achievements, there are some general opportunities for future research and development efforts. They are provided by projects below:

a) In the case of biocontrol of invasive weed Parthenium in East Africa the rearing and mass multiplication is a slow and tedious process, but the technology to do it is in place. The biocontrol agents have been released progressively in large numbers in three sites in Ethiopia. The team has successfully brought Parthenium and the biocontrol agent to an equilibrium economic threshold level in some places. Taking advantage of the situation and the potential to succeed in other locations in the future, research should focus on establishing mass rearing sites in strategic locations in different parts of countries where Parthenium is a problem. In addition, identification and mass rearing of additional biocontrol agents should be priority. Uganda has already received permits to import parasitoids and IPM IL has provided the two parasitoids to Uganda. Encouraging and assisting Kenya to get Government permission to import and release the biocontrol agent is another priority. Ethiopia can serve as the hub for biocontrol agents training, rearing, mass production and export of the biocontrol agents to other countries in Africa who need them.

b. Maize, rice and chickpea IPM in East Africa

PPT training has vastly helped extension agents and farmers in Kenya, Ethiopia and Tanzania. Operating demonstrations to train large numbers of farmers should be given priority. Training in *Desmodium* and *Brachiaria* seed production should also be given priority, since availability of seeds of these PUSH/PULL crops is a major problem that stands in the way of scale-up. Advanced training for graduate students to select new improved rice, maize and chickpea varieties with resistance to diseases combined with grain quality desired by the farmers and the market should be given priority.

Training for diagnosing and identifying appropriate IPM technologies to control insect pests including invasive chickpea leaf rust should be given priority.

c. Vegetable crops and Mango IPM in Asia has trained many different groups. These groups in turn are training farmers. The spill-over and leveraging effect of IPM IL funding for training is working very well in this system. Many graduate students are also continuing their studies and conducting research on various topics including impact assessment. Continuity in this direction is essential to accomplish the goal of institution and capacity building in Bangladesh, Cambodia and Nepal. Graduate students should be encouraged to develop new IPM technologies or use available technologies creatively in order to improve the efficiency and cost-savings of what is currently available.

d. Vegetable crops IPM for East Africa training continues to focus its energy on disease and pest diagnosis and predominantly IPM, using cultural control measures with the exception of *Trichoderma* and *Beauveria*. According to IPM ME, the project had some issues with leadership and reporting. TAC has also pointed out this problem. The task of the IPM ME is to see that the

PIs and the sub-awardees who lag behind may be encouraged and coaxed to improve their performance in order to meet expectations through suggestions and consultations. Afterall, institution building is one of the priority objectives of the ILs.

e. Rice IPM in Cambodia has conducted more than 70 short term trainings-field days, field visits, training workshops, etc. They appear to have trained numerous personnel. Some private sector companies are producing and marketing *Trichoderma* and *Beauveria*. It may be time to assess whether or not additional training is necessary and what purpose they will serve. Refinement in planning and rethinking the demands by the farmers' needs and how to approach the future need to be worked out.

f. IPM of exportable fruit crops in Vietnam have completed the training and demonstration of the technology and the farmers are eagerly adopting the technology. Many Asian countries are using such technology in various modified ways to protect fruit crops. A cost-benefit analysis and other impacts of the technology should be given priority.

g. Bio-diversity and climate change project has a number of graduate students and they should complete their research degree work. Training in the future should include identifying and mass multiplication of biocontrol agents to combat invasive pests like *Tuta absoluta* and FAW in Nepal and weeds such as *Lantana*, *Ageratina* and others mentioned earlier in Nepal.

h. Invasive species modeling project also has a number of graduate students and they should complete their studies. The portfolio of this project has various dimensions concerning invasive pests. They include, among others, forecasting, risk assessment, machine learning, social cost of pest outbreak and others, all of which have both policy and awareness creation opportunities to ensure food security.

Impact and Scaling

The successful output of the IPM projects are measured through impact assessment. Ex-ante assessment begins with the design and planning of the project. For example, the number of people to be trained, number of trials to be conducted, number of biocontrol agents released, etc. are set as targets against which we can measure the achievements. However, in IPM IL the immediate effect of intervention to control pests, pathogens or weeds can, at best, be only an estimate since it depends on various factors. Under these circumstances ex-post impact assessment is executed at appropriate time. But even for ex-post assessment the project should undertake a baseline study so that the impact before intervention and after intervention can be determined. Understanding and measuring how the IPM IL has impacted smallholder farmers in focus countries to achieve the target objectives is necessary to measure the project's success during this phase. In addition, efforts to scale-up and commercialize IPM technologies are essential for sustainability of project impacts even after the project ends. Therefore, this section is broken into two major components: (1) Documenting impact assessment of IPM technologies and (2) documenting scaling-up activities of IPM technologies. We will evaluate the eight sub-grants individually in terms of their impact assessment activities and scale-up activities and potential for the future.

1. How relevant are the IPM IL's strategies and plans to identify and engage potential scaling partners of key technologies.

Scale-up activities

The IPM IL sub-grants emphasize scale-up and commercialization to different degrees.

i). Innovative Scientific Research and Technology Transfer to Develop and Implement Integrated Pest Management Strategies for Vegetable and Mango Pests in Asia project. In Bangladesh, the

scaling up of the use of *Trichoderma* compost, leachate and powder to control vegetable diseases and pheromone traps to control eggplant and bitter gourd insect pests has occurred through Farmer Field days organized by Bangladesh Agricultural Research Institute (BARI), DAE, Private sector and NGOs such as MCC, GKSS and Practical Action.

The team has conducted impact assessment to measure the farmer level benefits of adopting IPM using Propensity score matching (PSM), inverse probability weighting (IPW), and inverse probability weighted regression adjustment (IPWRA). Market level benefits were estimated employing economic surplus analysis. Research from the projects indicates that farmers who use IPM reduce pesticide use and have lower cost of production for eggplant, bitter gourd and tomato, on an average, by US\$25/ha for adopters than for non-adopters based on nearest neighbor, kernel, and radius matching. The highest market level benefits were obtained for eggplant IPM research and training. IRR was also highest for eggplant IPM research (42%) followed by tomato (39%). Policy implications from this study indicate measures for more extension efforts and increased investment in IPM research and development (Rahman, et. al., 2018).

Bt eggplant is highly promising and it requires scaling up with the help of BARI, DAE, NGO partners (MCC, and GKSS) and companies like Isphani in the future. Mango IPM package including bagging of fruits on the tree and use of *Beauveria bassiana* were found to be effective in reducing fruit fly and mango leaf hopper respectively and they need scaling up. Pest monitoring revealed that *Tuta absoluta* damage on tomato is increasing and therefore, further research to refine the IPM technology is indicated in the future. In Nepal, IPM IL has worked with iDE who coordinated and worked with Nepal Government and USAID partners in scaling up the control measures for managing the invasive pest, *Tuta absoluta* on tomato. In Nepal CBFs and Agricare have sold 42,000 *Tuta absoluta* lures and are producing and marketing bio-pesticides and the IPM

IL-facilitated supply chain reached an estimated 22,000 households. Nearly 29% of the farmers who participated in the project use advanced IPM practices. Private sector firms Eco Center and Angkor Green Co. are producing and marketing biocontrol products and a few hundred farmers have adopted IPM packages.

ii). Ecologically-based Participatory IPM package for Rice in Cambodia (EPIC) appears to have the following three IPM technologies ready for scaling up based on their two-year field trials in different locations: First, rodent control in rice using the linear trap barrier system (LTBS) plus Community trap barrier system (CTBS) which is estimated to provide a 90% reduction in rodent damage and a 20% higher yield than the control. However, the profitability of these strategies is not clear and a cost-benefit analysis need to be conducted.

Second, the trials with rice variety CAR14 that is resistant to rice leaf blast and neck blast showed promising results. It is unclear whether the yield increase and the quality of the improved variety is acceptable to farmers and the market. Assuming that they are profitable, then the technology is ready for scaling-up. In addition, *Trichoderma* plus the resistant variety appear to have good control of the disease. Therefore, the resistant variety alone and with *Trichoderma* need to be compared to determine the efficacy and cost-effectiveness of the two components to determine which one is more profitable to recommend to farmers.

iii) Strengthening production and export of Vietnamese fruit crops through innovative and market-orientated IPM. Three simple technologies to protect fruit crops (dragon fruit, longan, lychee and mango) have been successfully evaluated and found to be acceptable to small-scale fruit growers in Vietnam. They are now ready for scaling-up. These technologies are: 1) Plastic sleeves to protect fruit against serious fungal disease, causing canker in dragon fruit. Plastic sleeves also reduce stink bugs and fruit flies on the fruit. 2) Covering longan fruit clusters with one gallon

plastic mesh bags 15 days after fruits set, effectively prevent damage due to fruit borers, stink bugs and fruit flies. 3) light traps are used to trap the pests for monitoring. 4) Bagging mango fruits with wax paper bags reduced chemical sprays by 2 times and the bags can be reused two or three times.

These simple technologies represent a significant potential improvement over the status quo as in over 90% of fruit farmers in Vietnam apply insecticides. Researchers estimate that farmers who use the bags reduce pesticide use by three to four times, and preliminary estimates suggest that profits increase by about 7%.

Finally, use of *Trichoderma* in the soil, pruning dead branches, GAP to ensure light, aeration for healthy tree growth and top working (top grafting) of existing mango trees to a new higher yielding variety (so that old trees can be recycled) are some of the other IPM technologies farmers in Vietnam are adopting.

iv) Biological control of the invasive weed *Parthenium hysterophorus* in East Africa. The project has streamlined the rearing and multiplication of biocontrol agents, *Zygogramma bicolorata* and *Listronotus setosipennis*. The project has already mass released the biocontrol agents in three strategic zones in farmers' fields. The scaling up should be undertaken in a massive scale in most of the invasive weed infested areas. Furthermore, they have to undertake mass production and export of the biocontrol agents to the neighboring countries to jump start the evaluation, for example, in Uganda and Kenya. It may be worthwhile to consider establishing mass multiplication facilities, similar to the one in Ethiopia, for Uganda and also Kenya.

v). Vegetable crops IPM in East Africa. *Trichoderma* and *Beauveria* are the only bio-logical IPM components that are being evaluated for vegetables in this project. All the other components are

cultural control measures and GAP. Technologies such as solarization, plastic mulch, raising healthy seedlings under plastic cover combined with use of *Trichoderma* and *Beauveria*, growing under net, using raised beds, staking, and grafting are some of the technologies that can be scaled-up. They have been widely evaluated and farmers are happy to adopt them. However, an evaluation of the extent to which they reduce use of pesticides and their cost-effectiveness needs to be assessed.

vi) Maize, rice, and chickpea IPM in East Africa project has conducted extensive systematic research, testing, demonstration, training and baseline surveys. For rice and chickpea, the major problem is stem borer and pod borer, respectively. For both crops, the recommended IPM packages consists of using resistant varieties that have been selected and recommended through demonstrations. For rice, the recommended varieties are TXD 306 (SARO) and KUMBOKO; for chickpea, they are Arerti and Habru. In addition, the bio-pesticides *Beauveria* and *Metarhizium* are recommended for both crops. For chickpea, nuclear polyhedrosis virus is also recommended.

It is worth noting that there is an issue of quality of KUMBOKO variety that needs to be resolved through selection of additional new variety (See chapter 3 for discussion of this issue). Scaling-up is required for these two crops since adoption to date is limited. For maize, the following hybrid varieties are used: Ethiopia-BH546 and SRDH; Tanzania-SDCO513; and Kenya-HB624.

The push pull technology (PPT) is extremely popular among maize farmers to overcome the maize stem borer and Striga. It also appears to control, to a certain extent, FAW. Adoption is moving quickly in Ethiopia and Kenya, while in Tanzania it is slowly gaining momentum. The availability of *Desmodium* and *Brachiaria* seed is the major constraint that stands in the way of

further scaling-up. Therefore, further scaling-up efforts should focus on mechanism by which the seeds of the two-PPT crops can be easily made available to small-scale maize farmers.

In the case of chickpea, pod borer, blight and wilt are the major problems. The improved varieties, Arerti and Habru were found to be tolerant to blight and wilt. Combined with the variety, raised bed and seed treatment provides excellent control of the disease problem. Pod borer is still a major problem. Chickpea rust and root-rot becoming new invasive problems in chickpea. Therefore, in the future, priority should be given to research and technology development for pod borer, root-rot and leaf rust.

vii) Biodiversity and climate change-Nepal, and Modeling of invasive species dispersal are modeling projects that do not engage in scale-up and commercialization of IPM technologies and practices. These two projects focus on generating information that may be timely for their focus countries to prepare themselves and undertake necessary preventive measures using appropriate IPM technologies, practices and other interventions, to avoid invasive species and other pests and diseases that threaten health and food security. As mentioned earlier these projects serve as a catalyst for policy changes and create timely awareness of the impending pest invasion.

IPM IL should continue to encourage PIs and partners to emphasize scale up and commercialization of successful IPM technologies in the next phase. Efforts should be made to link with NGOs and private sector to undertake scale-up and commercialization of the IPM technologies to ensure sustainability of the IPM IL footprint.

Results from IPM IL collaborator survey

The survey participants are a mixed bag of administrators, scientists, students, field staffs, PIs and TAC members. They have agreed to respond to the survey anonymously. The EET recognizes that some of the respondents have minimal knowledge on policy and budget issues. In interpreting the results of the survey EET has kept the above fact in mind and care is exercised in drawing conclusions. Participants in the IPM IL collaborator survey feel that scale-up/commercialization of IPM technologies and practices is well integrated into their programs (Appendix 3). Although most of them think that there are funds allocated for scale-up/commercialization of successful IPM technologies from their program, they feel that more funds should be allocated for scaling up/commercialization. In addition, most collaborators feel that the private sector is actively involved in their IPM program (Appendix 3). Furthermore, about 70% of collaborators believe that local government officials are actively or moderately involved in their IPM program. In the next phase, IPM IL should continue to put emphasis and allocate sufficient resources towards scale-up/commercialization. This includes encouraging business models with private-sector engagement to produce and market IPM technologies as has been done in the current phase.

2. How effectively has the IPM IL project fostered dissemination of research results to local stakeholders? In what ways could dissemination be improved (both content and audience) to enhance the uptake of research findings?

Impact assessment

Impact assessment is essential for documenting and quantifying the successes of the project and ways in which the project can be improved. Fortunately, the IPM IL has several team members who are leaders in impact assessment, particularly assessing the impacts of IPM technologies. As a result, numerous studies have been conducted over the years measuring the benefits of IPM on

smallholder farmers. Table 12 shows some of the most important studies that assess net benefits of adopting these practices. These include the well-known and highly successful introduction of the papaya mealybug parasitoid that generated between \$500 million and \$1.340 billion (over five years) in net benefits to Indian papaya farmers (Myrick, et. al., 2014)

Another recent impact assessment study that was conducted with IPM IL funding is by Rahman, et al., (2018). It measures the return to IPM technologies and practices for six vegetables in Bangladesh: eggplant, tomato, bitter gourd, cabbage, cucumber and country beans. The authors find that adopters of IPM reduced pesticide use by about US \$25 per hectare on average. This cost reduction generated the net present values (NPV) and internal rates of return seen in the table below. The total NPV for the six technologies was estimated at US \$768,625 and the highest IRR were for eggplant (42%), tomato (39%) and cucumber (30%).

Table 12: Studies assessing net benefits of IPM technologies and practices

Country and Authors	Crop	IPM Practice(s)	Net Benefits (millions)
Uganda, Moyo et al., 2007	Peanuts	Virus resistant variety	\$33-36
Mali, Nouhoheflin, et al., 2011	Tomato	Cultural	\$21-24
Uganda, Debass, 2000	Beans and maize	Cultural	\$36-202
Bangladesh, Debass, 2000	Eggplant and cabbage	Cultural practices	\$26-29
Bangladesh, Rakshit et al., 2011	Cucurbits	Pheromone traps	\$3-6
Ecuador, Baez, 2004	Plantain	Cultural	\$59-63
Ecuador, Quishpe, 2001	Potatoes	Resistant variety	\$50
Albania, Daku, 2002	Olives	Cultural	\$39-52
Honduras, Sparger, et al., 2011	Eggplant, onion, tomato, and pepper	Cultural practices	\$17
India, Myrick, S. et al., 2013	Mulberry, papaya, and cassava	Papaya mealybug parasitoid release	\$500-\$1,340

Source: IPM IL management entity

Table 13: Net Present Value (NPV) and Internal Rate of Return (IRR) for Vegetable IPM in Bangladesh

Vegetables	NPV (US \$)	IRR (%)
Eggplant	366,250	42
Tomato	97,375	39
Bitter gourd	13,750	13
Cabbage	95,875	29
Cucumber	113,125	30
Country bean	82,250	24
Total	768,625	-

Note: Reproduced from Table 8 in Rahman, et al., (2018)

In the case of rice, maize, and chickpea in East Africa the PPT the demonstration trials were increased in farmers' fields in stages from 2016 to 2018 in Ethiopia, Kenya and Tanzania (Table 14)

Table 14: Progressive increases in number of demonstration trials in Ethiopia, Kenya and Tanzania 2016-2018

Year	Country		
	Ethiopia	Kenya	Tanzania
2016	20	13	0
2017	120	40	11
2018	600	300	30

The yield increases in maize due to control of stem borer and FAW in PPT demonstration fields in 2016-2018 ranged from 15 to 25% compared to control (no PPT) (Table 15)

Table 15: Yield increases in maize due to PPT over control in Ethiopia, 2016-2018

Year	Maize Yield t/ha	
	PPT	Control
2016	4.6	3.8
2017	6.9	5.9
2018	6.8	5.5

PPT has set targets for each of the activities for rice, maize and chickpea in the initial planning

stages. At the end of 2018, about 26 to 370% against the targets were achieved (Table 16)

Table 16: Achievements against initial target indicators for rice, maize and chickpea in Ethiopia, Tanzania and Kenya (Aggregate number)

Indicators	Target	Achieved	Percent Achieved
No. of rural households received Info. About grain IPM	200,000	51,777	26
Farmer households practicing IPM technologies	1,500	1,647	110
Farm land under IPM (hectares)	375	185	49
Rural families directly benefiting From IPM	9,000	9,882	110
Women's group practicing IPM	20	74	370
Long-term training (students)	7	7	100
Short-term training participants	800	1,722	215

Currently the group is testing 5 new technologies and 4 technologies are ready for transfer to the farmers. A smart phone App has been developed for pest and disease identification. There are currently 200 farmers and extension agents have signed up for IPM WhatsApp group. In Ethiopia and Tanzania, 65% and 55% of the extension agents respectively, have smart phones.

Sixty per cent of rice IPM demonstration trial farmers are women, and cumulatively they are using IPM technology on 59 hectares of land. Based on the preliminary estimate from the data collected so far, the PPT has contributed between US\$140-142 million to Kenyan economy assuming there is 25% adoption of PPT. The number of people who will be lifted from poverty will be between 147,000 - 150,000, again assuming 25% adoption of PPT.

Abro, et. al. (2018 draft) conducted focus group discussions (FGD) with 32 farmers in three groups to ask about pest and IPM issues. The participants came from five different Kebeles in Ethiopia. They made the following key points:

- major pests of maize,

- farmers strategies of containing pests,
- the benefits of the PPT,
- farmers constraints in milk production,
- the role of PPT in providing feed for animals and
- challenges faced and the way forward in the implementation of PPT in the project areas.

Figure 9 shows the multidimensional benefits of PPT as expressed by the FGD.

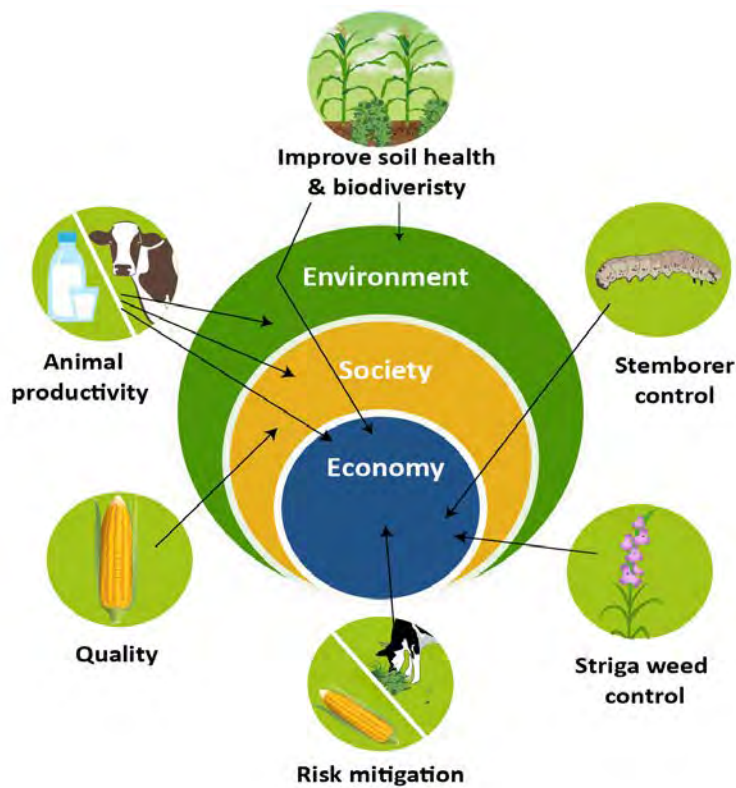


Figure 9: Multiple benefits of Push Pull Technology that is used to control maize stem borer, FAW, and Striga

(Courtesy of Menale Kassie, December 2018 power point presentation at *icipe*).

The FGD participants say that they have been experimenting with PPT since 2015. All of them say that they are aware of the potential benefits of the PPT. Stem borers, weevils, cut worms and FAW are the key pest problems in the area and they can cause yield losses of anywhere from 10-

100%. The yield of maize cultivated under PPT was about 7.75 t/ha while the control plot yield was 3 to 5t/ha. In addition, the cows that were fed with the recommended three part *Desmodium* (D) and one part *Brachiaria* (E) produced 2.25 to 4 liters of milk/day compared to 1.25 to 2.0 liters of milk for the cows control cows, and they produced calves every year instead once in two years. However, the lactation period of the cows fed with D and E was reduced by 2 to 5 months.

In addition, oxen that are fed with D and E fetched a better price at market due to their increased size and health. The price premium was estimated at \$150 more than normal price for the oxen on average. For the all the farmers in one Kebeles, Jara Gelelcha, the estimated benefit from PPT is US\$743,586 total. In two other Kebeles, Udo Wotate and Lebu Koremo it is about US\$1.01 million per year, total. In two other Kebeles, Mokbesa Korkie and Dore Bafano, the net benefits were estimated to be US\$2.7 million. However, many people in these locations may not adopt PPT since they have serious weed problems, which reduces maize yields there. Therefore, it appears that the PPT technology may need to refined in some locations where they have issues with other pests that limit the returns to PPT

Overall, the high estimated benefits of IPM adoption that have been calculated during previous phases of the IPM IL project suggest that there has been a positive return on investment for USAID from funding the IPM IL over the years. Each Kebele has about 8000 farmers and the project plans to scale up PPT to 24 Kebeles for a total of 192,000 farmers in the next phase. However, there is more work to be done to document the successful impacts of the project and make recommendations to improve future activities on the IL.

EET congratulates the excellent impact assessment studies conducted so far in Bangladesh and East Africa. EET recommends that it is important that ME continue to allocate sufficient funds to undertake systematic impact assessment studies in all instances

where an IPM technology has been evaluated and demonstrated to be successful with the farmers. Impact assessment should determine the multi-dimensional benefits of the IPM technology as it is being done in Bangladesh and East Africa.

3. What types of opportunities and constraints have been identified related to the widespread adoption and scaling technologies and practices by smallholder farmers? In what ways, if any, have opportunities been maximized to support scaling? What approaches have been identified to address these constraints? What could the project do to better address the challenges to improved access and use to smallholder farmers?

The majority of collaborators surveyed believe that impact assessment is well integrated in to their program (Appendix 3). Nearly half of the surveyed collaborators feel that their specific program is engaged in impact assessment. They also feel that their impact assessment studies have come up with valuable information and added value to their program. Since, the majority of respondents in the survey are production scientists and very few are economists it appears that they are not very much aware of the need for impact assessment. It points to the need for including social scientists in the team so that there is a built-in impact assessment component. In principle, Impact assessment studies should add value to IPM IL program development and implementation. For example, they can help PI's make decisions about program modifications, and make recommendations to farmers and/or policy makers.

Some projects engage in impact assessment and others do not. Projects such as the fruit IPM in Vietnam are new but it would have been valuable if a baseline survey had been conducted to assess the current situation and after the successful intervention impact assessment can be implemented to determine the benefit of the intervention. Other projects like the Asia Vegetable

and mango IPM has continued from previous phases and there is definitely a need to incorporate the impact assessment in that project. George Norton, is a leader on impact assessment is doing an excellent job of incorporating it into that project. Similarly, the PPT is an ongoing, very successful, farmer-friendly project with multiple benefits. To capture all of these benefits an able socio-economist from *icipe*, Menale Kassie has already conducted a baseline survey of 1100 households and is planning to undertake in depth ex-post impact assessment in the next phase. In the meantime, preliminary impact assessments are conducted to demonstrate the contributions of PPT to animal health, farm income, children's welfare, soil health and enrichment and conservation of natural resources and biodiversity. Such thinking of multifaceted contribution of IPM technology in addition to yield should be creatively investigated.

To scale up the technology once it is ready for adoption the IPM IL should encourage the private-sector, the Mission backed value chain or NGOs to pick up the production and marketing of the IPM technology components. These entities all have resources on the ground in host countries and are looking for ways to profit from bringing technologies and practices to farmers. It is a win-win combination. Such partnerships can make IPM IL resources for extension and scale-up go much further than they would on their own.

In the case of rice IPM in Cambodia, a base line survey of 400 farmers in 4 provinces using IPM and one control province (no IPM) has been conducted in 2016. In 2019, they are planning to work with George Norton to conduct ex-post impact assessment using farmers' diary data to measure the effect of IPM on yield, damage control, income, and input/output. Rodents are a problem in Cambodia due to the short duration variety planted at very high density. Weeds, defoliators such as rice hispa and grasshopper, diseases such as brown spot, neck blast and leaf blast are the serious problems. IPM technologies for rodent control include various trap barriers,

along with community rat hunts. Row planting using Eli seeder is used for minimizing the introduction of various weed seeds that come with the seed, while botanical and microbial insecticides and economic crop-based ecological engineering (ECBEE) are used for disease control.

Community Trap Barrier System (CTBS) and Linear Trap Barrier System (LTBS) appear to reduce rodent damage by 90% and yield increased by 0.5t/ha. Row planting increased rice yield by 8-11%, reduced seed cost by 75% and also reduced labor cost for planting. ECBEE used wild flowers to provide food and shelter for natural enemies. However, the technology was not attractive to farmers, so the team is trying sesame and mung bean plantings on the bunds which appear to be attractive to pests' natural enemies. A student is working on the effect of *Trichoderma* on blast and insect infestation in two Cambodian provinces and it will form part of the Ph. D dissertation for Nagoya university in Japan. However, use of *Beauveria* increased the yield by 15% and gave the farmers an increase in profit of US\$150/ha. Rice variety CAR 14 is moderately resistant to blast, and has 75% less disease observable in the field, compared to traditional varieties.

The rice IPM group is collaborating with General Directorate of Agriculture in Cambodia (GDAC), and Cambodian Agricultural Research Institute (CARDI) to conduct adaptive trials for new rice varieties, and with GIZ Cambodia and Agriculture Law under the Ministry of Agriculture Fisheries and Forestry (MAFF) to handle policy issues. They are also working with a number NGOs and private sector to promote their IPM technology. In order to determine the gender impacts they are planning to use the Most Significant Change Evaluation Method in three sites.

4. Gender impacts in IPM projects

Recognizing the role of women and men in IPM technology adoption, IPM IL focus on ensuring

that the women and men have equal opportunity, and ownership for rural livelihood activities, access to resources, and decision-making power, whenever possible. Therefore, gender considerations are included in all the projects. For example, IPM IL has trained 1,620 female producers (35% of all trained); 60 women government officials (35% of all government officials trained); 30 female professionals in private sector (43% of all private sector trained); and in order to empower women with technical and leadership skills 23 female candidates were supported for degree training (36% of all trained).

In the case of invasive weed *Parthenium*, controlling the weed is a “family affair” and it disproportionately affects women who are generally responsible for hand weeding. Many women suffer allergic reactions when they come in contact with *Parthenium* and weeding takes significant time which increases their burden and reduces the time that they have available for other family activities. As such, the biocontrol agents being developed by the IPM IL are expected to empower women and relieve their burden.

The IPM of exportable fruit crops, dragon fruit, longan, lychee and mango in Vietnam project team from SOFRI conducted an initial Rapid Gender Assessment (RGA) and gender participatory research methods workshop. The workshop included interviews with male and female fruit growers through a series of FGDs and key informant interviews. A mixed-method gender-sensitive impact assessment and evaluation included a structured survey (interviewing beneficiary and non-beneficiary farmers) and additional semi-structured interviews with beneficiary farmers to assess the gendered impacts from applying recommended IPM practices. The structured survey was based, in part on the new INGENAES Technology Assessment toolkit, and the semi-structured interviews utilized the Most Significant Change technique to understand key impacts on women’s and men’s lives resulting from applying IPM practices. Preliminary

results indicate that there are gender differences in the ways men and women experience the advantages and disadvantages of using IPM technology. The study is in progress.

The PPT project uses information from 410 individual woman farmers in 74 women's groups to evaluate the impact of PPT on women's empowerment, family nutrition, income generation, animal health and relieving the drudgery for women. This work is ongoing.

In Bangladesh women are involved in the production and marketing of *Trichoderma*-compost to get extra income. As a result, they have improved their well-being, independence and self-esteem.

In Cambodia, women are very much involved in rodent management by setting up rodent traps along with removing and disposing of captured rodents. Adopting improved traps can allow women to spend less time on rodent control and more time for other, more profitable activities. The survey of majority of collaborators agree that the gender is well integrated into their program, and around 40% of the collaborators have gender activities in their program. Half of the collaborators feel that there are funds allocated for gender activities but most of them are of the opinion that funds allocated are insufficient (Appendix 3). Most of the survey respondents feel that the gender activities added value to their program, as women are involved with IPM training and vegetable and rice cultivation activities so there is integration in that aspect. **IPM IL has excellent track record for gender inclusion in their activities. However, EET noted that many collaborators answered “don't know” in response to the gender questions, suggesting that many collaborators are not engaged with it in their role on the program. EET encourages the gender specialist to bring awareness of gender to the team members. Also, there should be some documentation about benefits to youth on the project. Can youth (and women) be involved in IPM technology scale-up?**

5. Are there extension processes that would merit research/appraisal that are best bet approaches for enabling wide adoption of specific IPM IL Innovations, e.g., block demonstrations vs farmer field Schools vs innovation platforms?

The common saying is that if you give a person fish then he can feed himself for a meal but if you teach him to fish then he can feed himself for life. What is the best method of teaching the farmer the IPM technology? “Learning by doing” is the best method. The extension agents (EA) should teach a group of farmers how to do, what to do, when to do and why they do it. The group of farmers should be given the tools in the beginning to adopt the technology under the supervision of the EA. The trend in extension these days is to include private-sector and NGOs as extension agents for rapid and mass transformation using the IPM technology. The private-sector also has a vested interest in marketing the IPM products if they are profitable, and therefore they will be more aggressive than regular EA. However, there is a set of knowledge and practices that go along with IPM technologies, not all of which can be capitalized on by the private sector, so there is still a role for public-sector EA to train and educate farmers.

Furthermore, the extension process should not only include the transfer of IPM technology but also include information on income generation, market intelligence, nutritional and health benefits culminating from the technology. For example, the PPT extension staff initially provided the technology to overcome the maize stem borer problem. However, the farmers themselves along with the EA found out that the PPT smothers other weeds, and controls Striga. In addition, they found that both *Desmodium* and *Brachiaria* can be fed to cattle and poultry. Additional research shed light on milk production by the cows fed with the PPT crops and the ox fed on the same were healthier and robust than the regular ox and it fetched better price. The quality of butter from the

milk produced by cows fed with Desmodium and Brachiaria were better than the regular one. Such multiple benefits of a technology enable the extension process easier and it spreads rapidly. This collaborative process between farmers, EA and researchers is crucial for finding sustainable solutions to pressing pest problems.

On the other hand, diffusion of biocontrol agents for Parthenium weed control appears to be moving slow mainly because the rearing and multiplication of the biocontrol agents is a slow process. This is a problem on the production and supply-side rather than lack of demand or interest on the part of farmers. Once the biocontrol agents are established, then they begin to spread and farmers are happy to use them.

Comparison of traditional EA extension process with that of multiple agencies extending the technology deserves merit for research in different IPM technologies. Sometimes, IPM has several components and recommendation includes more than one component. In such cases, farmer and researchers need to understand the priorities and which component is essential and or complementary to the others. Researchers should shed light on such trivial questions so that the EA can do their job in convincing the farmers.

Advanced satellite mapping and information and communications technologies (ICTs) are making agricultural extension more precise and productive. Farm radios, SMS communication, video vans (as used in FtF Ghana Agriculture Technology Transfer Project), and TV shows are becoming avenues of extension. The use of WhatsApp and other social media platforms are a way for participants and other stakeholders to communicate and work together. However, low literacy rates among smallholders in many countries and limited network coverage are constraints to completely relying on ICT based extension. To overcome the literacy problem in Cambodia, rice project is exploring the information and sensor technology in cooperation with VIAMO. VIAMO

3-2-1 audio-based reporting system is expected to be a perfect platform for a country where majority of farmers own phones but are illiterate. The usefulness and effectiveness of these emerging mechanisms for extension process are excellent research topics for budding young graduate students.

6. Building on IPM IL accomplishments, what general opportunities and priorities exist for future national and regional research and scaling engagements for IPM in Africa and Asia

Based on the accomplishments of IPM IL the EET believes that the following projects have excellent opportunity for scaling up (ranked from highest to lowest potential):

- 1) Push Pull Technology to control maize stem borer, FAW, Striga and weeds. Because of its multiple benefits and farmers' willingness to adopt it lends itself to pay rich dividends in terms of cost effectiveness for the investment to help the small-scale poor farmers.
- 2) Vegetable and mango IPM in Asia has made significant progress in evaluating several IPM components in demonstration trials. The government EAs, the private sector and NGOs have been trained to disseminate the technology. The private sectors are producing and marketing the IPM components. Such combination indicates that the project is a priority for scaling up.
- 3) The exportable fruit crop in Vietnam has made rapid headway in demonstrating to the exportable fruit growers in Vietnam various types of bagging for different fruits to protect them from pests and diseases. There is a need to identify NGOs and private sector (such as Exportable Fruit Growers' Association's) involvement in marketing the IPM bags for use in the fruit crops. The IPM technology is ready for scaling-up.
- 4) The invasive weed Parthenium control in East Africa has shown excellent promise. The biocontrol agents are effective but slow. The project has streamlined the rearing and mass

production technique and therefore, they should be able to produce substantially large numbers that can be released not only in Ethiopia but also in Kenya once they get the import permit. Therefore, scaling-up of the biocontrol agent is possible.

5) Rice and chickpea IPM in East Africa has identified resistant varieties and IPM components to go with it in demonstration trials. Farmers are enthusiastic about the technology. Partnering with NAFKA, the value chain project, creates an excellent option to scale-up the technology.

6) Rice IPM in Cambodia has demonstrated the efficacy of different trapping barriers for the control of rodents, row planting using Eli seeder to control weeds, and *Beauveria* and resistant variety CAR 14 to control diseases. These technologies are possible candidates for scaling. However, assessment needs to be conducted as to their profitability and cost-effectiveness.

7) Vegetable crops IPM in East Africa has moved slowly. Nevertheless, it has evaluated raising healthy, disease-free seedlings of vegetables with the help of IPM components, raised beds, plastic netting, solarization, and plastic mulching. To control the foliar diseases pruning and staking have been successfully evaluated. Grafting is used to protect vegetables from bacterial wilt disease. An opportunity may be given to scale these technologies up, after profitability assessment and cost-effectiveness analysis has been conducted.

Note: The two modeling projects are not engaged in scale-up or commercialization.

Chapter 6: Program Future

1. Building on the above general opportunities for research, stakeholder collaboration especially policy engagement, capacity building, and scaling, what **specific** areas are needed for effective future programming of IPM, if any, within IPM systems research linked to new or continuing investment, including technical research, capacity development, institutional support and scaling.

By the end of Phase V in 2019, the IPM IL will have completed 25 years. It is time for Silver Jubilee celebration. Looking back, IPM IL has come a long way, beginning with institutionalization of IPM in the first five years, regionalization of IPM in the next five years, globalization of IPM in the third phase, and in the fourth and current phase the theme has been participatory IPM (PIPM). The IL has made some crucial accomplishments include the mealybug control with biocontrol agent, development of PPT, vegetables and mango IPM in Asia and continuing fight against the invasive pest *Tuta absoluta*. IPM is extremely important to reduce pesticide residue in our foods and educate the farmers the importance of IPM in healthy, clean food production. It is a continuous fight. Therefore, more research, more training and more convincing needs to be undertaken with farmers. The work is not done, and the IPM IL definitely needs to be extended to keep up the pressure on policy makers, farmers and farming community, entrepreneurs and consumers.

As shown in the previous sections, the IPM IL has made significant advances in transferring successful, time and location tested IPM technologies for grain, vegetable and fruit crops over the years in a number of countries in various regions. The project has also conducted

evaluations of the success and extent of IPM adoption and conducted impact assessment to understand the benefits of the technologies and practices that have been developed and disseminated to farmers.

IPM IL has commenced this process for some of its mature programs such as IPM of vegetables in Asia and IPM PPT on maize in East Africa. Continued concerted efforts should be taken to assess the direct and indirect losses due to pests, diseases and weeds. The impact assessment should also include consumer surplus, producer surplus, social cost, internal rate of return, cost/benefit, health benefit, environmental benefit, gender care, nutritional benefits, animal health and building a better society in line with the FtF objective of ensuring food security. Adoption and commercialization of technologies and their benefits on the farmer-level, national-level and at policy-level need to be assessed. As such, impact assessment should receive priority.

Within each host country energetic, enthusiastic, hard-working, creative, ambitious IPM scientists need to be continually recruited as research coordinators. These people need to conduct innovative research, to identify new technologies-parasitoids, predators, entomopathogenic fungi, other biocontrol agents, and other novel IPM measures. The coordinators should be able to guide the new emerging talents from the participating countries to evaluate these new technologies for specific seasons and locations through multi-locational and seasonal trials prior to establishing demonstration trials for adoption. The technology whether it is old or new should be made available, and affordable to the small-scale farmers. The coordinator needs to engage with host-country governments and private-sector partners to ensure IPM sustainability after the project ends.

Based on the performance so far and the excellent chances of their technologies and practices being adopted on a large-scale, or change policies and create awareness the EET

recommends that the following projects in the IPM IL's portfolio deserve serious consideration for further continued funding: i) IPM of exportable fruit crops in Vietnam, ii) IPM for vegetable and mango pests in Asia, iii) rice, maize and chickpea IPM in East Africa, and iv) biocontrol of invasive weed, Parthenium in East Africa, vi) modeling project of Biocomplexity institute, vii) climate change and biodiversity project. Continued emphasis should be placed on current and potential invasive pests in the next phase.

Future funding should involve follow-up evaluation and demonstration trials and scaling up in cooperation with Mission value chain projects, NGOs, private contractors and private entrepreneurs

The ecologically based participatory IPM of rice in Cambodia is in a unique situation. Rodent control in rice is an age-old problem, but IRRI, Cambodia and IPM IL need to look at the root cause of the problem and try to see whether that problem can be resolved. Is it man-made, weather-made, or due to ecological disruption of rodent's homestead? Electric fences, baits, catch and kill and barriers have been recommended and used in many countries. The farmers are using these practices already, so it is not clear what is new or unknown from the set of practices and technologies that the project is recommending.

The project also called for planting wild flowers on rice bunds to attract beneficial insects, as "ecological engineering". The conclusion was that it backfired because the farmers did not plant the wild flowers after one season. Now the project is recommending farmers to switch over to planting mung bean and sesame on the bunds. Planting soybean and mung bean on rice bunds is a traditional practice in Korea, Japan and Taiwan, as the legume gives additional protein to crops and also enriches the soil. The use of improved rice variety with resistance to diseases is part of IRRI's core program. IPM IL needs to discuss further the details of a proposed future plan, so that

it is in line with IPM IL's objectives. If this project is to continue, the IPM IL needs to understand and document the situation and come up with a better resolution. This project also needs to measure cost-effectiveness and conduct impact assessment of the technologies they recommend.

IPM of vegetables in East Africa has had problems due to the project's leadership at OSU. In discussion with the partners in East Africa, they have no complaints about OSU. It is unclear whether the project is implemented according to proposed plans or the participants have deviated from the plan and conducted their own program. From the discussion with the partners in Tanzania and Ethiopia they have brought awareness through training farmers. They have conducted demonstration trials, and the private-sector has started to mass produce healthy seedlings and marketed them following the training. Furthermore, the vegetable fields that use plastic mulch, netting, raised beds, pruning, grafting and staking appear very good. It appears some of the technologies are ready for scaling-up. Maybe there is a need to explore new partner either in the US or abroad to revitalize this project in consultation with *icipe* and AVRDC (World Veg) who have the needed expertise on IPM of vegetables. Measuring cost-effectiveness and impact assessment is also needed on this project.

IPM IL leadership in raising awareness of invasive pests.

IPM IL has been a leader in raising awareness and calling for action on the invasive pest, *Tuta absoluta*, as it moves to new countries in Asia and Africa. IPM IL has conducted 18 workshops in 55 countries to bring awareness of the problem and potential IPM solutions. IPM for *Tuta absoluta* includes pheromone traps, biopesticides, growing seedlings under net and checking seedlings for *Tuta absoluta* before planting. Use of insecticides will only exacerbate the problem since the insect will develop resistance to the insecticide. Additional research needs to be conducted to identify new technology for *Tuta absoluta* management.

Another invasive pest is FAW. There is a FAW task force within USAID/BFS. A number of institutions, including AGRA, CABI, DFID, ICRISAT, IITA, FAO, CIMMYT, *icipe*, USAID, and World Bank are in one way or other involved in trying to spot FAW spread across Africa and Asia. A large number of workshops were conducted to create awareness for the problem. IPM IL in cooperation with *icipe* conducted a workshop with 18 participants from Ethiopia, Tanzania, Kenya, Niger, Cote d'Ivoire, and South Sudan from Feb 24 to March 1, 2019. These training scholars are expected to have hands-on training for rearing the newly identified biocontrol agents for FAW in addition to learning other IPM measures.

The FAW awareness and control strategy using IPM has become a very crowded arena. In addition to the FAW task force of USAID/BFS, FAO has established a Global Task Force for FAW (GTFFAW) and established a FAW monitoring and early warning system (FAMEWS). FAO has also organized vast number of surveys and monitoring using pheromone traps to identify hot spots in real time in Africa and around the world. FAO reported that the global cost of FAW management is estimated at US\$1.4 trillion and it is 5% of global GDP. They are aware and are exploring biocontrol agents for classical biological control of FAW combined with other tactics. The EU has recently granted €7 million for FAW research on microbial pesticides for control to *icipe* in February 2019. IPM IL has its own niche and comparative advantage for the biocontrol of FAW. The modeling project has prepared a Risk Assessment for USAID mission in Egypt. IPM IL's limited dataset modeling has accurately predicted the eastward movement of FAW from Sudan to Yemen which proved correct. All the above enabled IPM IL to organize a number of FAW awareness workshops in various countries and influence policy changes to prevent or minimize the pest damage and ensure food security. IPM IL was the first one to organize the hands-on training in Kenya for the multiplication of parasitoids to control FAW. IPM IL needs to

continuously identify such niche areas where it can make a positive contribution in the management of FAW.

Another pest (native pest) is the millet head miner. The IPM IL received a sub-award from SM IL to come up with a solution for this pest in Niger. The team found an augmentative control measure to combat the millet head miner through mass production and release of the biocontrol agent. In addition, IPM IL has encouraged a micro-enterprise private sector who is already multiplying and marketing the biocontrol agent. Further research has resulted in the identification of additional new biocontrol agents which is expected to supplement or complement the current biocontrol agent being used. IPM IL has been extremely successful in this sub-grant.

As mentioned in earlier chapters IPM IL should examine and interact with other Innovation Labs, such as Hort IL in Cambodia, Food Processing and Post-Harvest IL in Africa, Post-Harvest IL in Africa and Asia and Sustainable Intensification IL in Africa.

Collaborators in the survey indicate that the major challenges that they encountered on the project were Financial (28%), followed by technical (15%) then personnel related (11%). Financial issues have been mentioned across the project with delays in funds coming from USAID and moving through the management entity to the sub-grantees. It is worth noting that only 14% of collaborators state that they experienced no issues on the project (Appendix 3). The collaborators also feel that the future direction should put more emphasis on applied research and extension (Appendix 3). New technology should be developed and they should be available, affordable and easily adoptable. From collaborator's view if IPM IL is renewed the ranking of different priorities for the project are from the most important (low mean) and less important (higher mean) in Table 17.

Table 17: Collaborator Survey, If USAID renews the IPM IL for a new phase, please rank what you view as priorities for the project. {Most important (1) – least important (7)}

Topic	Mean	Std Dev
1. Applied research to develop new IPM technologies and practices	2.36	1.48
2. Extension (short-term training) for farmers and other stakeholders on IPM technologies and practices	3.28	1.39
3. Basic research on IPM	3.53	2.11
4. Scale-up/commercialization of IPM technologies and practices	3.62	1.91
5. Long-term training for students and other professionals	4.19	1.71
6. Policy engagement	5.40	1.40
7. Stakeholder communication	5.62	1.65

The collaborators would like the IPM IL to focus on basic research, to develop better IPM technologies and practices and diffuse them to stakeholders and work on commercialization and scale-up. In conclusion, based on all the evidences presented there is a need to extend the IPM IL for another five years to complete the on-going activities and for scaling up as well as to conduct additional impact studies.

Chapter 7: List of Recommendations from the External Evaluation Team

Based on our analysis, the External Evaluation Team (EET) makes the following recommendations about the Integrated Pest Management (IMP) IL, phase V.

1. The EET feels that review of progress once a year through semi-annual and annual reports can be more critical and stringent but constructive and helpful. It is true that we cannot expect a perfect score or performance from all collaborators. However, there are opportunities both at the time of the annual review meeting, and during the site visits to scrutinize and support the sub-awardees who are lagging behind in making progress or those who are not using proper IPM technologies. The EET recommends that the ME make extraordinary efforts to speed up the “slow-runners” among the PIs, who may be encouraged and provided with additional information or resources in terms of technical support to catch up with the best ones. This is an opportunity for ME to demonstrate their ability for institution building.
2. The EET recognizes the difficulties encountered by the IPM IL due to the delay in receipt of the budget. As a result, the program activities unduly suffered. Even under the difficult circumstances the IPM IL and its partners implemented the activities and made significant progress and impact in Asia and Africa. The EET recommends that BFS/USAID AOR appreciate the situation and make whatever efforts that are necessary to ensure timely funding.
3. The EET recommends that the IPM IL continue to serve as a catalyst to encourage and facilitate bio-pesticide business development with lead farmers, NGOs and private entrepreneurs as it has done with Bangladesh, India, Nepal and Niger to ensure sustainability. Specifically, the EET recommends that the IPM IL encourage the following: i) Vietnamese National Agricultural Research System (NARS) to stimulate the private-sector or lead farmers to pick up the sale of plastic sleeves, plastic mesh bags and wax bags marketing to the fruit farmers so that sustainability and scaling-up of the technology will be assured, ii) a mechanism be instituted for *Desmodium* and *Brachiaria* seed availability to the farmers for use in PPT.
4. The EET recommends that the IPM IL encourage and provide training to rear the biocontrol agents using locally available materials so that the sustainability is ensured. IPM IL should also conduct further research to examine the diversity in biocontrol agents since *Zygogramma bicolorata* is suitable for high rainfall areas and *Listronotus setosipennis* to harsh drought stricken areas, but *Parthenium* is adapted to both situations. The climate change and biodiversity project may shed light on this area. Once the biocontrol agents are established in the field, they will sustain and

spread themselves. The enemies of biocontrol agents also need to be studied so that the agents are not decimated by their enemies. Since Ethiopia has successfully introduced, tested and evaluated the release of biocontrol agents in farmers' field EET recommends that Ethiopia should serve as a hub and mentor for disseminating the technology to other neighboring countries.

5. The EET noted the enthusiasm of the rice farmers during the field visit and recommends that IPM IL pay attention to the marketing problem for improved rice varieties that they are promoting. We also suggest the team conducts a socio-economic analysis of the situation to determine the adoption potential for the improved varieties before proceeding further. Farmers also need market information and awareness to successfully grow and market these disease resistant, high yielding rice varieties that the project is promoting.
6. The EET recommends that exciting technology identification as has been done in Niger, Ethiopia, Kenya and Tanzania for invasive FAW control should be encouraged and promoted with other NARS so that new technologies are constantly feeding the pipeline for testing and adoption by the farmers.
7. The EET recommends that the IPM IL ME and collaborators make efforts to track how many IPM trainings are held by partner organizations that they have trained and also how many technologies have been sold by private-sector partners. This is important leverage and impact for the project's success that should be documented.
8. The EET recommends that the ME and AOR encourage all the FtF ILs to consider synergies among the Innovation Labs. Among the FtF Innovation Labs, Hort IL, SM IL, CRS IL, LS IL, FPL IL, PHL IL and SI IL likely have compatibility and synergy with IPM IL to have collaboration that may be considered in the formative stages.
9. EET commends the ME for focusing their attention in enhancing the knowledge base and strengthening the institutional capacity of the collaborators in Asia and Africa. Since there is a need for more trained personnel for Africa, EET recommends that in the future, more people from Africa should be given opportunity to earn advanced degrees using IPM IL funding. EET also recommends that the IPM IL advisors continue to serve as a catalyst to stimulate young minds to do original research creatively using their imagination and come up with new ideas, new tools, new technologies and new ways of doing research.
10. EET congratulates the excellent impact assessment studies conducted so far in Bangladesh and East Africa. EET recommends that it is important that ME continue to allocate sufficient funds to undertake systematic impact assessment studies in all instances where an IPM technology has been evaluated and demonstrated to be successful with the farmers. Impact assessment should determine the multi-dimensional benefits of the IPM technology as it is being done in Bangladesh and East Africa.

11. **IPM IL has excellent track record for gender inclusion in their activities. However, EET noted that many collaborators answered “don’t know” in response to the gender questions, suggesting that many collaborators are not engaged with it in their role on the program. EET encourages the gender specialist to bring awareness of gender to the team members. Also, there should be some documentation about benefits to youth on the project. Can youth (and women) be involved in IPM technology scale-up?**
12. **Based on the performance so far and the excellent chances of their technologies and practices being adopted on a large-scale, or change policies and create awareness the EET recommends that the following projects in the IPM IL’s portfolio deserve serious consideration for further continued funding: i) IPM of exportable fruit crops in Vietnam, ii) IPM for vegetable and mango pests in Asia, iii) rice, maize and chickpea IPM in East Africa, and iv) biocontrol of invasive weed, Parthenium in East Africa, vi) modeling project of Biocomplexity institute, vii) climate change and biodiversity project. Continued emphasis should be placed on current and potential invasive pests in the next phase.**

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- Myrick, S., Norton, G.W., Selvaraj, K.N., Natarajan, K. and R. Muniappan. 2014. Economic impact of classical biological control of papaya mealybug in India. *Crop Protection* 56: 82-86.
- UN DESA Report https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf

Appendix 1: Credentials of the External Evaluation Team Members

Dr. Subramanyam Shanmugasundaram (Sundar), (Team Leader)

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Somerset, New Jersey 08873
USA
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Current Status:

- Agri/horticultural consultant, born 1939
- Over 270 publication credits
- Skills and expertise
 - Program and project review, evaluation and impact assessment
 - Teaching
 - Fundraising
 - Project preparation, implementation and administration
 - Extension, project and personnel management
- Primary goals: Alleviation of hunger, poverty, and malnutrition

Rural and community development:

- Reviewed projects, research and management, and conducted feasibility studies
- Prepared business development plans
- Negotiated and forged international collaboration
- Solicited and ensured successful donor relations
- Implemented donor supported projects
- Wrote and presented project completion and impact assessment reports
- Developed and implemented disaster and emergency relief efforts
- Trained other field trainers
- Organized meetings, workshops and conferences linking policy makers, stakeholders, farmers extension specialists, researchers, processors, private sector, traders, and the public
- Encouraged and promoted cordial and disciplined interpersonal relations

Accomplishments:

- Presented two to four days lectures on Value Chain Analysis of Vegetables to Training scholars for the past five years at the World Vegetable Center's Regional Center in Thailand.
- Reviewed, evaluated and assessed the impact of the crop improvement programs at the ICRISAT, CIAT and IITA Tropical Legumes Program supported by the Bill and Melinda Gates Foundation.
- Reviewed, evaluated and assessed the impact of the Horticultural CRSP Program (currently Horticulture Innovation Lab) supported by the USAID at UC-Davis, CA, and various countries in Africa, Latin America and Southeast Asia.
- Generated funds from USAID, Sasakawa Peace Foundation, Rockefeller Foundation, Asian Development Bank, Department for International Development, U.K., IDRC, Canada, Council of Agriculture, Taiwan, Taiwan Grain and Feed Foundation, Japan Grains and Feed Foundation,

JIRCAS, Japan, GTZ, Germany, SDC in Switzerland, CIRAD-Flor in France, ACIAR in Australia, Asia-Pacific Seed Association and several private companies.

- Developed and promoted short growth duration, high yielding soybean, vegetable soybean (Edamame) and mungbean varieties to diversify the cropping system and improve the micronutrient nutrition of lactating mothers and children to about 500,000 farm families in Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka.
- Developed and promoted iron-rich recipe booklets using mungbean and vegetables to alleviate iron deficient anemia. Mungbean project was selected as one of the 20 successful projects for the “MillionsFed” project of IFPRI supported by the Bill and Melinda Gates Foundation in 2009.
- Created a business development plan for Newlands Mashu Community Development Centre and the eThekweni Municipality in Durban, South Africa and established a vegetable soybean industry which is on track with vegetable soybean production, processing and marketing as well as nutrition improvement at the community urban levels. Recently (Oct-Nov.2014) helped them obtain and air transport 1.2 tons of improved vegetable soybean seed (BeSweet292) from USA to South Africa.
- Trained a large number of young men and women in home gardening, vegetables and legume production, home economics, and use of improved recipes to improve income and micronutrient nutrition.
- Organized South Asia, Southeast Asia, Cambodia, Laos, and Vietnam vegetables and legume networks to improve the income and micronutrient nutrition of the poor families and diversify dryland cropping systems.
- Organized multiple national, regional, and international conferences, workshops, symposia, and donor support group meetings in various countries; gatherings involved policy makers, donors, scientists, extension staffs, processors, traders, and the public. Edited and published proceedings of the meetings, which covered diverse topics.
- Facilitated and promoted collaboration between multiple stakeholders to help poor children and women improve their income and nutrition in developing countries around the world

Education:

- Ph.D. 1981. Kyushu University, Fukuoka, Japan. Crop Science.
- M.S. 1968-1971. Univ. of Wisconsin, Madison, WI. Plant Pathology
- M.S. 1966-1968. Univ. of Hawaii, Honolulu, HI. Horticulture.
- M.Sc. (Ag.) 1962-1964. Univ. of Madras, India. Plant Breeding and Cytogenetics
- B.Sc. (Ag.) 1958-1961. Univ. of Madras, India. Agriculture

Appointments:

- Consultant to World Vegetable Center’s Regional Center in Thailand for giving lectures to Training Scholars on “Value Chain Analysis of Vegetables” two to four days duration in each year from 2012-2017
- Consultant to Newlands Mashu Community Development Center and eThekweni Municipality, Durban, South Africa to monitor and advice on the progress of Vegetable Soybean Business. Jan. 18, Jan. 30, 2016
- Team Leader, External Evaluation Team, Horticulture CRSP for USAID currently Hort Innovation Lab). Mar. 10, 2013 to July 31, 2013
- Member, Expert Panel to review Canada-India Research Centre of Excellence Competition for the Networks of Centre of Excellence (NCE), The Natural Sciences and Engineering Research Council of Canada, the Social Sciences and Humanities Research Council of

Canada, the Canadian Institutes of Health Research in partnership with Industry Canada and Health Canada. Aug. 20-22, 2012.

- Consultant to Jacob MacKellar Farms for Vegetable Soybean Development, Ontario, Canada. Aug.-Sep. 2012
- Consultant to Jacob MacKellar Farms for Vegetable Soybean Production and Processing. Aug.-Sep. 2011
- Consultant to Newlands Mashu Community Development Center and eThekweni Municipality, Durban, South Africa to prepare Vegetable Soybean Business Development Plan. Sep.-Oct. 2010
- Chairman, Advisory Board for Tropical Legume Project II of ICRISAT, CIAT and IITA supported by Bill and Melinda Gates Foundation. 2008-2010.
- Consultant to Monsanto, St. Louis, Missouri for Asian Soybean Rust Management. Sep. 2009.
- External Examiner for Ph.D. candidate evaluation, Kwazulu Natal University, Durban, South Africa. Oct. 2008
- Chair, Center Commissioned External review of Global Themes Crop Improvement and Biotechnology, ICRISAT, Patancheru, India. Apr. 28- May 11, 2007
- Deputy Director General for Research, AVRDC. May 2003-Apr. 2005 (Retired)
- Secretary to AVRDC Director General Search Committee. 2002.
- Secretary to AVRDC Board of Directors. 1995-2006
- Plant Breeder and Director/ Program I - Vegetables in Cereal-Based System, AVRDC. Jan. 1998-Apr. 2003 (also Coordinator for Mungbean Network and SAVERNET)
- Secretary to AVRDC Director General Search Committee. 1994
- Plant Breeder, Soybean Breeding/CIP and Director/ International Cooperation Program (ICP), AVRDC. 1990-1998.
- Plant Breeder, Soybean/CIP, Training Officer and Director, International Cooperation Program AVRDC. 1992-Jan.1998 (also coordinator for AVNET and SAVERNET)
- Plant Breeder, Legumes/CIP and Acting Director, Development Program, AVRDC. 1988-1998
- Plant Breeder, Legumes/Crop Improvement Program (CIP), AVRDC. Aug. 1986-1988
- Plant Breeder, Soybean Crop Coordinator and Director, Legume Program, AVRDC. June 1985-June 1986.
- Associate Plant Breeder and Soybean Crop Coordinator, AVRDC. Jan. 1978-Dec. 1978.
- Associate Plant Breeder, Soybean Crop Coordinator and Legume Program Leader, AVRDC. Jan. 1979-Dec. 1982.
- Plant Breeder, Soybean Crop Coordinator and Legume Program Leader, AVRDC. Jan. 1983-May 1985.
- Associate Plant Breeder and Soybean Crop Coordinator, AVRDC. Jan. 1978-Dec. 1978.
- Scientific Associate and Soybean Crop Coordinator, AVRDC. Jan. 1977-Dec. 1977.
- Scientific Associate (Soybean Breeding), AVRDC. Jan. 1976-Dec. 1976.
- Research Associate (Soybean Breeding), AVRDC. Nov. 1972-Dec. 1975.
- Specialist in Plant Pathology, Univ. of Wisconsin, Madison, WI. Mar. 1972-Oct. 1972
- Research Assistant in Plant Pathology and U.S.D.A. Onion and Carrot Project, Univ. of Wisconsin, Madison, WI. Mar. 1971-Feb. 1972.

- Graduate Research Assistant in Horticulture and Plant Pathology, Univ. of Wisconsin, Madison, WI. 1968-Feb. 1971.
- Graduate Research Assistant in Horticulture, Michigan State Univ., East Lansing, MI. 1968 (summer)
- East-West Scholarship Grantee at the Univ. of Hawaii, Honolulu, HI. 1966-68.
- Assistant Lecturer in Botany, Univ. of Madras, India 1964-66.
- Research Assistant in Plant Physiology, Univ. of Madras, India 1961-62.

Honors and Awards:

- World Soybean Conference Prize for great contribution to Global Soybean Research and Soybean Industry Development awarded by the Continuing Committee for World Soybean Research Conference WSRC VIII held from August 10-15, 2009 Beijing, China.
- Taiwan President's Award for Poverty Alleviation- one of twelve from AVRDC – 2006
- Agricultural Gold Medal awarded for the First Time to a Foreign National by the Council of Agriculture, Taiwan for Outstanding Contribution to the World and Taiwan – June 2005.
- Award for Outstanding Scientific Contribution to the Edamame growers and processors in Taiwan and the world given by the Taiwan Regional Frozen Food Manufacturer's Association – June 2005.
- Gold Medal for 30 years of outstanding research at AVRDC and contribution to tropical agriculture – Nov. 2004
- Award for significant contribution to soybean, vegetable soybean and mungbean development in Thailand by the Ninth National Soybean Research Conference Committee – 2004
- Award of Honor presented by the Mungbean Growers of Punjab – 2004.
- Punjab Agricultural University, India Recognition Award and a Plaque – 2004.
- Indian Society of Pulses Research and Development (ISPRD) Gold Medal Award 2003 for Outstanding Contribution in Pulses Improvement at Global level presented by the Minister for Agriculture, India – Dec. 2003.
- American Society of Horticultural Science (ASHS) Vegetable Breeding Working Group Award of Excellence – Dec. 2003.
- Recognition Plaque from Bangladesh Agricultural Research Council – Jan. 2003.
- Gratitude Plate and Certificate of Appreciation from the Agricultural Research and Extension Unit of the Republic of Mauritius – Oct. 2002
- Recognition and Thank You Plaque from Taiwan Regional Association of Frozen Vegetable and Fruit Manufacturers, Kaohsiung, Taiwan – Aug. 2002.
- Gold Medal for Thirty Years of dedicated outstanding research on vegetables for the tropics from AVRDC – 2002.
- Certificate of appreciation and a Gratitude Plate from the Administrator, Rural Development Administration, Republic of Korea – Sep. 2001.
- Fellow of the Indian Society of Vegetable Science – 1999.
- Plaque for twenty years of dedicated outstanding research work at AVRDC for tropical agriculture – 1994.
- Award for dynamic leadership, commitment and inspiring world soybean expert for global collaboration for research and development by World Soybean Research Conference V – 1994.

- Elected as Chair/Continuing Committee, World Soybean Research Conference V – 1989-1994.
- Award (plaque) for assisting in the development and release of vegetable soybean varieties Kaohsiung No. 1, 2 and 3 by the Director General, Kaohsiung DAIS, Taiwan – 1992.
- Elected as Chair/Continuing Committee, World Soybean Research Conference IV – 1984-1989.
- Distinguished Foreign Scholar Award from the World Food Institute, Iowa State University, Ames, Iowa – 1985
- Plaque for ten years of dedicated outstanding research work at AVRDC for tropical agriculture – 1984
- East-West Center Scholarship Award – 1966-68
- Sambamurthy Medal for being outstanding student in Agricultural Economics – 1961
- D'Silva Memorial Medal for being an outstanding student in Veterinary Science – 1960

Professional Societies, Committees, and International Activities:

- Member, Editorial Board, Experimental Agriculture, UK, 2005- ongoing.
- Founding Member VEGINET of Prem Nath International Foundation for Vegetable Science, 2004.
- Member and Secretary, Continuing Committee for International Soybean Processing and Utilization Conference IV, 2000-2004; 2004-2008
- Member, Advisory Committee for World Soybean Conference VI, 1999.
- Member, Continuing Committee for International Soybean Processing and Utilization Conference III, 1996-2000.
- Technical Adviser, International Foundation for Science, Stockholm, Sweden. 1997-continuing.
- Member and Chair of the Continuing Committee for the World Soybean Research Conference IV (1984-1989) and V (1989-1994)
- Consultant to IDRC Soybean Project - Pakistan, Aug. 31 - Sep. 21, 1988.
- Consultant for ACIAR, Australia - Review resource person for the ACIAR grain legume project in Thailand, Apr. - May. 1988.
- Consultant for UNDP ESCAP CGPRT Centre for Indonesia - Review of Soybean Yield Gap Project in Indonesia, Feb. - Mar. 1987.
- Consultant, IAEA Plant breeding of grain legumes for disease resistance, Philippines, Thailand, Malaysia, Oct. - Nov. 1986; Indonesia, Dec. 1986.
- Consultant, IAEA project on Screening Legumes for Diseases Resistance in Batan, Jakarta, Indonesia, Aug. - Sep. 1985.
- Member, Advisory Group on Mutation breeding for disease resistance using in-vitro culture techniques organized by the FAO/IAEA Division of Isotope and Radiation applications of Atomic Energy for Food and Agricultural Development, Oct. 1984.
- Consultant, IAEA project on Screening Legumes for Diseases Resistance in Batan, Jakarta, Indonesia, Nov. - Dec. 1983.
- Consultant, World Bank Sponsored Extension Project on 'Palawija' crop in Indonesia, Mar. 19, 1983 - Apr. 20, 1983.

- Member American Society of Agronomy
- Member Crop Science Society of America
- Member Society for the Advancement of Breeding Research in Asia and Oceania (SABRAO)
- Member SABRAO Plant Genetic Resources Committee
Secretary for International Working Group on Soybean Rust and and Co-editor for Soybean Rust Newsletter.
- Project Coordinator, Tropical Vegetable Information Service.
- Member IBPGR/SEAP Working Group on Food Legumes.
- Member IBPGR Ad-hoc Working Group on Glycine sp.
- Member, Editorial Committee of Tropical Vegetable Information Service News
- Established and maintained commodity expertise on legumes (emphasis on soybean, vegetable soybean (Edamame), mungbean, adzuki bean), and vegetables (including indigenous vegetables) around the world.

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PROFESSIONAL APPOINTMENTS

2016-present: Associate Professor of Agricultural Economics, Purdue University
2011-2016: Assistant Professor of Agricultural Economics, Purdue University
2007-2011: Graduate Research Assistant, Michigan State University
2005-2007: Agricultural Economist, Economic Research Service of the USDA
2003-2005: Graduate Research Assistant, Virginia Tech

EDUCATION

Ph.D. in Agricultural Food & Resource Economics, Michigan State University (August 2011)
M.S. in Agricultural & Applied Economics, Virginia Tech (August 2005)
B.S. in Community Development & Applied Economics, University of Vermont (May 2002)

AWARDS & HONORS

- Bravo Award winner at Purdue for “moving the university forward” in 2018.
- Member of a team that won the 2017 Bruce Gardner Memorial Prize for Applied Economic Policy Analysis at the Agricultural and Applied Economics Association (AAEA).
- Member of a team that won the 2016 Dean’s Team Award in the College of Agriculture at Purdue for work on the Purdue Improved Crop Storage (PICS) project.

- Member of a team that won the 2015 Purdue University Core Engagement (Extension) Award for work on the Purdue Improved Crop Storage (PICS) project.
- A Best Contributed Paper Award (with Jordan Chamberlin) at the Inaugural Research Symposium of the Economics Association of Malawi, 2014.
- Best Contributed Paper Award at the Triennial Meeting of the African Association of Agricultural Economists (Runner-up), 2010.
- T.W. Schultz Award, given for the best contributed paper at the Triennial Meeting of the International Association of Agricultural Economists, 2009.
- *Awarded Outstanding Senior*, concentrating in International Development & Applied Economics at the University of Vermont, 2002.

PEER-REVIEWED PUBLICATIONS (27); * denotes that co-author is current or former graduate student

- Omotilewa, O.*, **J. Ricker-Gilbert**, and J.H. Ainembambazi. 2019. "Subsidies for agricultural technology adoption: Evidence from randomized experiment in Uganda." (Forthcoming) *American Journal of Agricultural Economics*.
- Kaiyatsa, S.*, **J. Ricker-Gilbert** and C. Jumbe, and. 2019. "Supply-Side Crowding-out and Crowding-in effects of private sector participation in Farm Input Subsidies: A quasi-experimental field study for Malawi." *Journal of Agricultural Economics* doi: 10.1111/1477-9552.12286
- Ricker-Gilbert, J.**, and J. Chamberlin. 2018 "Transactions Costs in Land Rental Markets and Their Impact on Youth Access to Agriculture in Tanzania." *Land Economics* 94(4):541-555.
- Omotilewa, O.*, **J. Ricker-Gilbert**, J.H. Ainembambazi, and G. Shively. 2018. "Does improved storage technology promote modern input use and food security? Evidence from a randomized trial in Uganda." *Journal of Development Economics* 135:176-198.
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- Darko, F.A.*, A. Palacios-Lopez, T. Kilic, and **J. Ricker-Gilbert**. 2018. "Micro-level Welfare Impacts of Agricultural Productivity: Evidence from Rural Malawi." *Journal of Development Studies* 5:915-932.
- Sesmero, J.P., **J. Ricker-Gilbert**, and A. Cook*. 2018. "How Do African Farm Households Respond to Changes in Past and Current Weather Patterns? A Structural Panel Data Analysis from Malawi." *American Journal of Agricultural Economics* 100(1):115-144.

- Ricker-Gilbert, J.**, and T.S. Jayne. 2017. "Estimating the Enduring Effects of Fertilizer Subsidies on Commercial Fertilizer Demand and Maize Production: Panel Data Evidence from Malawi." *Journal of Agricultural Economics* 68(1):70-97.
- Wossen, T., T. Abdoulaye, A. Arega, F. Shiferaw, **J. Ricker-Gilbert**, V. Manyong, and B.A. Awotide, 2017. "Productivity and Welfare Effects of Nigeria's e-Voucher Based Input Subsidy Program." *World Development* 97:251-265.
- Byrd, E.*, N.J.O. Widmar, and **J. Ricker-Gilbert**. 2017. "The Effects of Attribute Non-Attendance, Simple Validation Questions, and Their Interactions on Willingness to Pay Estimates for Meat Choice Experiments" *Cogent Food & Agriculture* 3: 1331949
- Chamberlin, J, and **J. Ricker-Gilbert**. 2016. "Participation in Rural Land Rental Markets in sub-Saharan Africa: Who benefits and by how much? Evidence from Malawi and Zambia." *American Journal of Agricultural Economics* 98(5):1507-1528.
- Kadjo, D.*, **J. Ricker-Gilbert**, and C. Alexander. 2016. "Estimating Price Discounts for Low-Quality Maize in sub-Saharan Africa: Evidence from Benin." *World Development*. 77:115-128.
- Jones, M.*, C. Alexander. C., N.J. Olynk, **J. Ricker-Gilbert** and J. Lowenberg-DeBoer. 2016. "Consumer Preferences for Maize in Malawi: A Stated Preferences Approach with Attribute Non-Attendance to Evaluate Impact of Insect Damage, Variety, and Mold." *Modern Economy* 7:1168-1185.
- Tonitto, C., and **J. Ricker-Gilbert**. 2016. "Nutrient management in African sorghum cropping systems: applying meta-analysis to assess yield and profitability." *Agronomy for Sustainable Development* 36(1):1-19.
- Ricker-Gilbert, J.**, and M. Jones*. 2015. "Does Storage Technology Affect Adoption of Improved Maize Varieties in Africa? Insights from Malawi's Input Subsidy Program." *Food Policy* 50:92-105.
- Jayne, T.S., D. Mather, N. Mason, and **J. Ricker-Gilbert**. 2015. "Rejoinder to: How do Fertilizer Subsidy Programs Affect Total Fertilizer Use? A Synthesis of the Evidence on "Crowding in/out" in sub-Saharan Africa." *Agricultural Economics* 44(6):687-703.
- Bezu, S., G. Tesfahun., B. Shiferaw, and **J. Ricker-Gilbert**. 2014. "Impact of Improved Maize Adoption on Welfare of Farm Households in Malawi: A Panel Data Analysis." *World Development* 59:120-131.
- Ricker-Gilbert, J.**, C. Jumbe, and J. Chamberlain. 2014. "The Impact of Increasing Population Density on African Agriculture and Livelihoods: The Case of Malawi." *Food Policy* 48:114-128.

Josephson, A.L.*, **J. Ricker-Gilbert**, and R. Florax. 2014. “How Does Population Density Affect Agricultural Productivity? Evidence from Ethiopia.” *Food Policy* 48:142-152.

Ricker-Gilbert, J. 2014. “Wage and Employment Effects of Malawi’s Fertilizer Subsidy Program.” *Agricultural Economics* 45(3):337-353.

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Lunduka, R., **J. Ricker-Gilbert**, and M. Fisher. 2013. “The Consistent and Contrasting Results of Research Examining the Economic Impacts of Malawi’s Fertilizer Subsidy Program.” *Agricultural Economics* 44(6):563-579.

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Mason, N.M. and **J. Ricker-Gilbert**. 2013. “Disrupting Demand for Commercial Seed: Input Subsidies in Malawi and Zambia.” *World Development* 45: 75-91.

Ricker-Gilbert, J., T.S. Jayne and E. Chirwa. 2011. “Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi.” *American Journal of Agricultural Economics*. 93(1): 26-42.

Ricker-Gilbert, J., G. Norton, J. Alwang, M. Miah and G. Feder. 2008. “Cost Effectiveness of Alternative IPM Extension Methods: An Example from Bangladesh.” *Applied Economic Perspectives and Policy*. 30(2): 252-269.

ARTICLES UNDER REVIEW (6); * denotes that co-author is current or former graduate student

Prieto, S.*, **J. Ricker-Gilbert**, J. Bauchet, and M. Sall. 2018. “How do traders and consumers in sub-Saharan Africa value maize moisture content? Evidence from an experimental auction in Senegal” *Revise and Resubmit Completed for Economic Development and Cultural Change*.

Channa, H.*, A. Chen, P. Pineda, **J. Ricker-Gilbert** and D. Stein. 2018. “What drives smallholder farmers’ willingness to pay for a new farm storage technology? Evidence from an Experimental Auction in Kenya.” *Revise and Resubmit Completed for Food Policy*.

Darko, F.*, **J. Ricker-Gilbert**, T. Kilic, and G. Shively. 2018. “Profitability of Fertilizer use in sub-Saharan Africa: Evidence from Rural Malawi.” *Revise and Resubmit Requested by Journal of African Economies*.

Ricker-Gilbert, J., C.B. Jumbe, J. Kanyamuka*, J. Chamberlin, R. Lunduka and S. Kaiyatsa*. 2018. “Are Rural Smallholder Landlords Caught in a Poverty Trap? New Evidence from a Matched Tenant-Landlord Sample in Malawi.” *Revise and Resubmit Requested by Agricultural Economics*.

Prieto, S.*, J. Bauchet, and **J. Ricker-Gilbert**. 2018. “Improved drying and storage practices that reduce aflatoxins in stored maize: Experimental evidence from smallholders in Senegal.” *Revise and Resubmit Requested by Proceedings of the National Academy of Sciences*

Kadjo, D.*, **J. Ricker-Gilbert**, J. Shively, and T. Abdoulaye. 2018. “Do farmers’ storage practices and food safety knowledge explain their market participation? Evidence from maize markets in Benin.” *Revise and Resubmit Requested by Journal of Agricultural Economics*.

OTHER PUBLICATIONS AND POLICY BRIEFS (9)

Abdoulaye, T., J.H. Ainembabazi, C. Alexander, D. Baributsa, D. Kadjo, B. Moussa, O. Omotilewa, **J. Ricker-Gilbert**, and F. Shiferaw. 2016. “Postharvest Loss of Maize and Grain Legumes in Sub-Saharan Africa: Insights from the Purdue Improved Crop Storage (PICS) Project.” Purdue Extension Report EC-807-W, West Lafayette, IN. USA

Lunduka, R., **J. Ricker-Gilbert**, G. Shively, and T. Jayne. 2014 “Redefining the Goals and Objectives of Malawi’s Farm Input Subsidy Program.” Policy Brief #1, Prepared for the World Bank, and the African Development Bank. Lilongwe, Malawi.

Ricker-Gilbert, J., Lunduka, R., G. Shively, and T. Jayne. 2014 “Improving the Effectiveness of Malawi’s Farm Input Subsidy Program.” Policy Brief #2, Prepared for the World Bank, and the African Development Bank. Lilongwe, Malawi.

Lunduka, R., **J. Ricker-Gilbert**, G. Shively, and T. Jayne. 2014 “Understanding and Improving the Targeting of Malawi’s Farm Input Subsidy Program.” Policy Brief #3, Prepared for the World Bank, and the African Development Bank. Lilongwe, Malawi.

Ricker-Gilbert, J., Lunduka, R., G. Shively, and T. Jayne. 2014 “Malawi’s Farm Input Subsidy Program to Alternative Programs for Smallholders.” Policy Brief #4, Prepared for the World Bank, and the African Development Bank. Lilongwe, Malawi.

IARNA, & FAUSAC. 2013. *Evaluación del Programa de Fertilizantes del Ministerio de Agricultura, Ganadería y Alimentación (MAGA)*. Guatemala: Instituto de Agricultura, Recursos Naturales y Ambiente (IARNA), Universidad Rafael Landívar; & Facultad de Agronomía (FAUSAC), Universidad de San Carlos de Guatemala.

- Shively, G., and **J. Ricker-Gilbert**. 2012. “Measuring the Impacts of Agricultural Input Subsidies in Sub-Saharan Africa: Evidence from Malawi’s Farm Input Subsidy Program.” Policy Brief prepared for the Global Policy Research Institute at Purdue University; West Lafayette, IN.
- Kelly, V., E. Crawford, and **J. Ricker-Gilbert**. 2011. “The New Generation of African Fertilizer Subsidies: Panacea or Pandora’s Box?” Food Security II Policy Synthesis, Number 87. Department of Agricultural, Food & Resource Economics, Michigan State University.
- Jayne, T.S., N. Sitko, **J. Ricker-Gilbert** and J. Mangisoni. 2010. “Malawi’s Maize Marketing System.” Department of Agricultural, Food & Resource Economics, Michigan State University.

INVITED SEMINARS, CONFERENCE PRESENTATIONS & ORGANIZED SYMPOSIA

- Invited Seminar, University of Minnesota, November 2018.
- AAEA Annual Meeting: Washington DC, August 2018.
- International Association of Agricultural Economists: Vancouver, Canada, July 2018.
- Midwest International Economic Development Conference: Minneapolis, MN., April 2018.
- CSAE Conference on Economic Development in Africa, Oxford England, March 2018.
- USAID, AGRI-LINKS Seminar, Washington D.C., February 2018.
- Invited Seminar, NC State University, November 2017.
- AAEA Annual Meeting: Chicago IL, July 2017.
- Invited Seminar, Virginia Tech, April 2017.
- Invited Seminar, University of Illinois, March 2017.
- African Association of Agricultural Economists: Addis Ababa, Ethiopia, September 2016.
- AAEA Annual Meeting: Boston MA, July-August 2016.
- World Bank Conference on Land and Poverty: Washington DC, March 2016.
- International Association of Agricultural Economists: Milan, Italy, August 2015.
- AAEA Annual Meeting: San Francisco CA, July 2015.
- Midwest International Economic Development Conference: Madison WI., April 2015.
- World Bank Conference on Land and Poverty: Washington DC, March 2015.
- AAEA Annual Meeting: Minneapolis MN, August 2014.
- African Association of Agricultural Economists: Hammamet, Tunisia, September 2013.
- AAEA Annual Meeting: Washington DC, August 2013.
- Midwest International Economic Development Conference: Madison WI., April 2013.
- International Association of Agricultural Economists: Foz Do Iguacu, Brazil, August 2012.
- AAEA Annual Meeting: Seattle WA, August 2012.
- AAEA Annual Meeting: Pittsburgh PA, July 2011.
- Africa Growth Forum at the Brookings Institute: Washington D.C., January 2011.
- African Association of Agricultural Economists: Cape Town, S.A., September 2010.
- AAEA Annual Meeting: Denver CO, July 2010.
- Future of Food & Nutrition Conference at Tufts University: Boston MA, April 2010.
- International Association of Agricultural Economists: Beijing China, August 2009.
- AAEA Annual Meeting: Milwaukee WI, July 2009.
- AAEA Annual Meeting: Orlando FL, July 2008.
- International Association of Agricultural Economists: Brisbane, Australia, August 2006.
- NC-1003 Annual Meeting: Jekyll Island GA, March 2006.*

INVITED POLICY PRESENTATIONS (11)

- Ricker-Gilbert, J.,** C. Jumbe, J. Kanyamuka, J. Chamberlin, R. Lunduka, and S. Kaiyatsa. 2017. “Do Farm Land Rental Markets Really Promote Efficiency and Equity in Smallholder Agriculture? Evidence from a Matched Tenant-Landlord Sample in Malawi.” Presentation made at the Second National Land Symposium. May 8, 2017 in Lilongwe, Malawi.
- Ricker-Gilbert, J.** and J. Chamberlin. 2016. “Participation in rural land rental markets in Sub-Saharan Africa: who benefits and by how much? Evidence from Malawi.” Presentation made at the First National Land Symposium. April 20, 2016 in Lilongwe, Malawi.
- Ricker-Gilbert, J.,** and T.S. Jayne. 2015 “Access of Smallholder Farms to Seeds and Fertilizer Use in sub-Saharan Africa.” Presentation at the European Commission Workshop on Local Level Food and Nutrition Security and the Role of Subsistence/Smallholder Farms. Seville, Spain. September 9-10.
- Ricker-Gilbert, J.,** and R. Lunduka. 2014 “Comparing Input Subsidies to Alternative Investments for Smallholders.” Presentation at the LUANAR/IFPRI Policy Workshop titled “Eight Years of FISP: Impact and What’s Next?” Lilongwe, Malawi. July 14-15.
- Lunduka, R., and **J. Ricker-Gilbert.** 2014 “What are the Household-Level Impacts of Malawi’s Farm Input Subsidy Program.” Presentation at the LUANAR/IFPRI Policy Workshop titled “Eight Years of FISP: Impact and What’s Next?” Lilongwe, Malawi. July 14-15.
- Snapp, S., T.S. Jayne, W. Mhango, T. Benson, and **J. Ricker-Gilbert.** 2014. “Maize-Nitrogen Response in Malawi’s Production Systems.” Presentation at the LUANAR/IFPRI Policy Workshop titled “Eight Years of FISP: Impact and What’s Next?” Lilongwe, Malawi. July 14-15.
- Jacob Ricker-Gilbert, J.** 2013. “Evaluating the Impact of Input Subsidy Programs.” Invited Presentation at the “3rd Annual Conference for Fiscal Policy and Equitable Society.” World Bank Headquarters, Washington D.C., June 10.
- Ricker-Gilbert, J.** 2012. “Input Subsidies: What We Know.” Invited Policy Presentation for Guatemalan Ministry of Agriculture and the Inter-American Development Bank at Rafael Landivar University. Guatemala City, Guatemala. December 13.
- Ricker-Gilbert, J.** 2011. “Analysis of Key Policy Issues in Malawi.” Invited Presentation at USAID Malawi. Lilongwe, Malawi. October 28.
- Ricker-Gilbert, J.** and T.S. Jayne. 2011. “Are there Enduring Benefits of Fertilizer Subsidies on Household Well-being? Evidence from Malawi.” Invited Presentation at the COMESA/ACTESA/ MINAGRI Policy Symposium on Smallholder-led Agricultural Commercialization and Poverty Reduction. Kilgali, Rwanda. April 20-22.

Ricker-Gilbert, J. and T.S. Jayne. 2010. “The Impact of Fertilizer Subsidies on Displacement and Total Fertilizer Use.” Invited Presentation at the Malawi Agricultural Input Subsidy Program Evaluation Workshop for the Malawian Ministry of Agriculture: Lilongwe, Malawi. May 11.

GRADUATE STUDENT ADVISING AT PURDUE

a. Current Ph.D. Students, Major professor: (4)

- Hira Chana. Expected Graduation in 2019.
- Tabitha Nindi. Expected Graduation in 2020.
- Mrunal Shah. Expected Graduation in 2021.
- Nina Jovanovic. Expected Graduation in 2021.

b. Current Ph.D. Students, Committee member: (1)

- Kayanet Kabir, Expected Graduation in 2019

c. Completed Ph.D. Students, Major professor: (4)

- Darko, Francis Graduated in 2016. *Employed as Economist by the World Bank*
- Kadjo, Didier. Graduated in 2017. *Employed as a consultant in Cote d’Ivoire*
- Omotilewa, Oluwatoba. Graduated in 2018. *Employed as Economist by the World Bank*
- Stacy Prieto. Graduated in 2018. *Employed as a Manager at Catholic Relief Services*

d. Completed Ph.D. Students, Committee member: (5)

- Raszap, Sharon. Graduated in 2014. *Employed as an economist for the Economic Research Service of USDA.*
- Thapa, Ganesh. Graduated in 2015. *Employed by World Bank.*
- Halimi, Ghulam. Graduated in 2016. *Employed by the government of Afghanistan.*
- Hatzenbuehler, Patrick. Graduated in 2016. *Employed by IFPRI.*
- Josephson, Anna. Graduated in 2017. *Assistant Professor at University of Arizona.*
- Pasley, Heather (Agronomy). Graduated in 2018. *Post-doc at Purdue University*

e. Current M.S. Students, Major Professor: (2)

- Amanda Fuller, Expected Graduation in 2019.
- Laura Leavens, Expected Graduation in 2020.

f. Completed M.S. Students, Major Professor: (8)

- Josephson, Anna. Graduated in 2013. *Ph.D. student in the Agricultural Economics department at Purdue.*
- Kadjo, Didier. Graduated in 2013. *Ph.D. student in the Agricultural Economics department at Purdue.*
- Cook, Aaron. Graduated in 2013. *Ph.D. student in the Agricultural Economics department at Penn State.*
- Ghambi, Daniel. Graduated in 2014. *Agribusiness officer with the Malawian Ministry of Agriculture and Food Security.*
- Harringx, Shannon. Graduated in 2014. *Currently employed by Syngenta.*

- Weinert, Brian. Graduated in 2016. *Currently employed by John Deere*
- Ha, Kim. Graduated in 2016.
- Alwang, Albert. Graduated in 2017. *Currently employed by Virginia Tech*

g. Completed M.S. Students, Committee member: (8)

- Jones, Michael. Graduated in 2012. *PhD student in Agricultural Economics at North Carolina State University.*
- Kumaraswamy, Gautam. Graduated in 2012.
- Sununtnasuk, Celeste. Graduated in 2013. *Employed by IFPRI.*
- Mbulukwa, Mphatso. Graduated in 2014. *Agribusiness officer with the Malawian Ministry of Agriculture and Food Security.*
- Aghasili, Onyekachi. Graduated in 2015.
- Flock, James. Graduated in 2015. *Employed by ACDI-VOCA.*
- Zhao, Sidi. Graduated in 2016.
- Donovan, Natalie. Graduated in 2018.

h. Awards with Graduate Students

- Advisor to Albert Alwang. Winner of the Best Master's Thesis in the Department of Agricultural Economics at Purdue University, 2017.
- Co-Advisor (with Juan Sesmero) to Aaron Cook. Winner of the Best Master's Thesis in the Department of Agricultural Economics at Purdue, 2014.

RESEARCH GRANT ACTIVITIES

(\$25,480,665 in total; \$17,724,772 to Purdue; \$2,885,100 directly to Ricker-Gilbert)

Universidad Nacional de San Agustín, Peru. January 2018 – December 2020. “A Purdue-UNSA Initiative to Establish a Center on Food Security in Peru.” (with Gebisa Ejeta, Sylvie Brouder, Connie Weaver, Laurel Weldon, and Gary Burniske); \$160,332 with direct responsibility for \$16,033.

USAID. October 2017 – September 2019. “Increasing Malawian Smallholder Farmers’ Access to Improved Storage Technology and Credit.” (with Dieudonne Baributsa); \$275,000 with direct responsibility for \$137,500.

USAID. October 2016 – September 2018. “Increasing Tanzanian Smallholder Farmers’ Access to Improved Storage Technology and Credit.” (with Dieudonne Baributsa, Tahirou Abdoulaye, and Feleke Shiferaw); \$275,000 with direct responsibility for \$137,500.

USAID. November 2016 – October 2017. “Measuring African Farmers’ and Traders’ Willingness to Pay for a Low Cost Maize Moisture Meter: Evidence from an Experimental Auction in Kenya.”

(with Jonathan Bauchet, Charles Woloshuk, Paswel Marenza and Hugo De Groote); \$15,000 with direct responsibility for \$5,000.

USAID. October 2015 – September 2016. Norman E. Borlaug Leadership Enhancement in Agriculture Program (LEAP) – Fellowship.” (with Oluwatoba Omotilewa, and John Herbert Ainembabazi); \$20,000 with direct responsibility for \$20,000.

USAID. May 2014 – April 2019. “Feed the Future Innovation Lab for Food Processing and Post-Harvest Handling” (with B. Bugusu, J. Lowenberg-Deboer, C. Alexander, B. Hamaker, S. Nielson, M. Ferruzzi, K. Ileleji, C. Woloshuk); \$5,000,000 with direct responsibility for \$350,000.

Bill and Melinda Gates Foundation. April 2014 – March 2019. “*Commercializing Hermetic Storage Technology in sub-Saharan Africa.*” (with D. Baributsa, C. Alexander, L. Murdoch, J. Lowenberg-Deboer, C. Woloshuk); \$10,000,000 with direct responsibility for \$1,500,000.

Bill and Melinda Gates Foundation. January 2013 – December 2016. “*Guiding Investments in Sustainable Agricultural Intensification in Africa (GISAIA) Project.*” (with T.S Jayne, C. Jumbe, M. Smale, N. Mason, N. Sitko, D. Mather, others); \$7,900,000 with direct responsibility for \$449,728.

USAID. October 2013 – September 2014. Norman E. Borlaug Leadership Enhancement in Agriculture Program (LEAP) – Fellowship.” (with Didier Kadjo, and Tahirou Abdoulaye); \$20,000 with direct responsibility for \$20,000.

USAID. August 2012 - August 2013. “*Initiative for Long-term Training and Capacity Building (UILTCB) in Malawi.*” (with J. Lowenberg-Deboer, G. Shively, others); \$266,333 with direct responsibility for \$47,940.

Bill and Melinda Gates Foundation. April 2011 - Sept 2013. “*Encouraging Marketing and Trade in Sub-Saharan Africa through Hermetic Storage of Crops by Smallholder Farmers.*” (with L. Murdoch, J. Lowenberg-Deboer, C. Alexander, D. Baributsa); \$1,099,000 with direct responsibility for \$57,130.

Bill and Melinda Gates Foundation. Sept 2011 - Sept 2012. “*Impact of Increasing Population Density on African Farming Systems.*” *Supplemental Funding to the Guiding Investments in Sustainable Agricultural Markets in Africa (GISAMA) Project.* (with T.S. Jayne, R. Benfica, J. Chamberlin, Milu Muyanga, and D. Mather); \$450,000 with direct responsibility for \$144,269.

TEACHING

- AGECE 340: Undergraduate-level *International Development Economics* (Spring Semester: 2012-2017).
- AGECE 619: PhD-level *Applied Microeconomic Theory* (Spring Semester: 2013, 2015, 2017, 2018).
- AGECE 643: PhD-level *Development Economics* (Fall Semester: 2018).

PROFESSIONAL AFFILIATIONS

Agricultural and Applied Economics Association (AAEA), since 2008
International Association of Agricultural Economists (IAAE), since 2009
African Association of Agricultural Economists (AAAE), since 2010

REFEREEING SERVICES

Economic Journal, *American Journal of Agricultural Economics*; *World Development*; *Agricultural Economics*; *Oxford Development Studies*; *Journal of Development Studies*; *African Journal of Agriculture and Resource Economics*; *Journal of International Development*; *Food Policy*; *Journal of Agricultural Economics*; *China Economic Review*; *Journal of African Economies*; *Environment and Development Economics*; *Land Economics*; *Food Security*; *Applied Economics Perspectives and Policy*; *Crop Protection*; *Journal of Borderland Studies*; *Agricultural Systems*.

Section Leader for the 2014 & 2015 Agricultural and Applied Economics Association Annual Meeting (in charge of coordinating abstract reviews for the international development section of the conference); Abstract reviewer, 2011, 2012 & 2013 & 2018 Agricultural and Applied Economics Association Annual Meeting; Selected paper reviewer, 2010 & 2013 African Association of Agricultural Economics Tri-annual Meeting; Selected paper reviewer, 2009 & 2012 International Association of Agricultural Economics Tri-annual Meeting.

EDITORIAL BOARD SERVICE

- Associate Editor *American Journal of Agricultural Economics*: 2018 - present
- Associate Editor *Agricultural Economics*: 2018 – present
- External Member of the International Food Policy Research Institute's (IFPRI) Publication Review Committee: 2016 - present

LANGUAGES

- **English:** Native
- **Spanish:** Spoken = Good; Written = Fair; Read = Good

Personal

- U.S. Citizen
- **Date of Birth:** October 16, 1979

Appendix 2: Scope of Work for the External Evaluation Team

External Evaluation Approach of the

Feed the Future Innovation Lab for Integrated Pest Management (IPM IL)

November 2018

Introduction:

The Feed the Future Innovation Lab for Collaborative Research on Integrated Pest Management (IPM IL) is a global leader, providing a platform for stakeholders to jointly engage and share knowledge in interdisciplinary research, and capacity building on Integrated Pest Management (IPM).

The overall mission of the Integrated Pest Management Innovation Lab is to raise the standard of living while creating sustainable development. The program works to develop and implement a replicable approach to IPM that will help reduce the following:

- agricultural losses due to pests
- damage to natural ecosystems including loss of biodiversity
- pollution and contamination of food and water supplies

By combining expertise from the United States, IARCs centers, and host country institutions, the goals of the IPM Innovation Lab are to:

- measurably reduce crop losses due to pests
- increase farmer income
- reduce chemical pesticide use
- reduce residues on export crops
- improve IPM research, extension, and education program capabilities
- improve ability to monitor and manage pests
- improve ability to monitor, forecast, and manage invasive pest species
- increase the ability of women in IPM decision-making and program design

By reaching these goals, the IPM Innovation Lab directly contributes to the strategic objectives of USAID and its partners to advance IPM and good agricultural practices that provide long-term social, economic, and environmental benefits.

IPM Innovation Lab program objectives relate to research, communication, and education for behavioral change, institutional capacity building, policy and institutional reform, and the development of sustainable, resource-based local enterprises. Specifically, the IPM Innovation Lab pursues:

In its current phase (Phase V), the IPM Innovation Lab is managing eight projects, each designed to address a specific challenge:

- Strengthening production and export of Vietnamese fruit crops through innovative and market-orientated IPM
- Innovative Scientific Research and Technology Transfer to Develop and Implement Integrated Pest Management Strategies for Vegetable and Mango Pests in Asia
- Participatory Biodiversity and Climate Change Assessment for Integrated Pest Management in the Annapurna-Chitwan Landscape, Nepal
- Development of Ecologically based Participatory Integrated Pest Management (IPM)

Package for Rice in Cambodia (EPIC)

- A High-resolution Interaction Based Approach to Modeling the Spread of Agricultural Invasive Species
- Biological Control of the Invasive Weed *Parthenium hysterophorus* in East Africa
- Rice, Maize, and chickpea IPM for East Africa
- Integrated Pest Management for Vegetables in East Africa

Evaluation Purpose:

The purpose of this commissioned performance evaluation of the Feed the Future Innovation Lab for Collaborative Research on Integrated Pest Management (IPM IL) is to:

- assess progress on activities and outcomes;
- improve effectiveness of ongoing activities;
- provide robust evidenced-based findings, conclusions, and recommendations, assessing needs and opportunities, for tackling outstanding key research questions connected to integrated pest management (IPM) in developing countries; and
- provide an assessment as to the rationale for extending the Lab for another 5 years vs. undergoing a re-competition for years 6-10. What critical aspects of momentum, impact and success might be lost if a decision is made to re-competed the Lab instead of granting a 5 year extension.

The evaluation results will also be made available to the Bureau for Food Security (BFS)/U.S. Agency for International Development (USAID) to support evidenced-based decision making on the potential extension of the IPM IL award for another five years.

To accomplish this, the evaluation will assess implementation and progress toward objectives amongst the different IPM IL projects, including relevance of research; technology, and institutional development, including capacity building and scaling accomplishments (i.e., delivering on milestones and project proposal as described in the technical application). Furthermore, since the IPM IL will be completing its first five-year phase in November 16, 2019, the evaluation team is expected to make recommendations for IPM research on new or continuing investments, including technical research, capacity development, and institutional support towards scaling and impact.

Audience and Intended Uses:

The primary audience and intended users are the IPM IL Management Entity (ME) and the BFS/USAID Program for Research, Missions, and implementing partners and universities.

Evaluation Approach

The evaluation approach for the research project reviews from the External Evaluation Team (EET) will include but does not have to be limited to:

- *Document Reviews:* Project proposals, annual technical workplans, annual and semi-annual reports, travel reports, project publications including success stories, research publications, indicator outputs, and associated documents, etc.;
- *Key Informant Interviews:* IPM IL researchers, IPM IL management team, and country coordinators;
- *Field visits:* to project sites in the participating regions, as necessary;
- *Group Discussions:* with farmers engaged in the project and others at project sites,

development agents and other change agents operating at site.

Composition of the External Evaluation Team (EET)

The evaluation team will be composed of two external members with the expertise to conduct the evaluation. There will be one Chair to serve as the team leader of the evaluation efforts. Care will be taken to avoid conflicts of interest. Each team member's Curriculum Vitae is attached to this document demonstrating their relevant experience in technical, evaluation, and management skills.

The team members are:

- S. Shanmugasundaram (Chair), retired, AVRDC
- Jacob Ricker-Gilbert, Purdue University

The following technical skills are present among the team as a whole:

- Integrated Pest Management
- Horticulture
- Socio-economics, gender and value chains;
- Agricultural economics;
- Institutional innovations/scaling adoption;
- Managing multi-partner, agricultural research projects, and;
- Monitoring and evaluation of complex agricultural research projects utilizing quantitative and qualitative evaluation methodologies.

The selected team members have the expertise necessary to evaluate sub-award projects, to assess the different technical and programmatic components of the IPM IL, including research, management and implementation, capacity development, and partnerships and institutional collaboration, address the evaluation questions rigorously, and collect, triangulate, and analyze primary and secondary data in a robust manner to generate unbiased and evidenced-based findings.

Deliverables from the EET:

The review team will submit the following deliverables:

- Short presentation of interim findings for a debriefing meeting, optional;
- Draft report detailing the findings of the review and recommendations for comment from the IPM IL ME team;
- Final report

Timing of the Review:

- Document reviews: November/December 2018;
- Key informant virtual interviews: December 2018;
- Travel to Focus Country to meet with further key informants and conduct field visits: December 2018: 3-5 days per visit, as appropriate;
 - o S. Shanmugasundaram to visit Ethiopia and review the Grains IPM, Biocontrol of Parthenium, and Vegetable IPM projects
 - o Jacob Ricker-Gilbert to visit Tanzania and review the Grains IPM and the vegetable IPM projects

- Draft Report: by January 10, 2019
- Final Report: by January 31, 2019

Scope of Work:

This performance evaluation will provide the IPM IL ME with constructive feedback on the research programs, training programs, and institutional capacity collaboration of the IPM Innovation Lab. Specifically, the evaluation team will objectively evaluate the following potential questions using an evidenced-based and data-driven approach.

Management and Implementation:

- How relevant are the IPM IL research themes and approach, to the current challenges of agricultural pest management in the African and Asian regions and in the target countries?
- How effective is the IPM IL structure of target country sub-awards and supplementary activities?
- How has the IPM IL ME promoted and maximized values such as collaboration, capacity development, and outreach among sub awardees?
- In what ways has the IPM IL program been responsive to requests for technical assistance from USAID (Headquarters and Missions) and host country institutions? In what ways could the IPM IL team have been more responsive?
- How does the IPM IL ME continue to be forward thinking about research ideas and plans, including improving alignment with the Feed the Future and Global Food security Research strategy?
- What systems are in place to keep the research activities on track according the IPM IL program goals?
- What are the roles and functions of the IPM IL Technical Advisory committee (TAC)? Have they been effective and efficient?
- What major challenges has the IPM IL ME faced and how have they been addressed?

Technology Development:

- To what extent did the IPM IL generate quality research technologies/outputs using systems and gender-sensitive approaches and appropriate metrics for productivity, sustainability and resilience?
- Are the outputs relevant and appropriate for a demand-driven research-for-development (e.g., did they generate/develop new technologies of relevance to Feed the Future countries that practitioners and/or smallholder farmers are likely to use)?
- Describe and highlight which research methods have been most effective and which technologies have the greatest potential impact. What opportunities are there to improve ongoing IPM IL research (in terms of both increasing quality and generating appropriate outputs for Feed the Future countries)?
- Building on IPM IL results, what general opportunities and priorities exist for future national and regional research for IPM in Africa and Asia?

Stakeholder Collaboration for Enabling Environments:

- In what ways are relevant partners, including USAID missions and projects, Feed the

Future, IARCs, NGOs, host country governmental and academic institutions, private sector and community stakeholders (if applicable) being informed and engaged (as appropriate) in target countries and regions, and at Lab level?

- How do the host-country stakeholders perceive the IPM IL initiatives? To what extent do they share ownership and share a common vision of foci, approaches and process (what, why, and how)?
- What potential is there for other partnerships and collaborations, including other Feed the Future Innovation Labs and other relevant USAID programs in the target countries?
- In what ways does the research capacity of U.S. universities, IARCs compliment (not replicate) capacities of the national programs and their non-governmental organization (NGO) partners in target countries?

Capacity Building:

- How relevant are the IPM IL identified academic and technical capacity needs for IPM of host country and regional stakeholders?
- How effectively has IPM IL addressed academic and technical capacity needs of stakeholders, and how could IPM IL better serve and provide for the capacity needs of these stakeholders in the future?
- What improvements, if any, are needed in how academic and technical capacity strengthening activities are identified and implemented?
- In what ways, if any, have the training programs contributed to strengthening organizational capacity, including fostering institutional innovation and learning cultures, and inter-organizational and inter-sectoral cooperation in target countries?
- To what extent has capacity building enabled target country partner organizations to maintain IPM research activities after the completion of IPM IL?
- Building on IPM IL achievements, what general opportunities and priorities exist for future national and regional capacity development for sustainable intensification in Africa and Asia?

Impact and scaling:

- How relevant are the IPM IL's strategies and plans to identify and engage potential scaling partners of the key technologies?
- How effectively has the IPM IL project fostered dissemination of research results to local stakeholders? In what ways could dissemination be improved (both content and audience) to enhance the uptake of research findings?
- What technologies are more likely to be adopted by farmers (including women) and scaled sustainably in each region and/or country? And why, why not?
- What types of opportunities and constraints have been identified related to the widespread adoption and scaling of technologies and practices by smallholder farmers? In what ways, if any, have opportunities been maximized to support scaling? What approaches have been identified to address these constraints? What could the project do to better address the challenges to improved access and use for smallholder farmers?
- Are there any extension processes that would merit research/appraisal that are best bet approaches for enabling wide adoption of specific IPM IL innovations, e.g., block demonstrations vs. farmer field schools vs. innovation platforms?

- Building on IPM IL accomplishments, what general opportunities and priorities exist for future national and regional research and scaling engagements for IPM in Africa and Asia?

Program Future:

Building on the above general opportunities for research, stakeholder collaboration especially policy engagement, capacity building, and scaling, what specific areas are needed for effective future programming of IPM, if any, within IPM systems research linked to new or continuing investment, including technical research, capacity development, institutional support, and scaling?

Appendix 3: Summary of IPM IL Collaborator Survey

The external evaluation team (EET) designed a survey, with 28 questions, that was sent out to all collaborators and sub-grantees for the current phase of the IPM IL. The survey was designed using Qualtrics license through Purdue University and took about 15 minutes for collaborators to complete. The survey was sent via email to over 100 collaborators who were given one week to complete the survey, between the dates of December 17-24, 2018.

In total, 103 people responded to the survey. The majority of collaborators are from Eastern or Southern Africa, South Asia, or Southeast Asia. Nearly 89% of the collaborators on the IPM IL project are in Production sciences (including seed, soil, or weed science, pathology/entomology, integrated Pest Management (IPM), physiology, farming practices, management, breeding and selection, etc.) . Four percent are in social sciences and the rest are spread across other fields, like food science, extension or others. The survey responses should be viewed from this perspective.

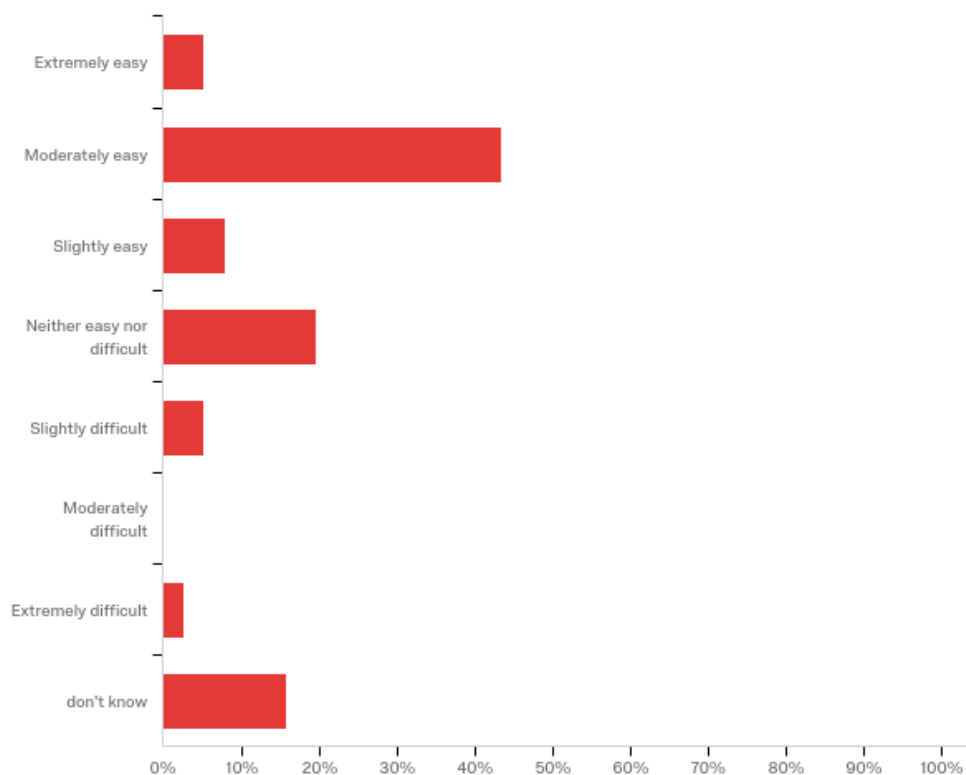
Collaborator views on financial management

IPM IL collaborators were asked to comment on several aspects of the labs financial resources and management. About 50% feel that the IPM IL fully or nearly fully covers their costs relative to program objectives, while about 40% percent say that it covers 60% of costs or less, and 10% do not know.

Collaborators were also asked to comment on how easy is it to comply with financial reporting requirements implemented by the IPM IL to receive funds and/or reimbursements, relative to other projects they have participated in. The findings from figure A.3.1 suggest that a plurality of respondents feel it is moderately easy to comply with financial reporting requirements. The rest say that is either extremely easy, slightly easy, neither easy nor difficult, or they do not

know. Very few say that is difficult to comply with financial reporting requirements.

Figure A.3.1: How easy is it to comply with financial reporting requirements implemented by the IPM IL to receive funds and/or reimbursements?



Collaborators were also asked how easy is it to comply with administrative reporting requirements implemented by the IPM IL to comply with USAID guidelines, relative to other projects. Most feel that it is moderately easy to comply with administrative reporting requirements (nearly 45%). The rest say that is either extremely easy, slightly easy, neither easy nor difficult, or they do not know. Very few say that is difficult to comply with administrative reporting requirements.

Collaborators also had specific comments on financial and administrative issues on the IPM IL. They suggest that the administration is generally good, but resources devoted to collaborator salaries and expenses are a bit low, given the work that is required. There were some complaints about creating a standard template for reporting to USAID.

Collaborator views on basic research

The IPM IL collaborator survey asked a series of questions about how they viewed basic research on IPM in their individual programs and the IPM IL project as a whole. As shown in Figure A.3.2 that nearly everyone (>90%) believes that basic research is extremely well integrated, very well integrated, or moderately integrated into the IPM IL program. Very few collaborators feel that there is less than adequate integration of basic research.

Figure A.3.2: How well is basic research of IPM technologies and practices integrated into your IPM IL program?

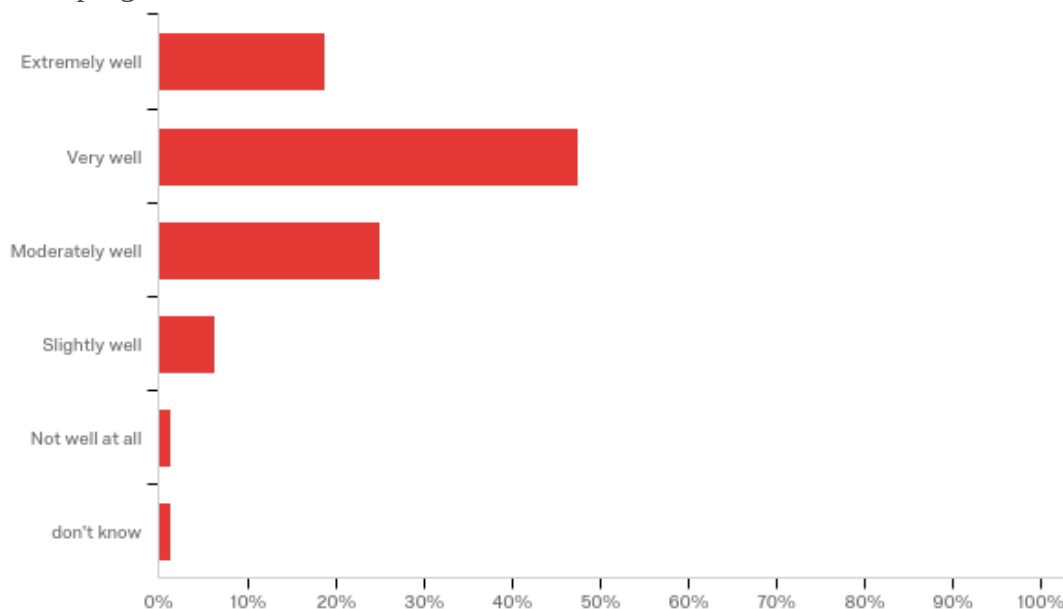
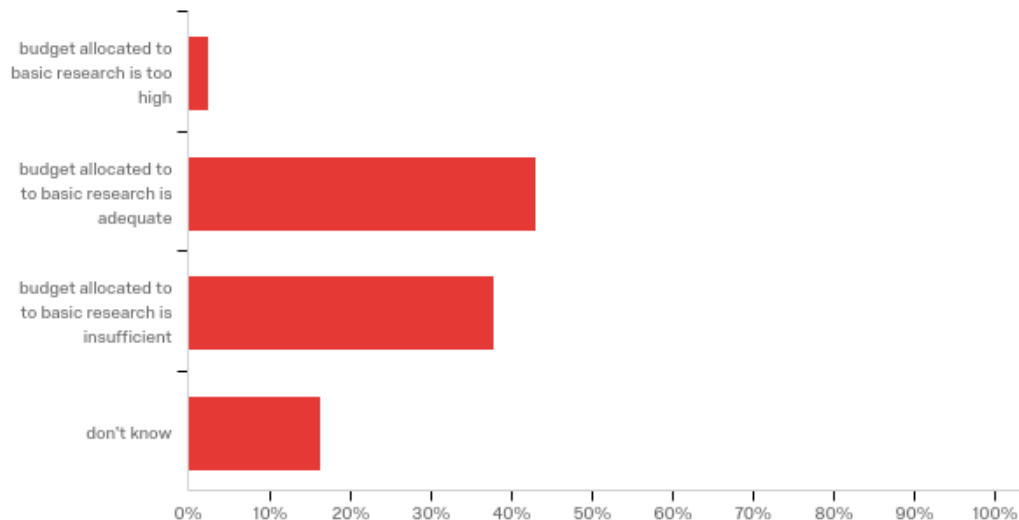


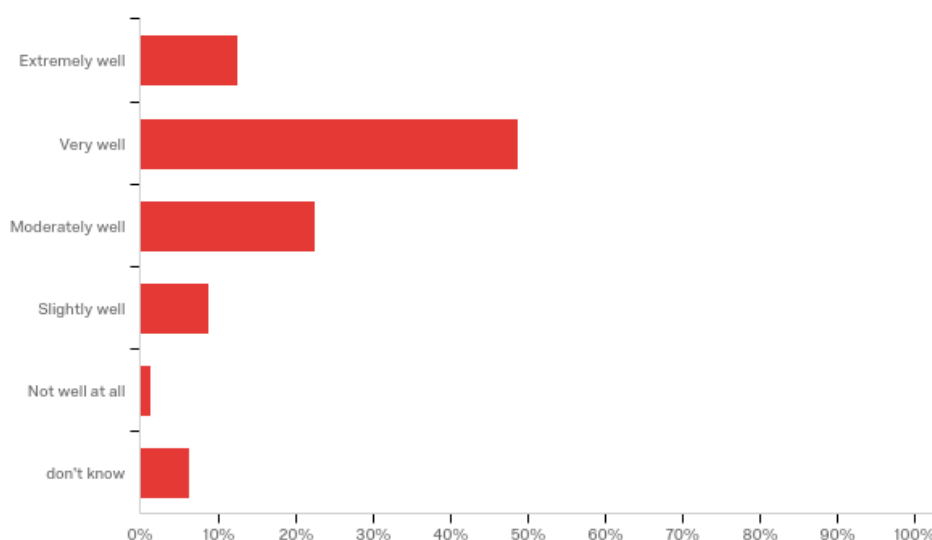
Figure A.3.3 indicates that nearly 40% of collaborators feel that insufficient funds are allocated to basic research on IPM in the IL. About 45% feel that that budget allocated to basic research is adequate and about 15% do not know. Almost no one feels that the budget allocated to basic research is too high. **The collaborators' sentiments on basic research funding suggest that it may be worth discussing the role of basic research in the next phase of the IPM IL.**

Figure A.3.3: How adequate is the budget allocated to basic research of IPM technologies and practices in your IPM IL program?



It is also essential that basic research ultimately reach, educate and improve production practices of farmers. Results revealed that nearly 50% of respondents believe that basic research from The IPM IL has done very well to help improve the production practices of farmers. About 13% feel that basic research has helped farmers extremely well, while about 23% feel that it has done so moderately well. Only about 10% of respondents feel that basic research on the IPM IL has only slightly or not at all helped farmers' production practices (Figure A.3.4).

Figure A.3.4: How well has the basic research component of your IPM IL program reached, educated and improved production practices of farmers?



In addition, the collaborators had the following specific comments on basic research on IPM IL. The general theme of the comments is that they collaborators do the best research they can with the funds available, but the IPM IL is mainly applied research and extension. **There is a feeling among collaborators that more funds are needed for basic research.**

Collaborator views on applied research

The IPM IL collaborator survey also asked a series of questions about how they viewed applied research on IPM in their individual programs and the IPM IL project as a whole. Figure A.3.5 assesses how well collaborators feel that applied research of IPM technologies and practices is integrated into their program. Results suggest that most collaborates feel that applied research is integrated into their IL program. About 18% say that applied research is extremely well integrated, 53% say that it is very well integrated and 19% say that is moderately well integrated. Only 8% say that it is not well integrated and nobody said that is not integrated at all. These results make sense as applied research is the main focus of the IPM IL.

Figure A.3.5: How well is applied research of IPM technologies and practices integrated into your IPM IL program?

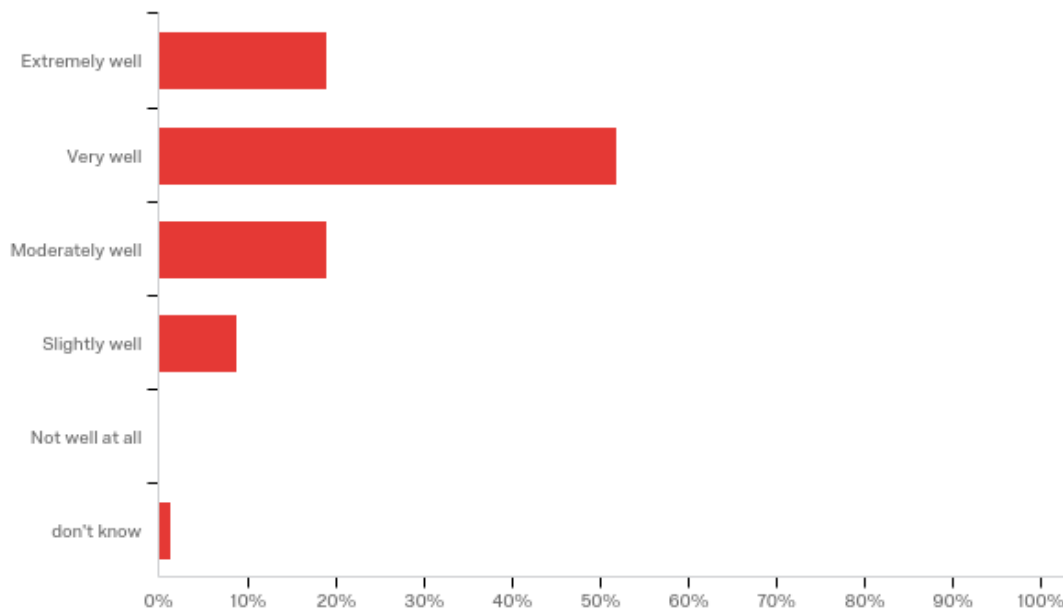
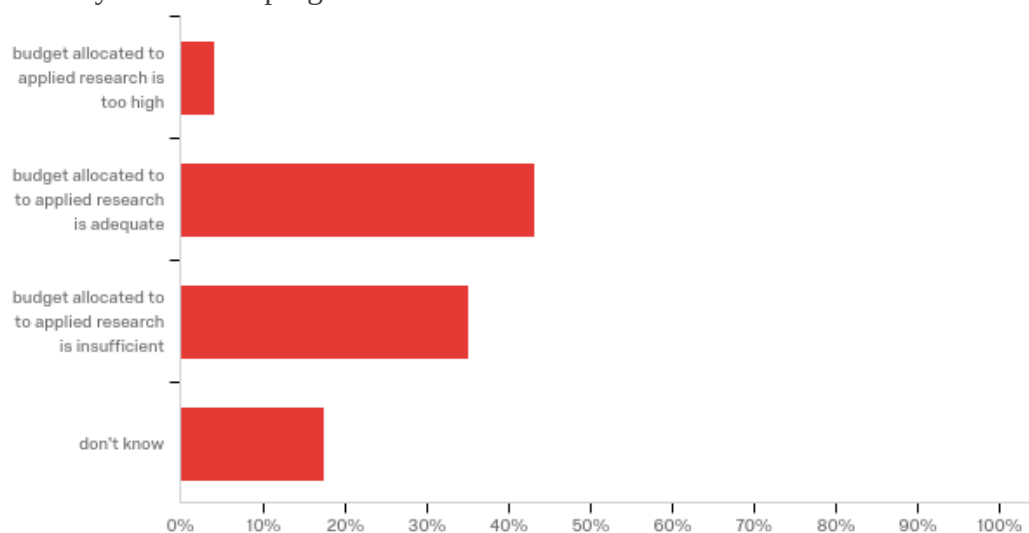


Figure A.3.6 suggest that about 46% of collaborators feel that the budget allocated to applied research is adequate. While 33% feel that the budget allocated to applied research is insufficient. Only 4% believe that it is too high and 17% do not know.

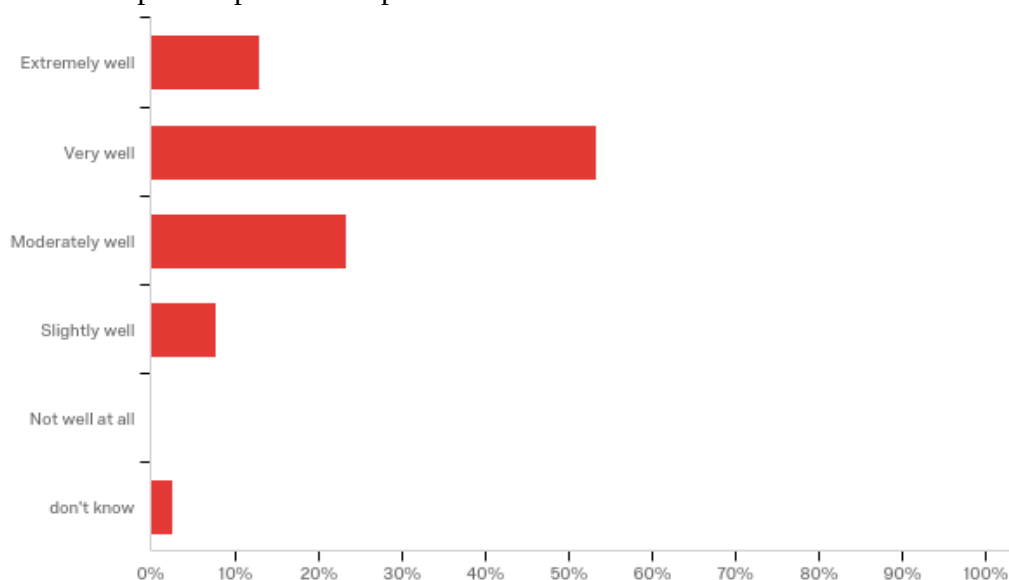
Figure A.3.6: How adequate is the budget allocated to applied research of IPM technologies and practices in your IPM IL program?



In terms of how applied research ultimately reaches, educates and improves production practices of farmers,

the collaborator survey indicates that 56% of collaborators believe that the project does that very well (Figure A.3.7). About 12% believe that the IL does it extremely well and 22% believe that it reaches farmers moderately well. Only 7% feel that it reaches farmers slightly well and nobody feels that it does not reach farmers at all.

Figure A.3.7: How well has the applied research component of your IPM IL program reached, educated and improved production practices of farmers?



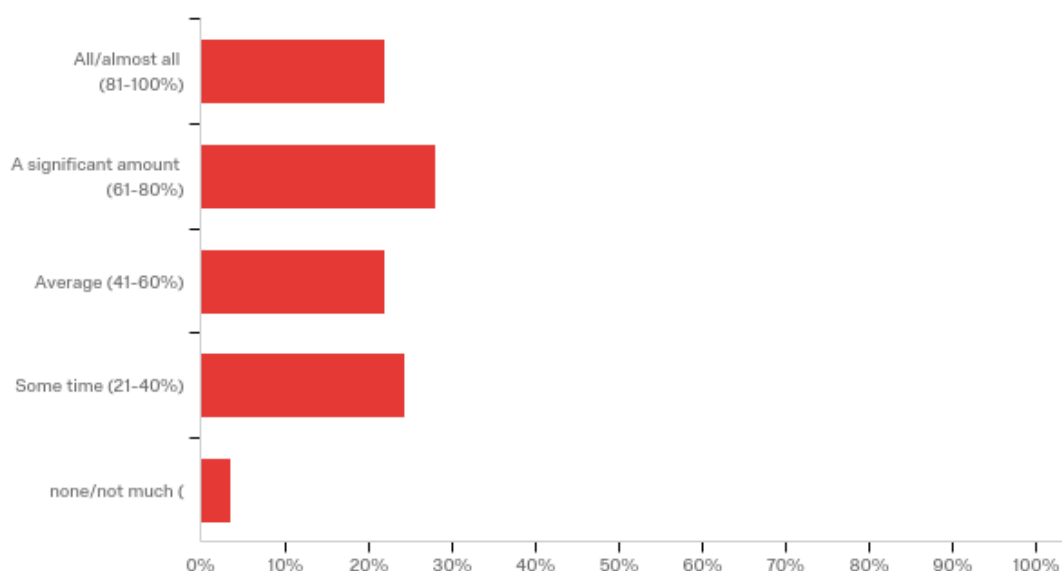
In addition, collaborators had the following specific comments about applied research on IPM technologies and practices. **There are some comments suggesting that funding for applied research needs to increase and that involving extension personnel and perhaps farmers and other stakeholders to identify problems of pressing concern could improve the applied research component of the IPM IL.**

Collaborator views on the contribution of IPM IL to their research and extension program

Given that many of the host country scientists and extension personnel operate in environments of limited resources and funding, support from the IPM IL has the potential to make a large impact

on their ability to conduct research. Figure A.3.8 presents the results of the proportion of collaborators' time that gets devoted to IPM activities including IPM IL. About 50% of all collaborators say that IPM research takes all/almost all of their time (22%), or a significant amount of their time (28%). About 22% say that it takes up an average amount of their time and 24% say that it takes up some of their time. This figure confirms that the collaborators on the IL are heavily involved in IPM activities.

Figure A.3.8: How much of your work/research time do you allocate to IPM research, studies and activities on an annual basis (including the time you allocate to IPM IL activities), (% of your total professional time)?



Related to the previous figure, figure A.3.9 shows results from the question asking specifically how much time is devoted to IPM IL activities. Results show that about 42% of collaborators spend all/almost all of their time on IPM IL activities (20%) or a significant amount of their time on IPM IL activities (22%). About 26% spend an average amount of their time on IPM IL activities, while 26% spend some time on IPM IL. Only about 6% of collaborators spend not much

or no time working on the IPM IL. These results suggest that many collaborators spend a substantial amount of time on IPM IL activities.

Figure A.3.9: How much time do you allocate specifically to IPM IL experiments, studies, extension, scale-up or other activities on an annual basis (% of your total professional time)?

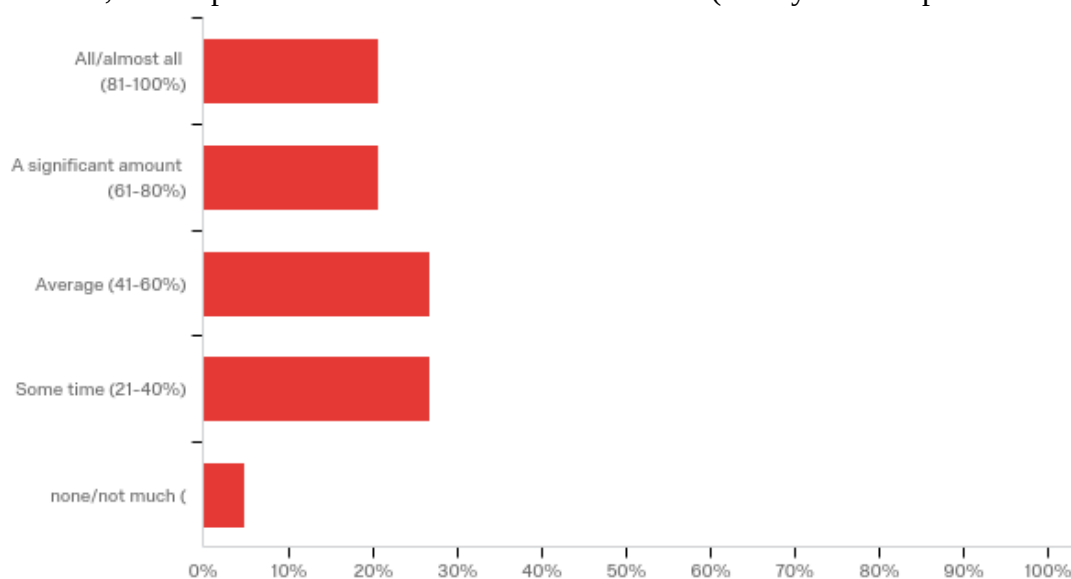
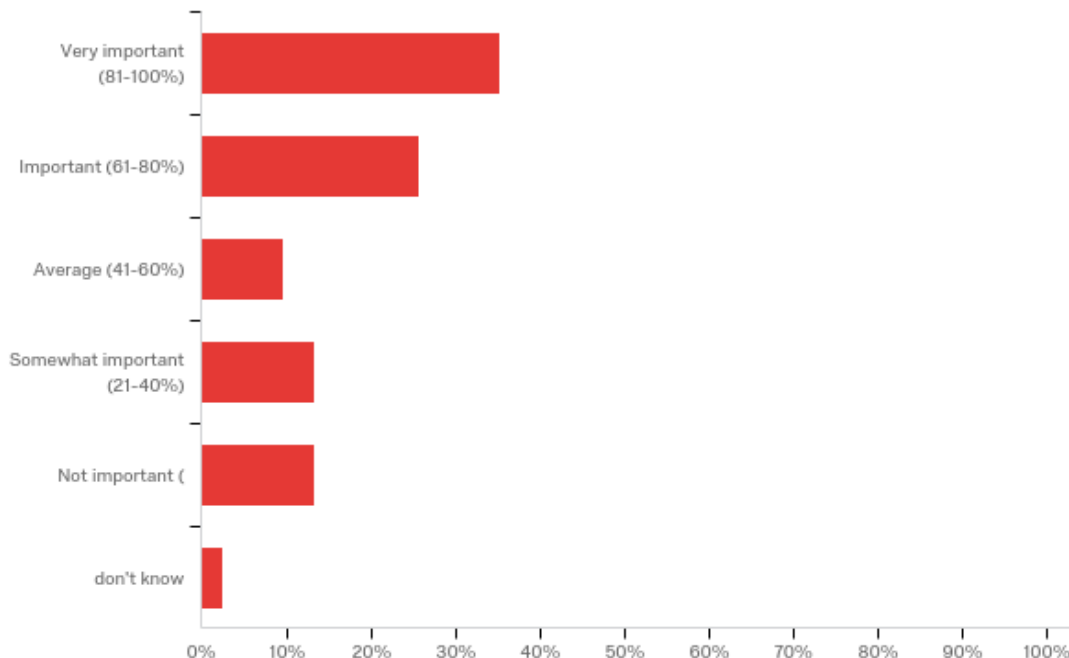


Figure A.3.10 presents results on the importance of the IPM IL's financial contribution to collaborators' research and extension programs. These results indicate that nearly 60% of collaborators say that IPM IL funds are very important (35%) or important (25%) to their research programs. About 12% say that IPM IL funding is of average importance while 13% say it is somewhat important. Only about 13% say IPM IL funding is not important to their research. **The findings indicate that collaborators rely significantly on IPM IL resources to conduct their research and extension programs and therefore, cutting funding and/or delaying funding would have detrimental effects on their programs.**

A.3.10: How important is the financial contribution from IPM IL to your experiments, studies and

activities? In other words, what percentage of your research budget is funded by IPM IL (% of your total working budget)?



Collaborator survey responses to participation in IPM IL

Collaborators were asked questions in the survey about how engaged they are in setting research objectives of the project. Results suggest that 64% of respondents feel that they were extremely well engaged (27%) or very well engaged (37%) with setting research objectives on the project. About 22% said that they were moderately well engaged and 11% said that they were slightly well engaged. Only 2.5% said that they were not engaged at all.

Collaborators had specific comments on their engagement in research participation. These comments suggest that some collaborators feel the need to be more engaged in the research objectives and would appreciate more support from the ME in this regard. **The overall assessment is that most collaborators are involved with research priority setting but some feel they could have been included to a larger degree.** The survey also asked collaborators how they feel about their role in writing and being involved in research reports and publications. Results suggest that 85% of collaborators feel that they have some role in the research generated by the project.

About 13% feel that they initiate the research, 30% feel that they share in the research and 42% feel that they contribute to the research in some way. **However, increasing the research leadership of scientists in host countries is extremely important.**

Collaborator responses to short-term/extension training on the project

The IPM IL collaborator survey asked a series of questions about how they viewed short-term/extension training in their individual programs and the IPM IL project as a whole. Figure A.3.11 assesses how well collaborators feel that short-term/extension of IPM technologies and practices is integrated into their program. Results suggest about 15% of respondents feel that it is extremely well integrated, 42% feel that it is very well integrated, and 28% feel it is moderately well integrated. Only 5% feel it is just slightly well integrated with 2% feel it is not integrated at all.

Figure A.3.11: How well is short-term/extension training of IPM technologies and practices integrated into your IPM IL program?

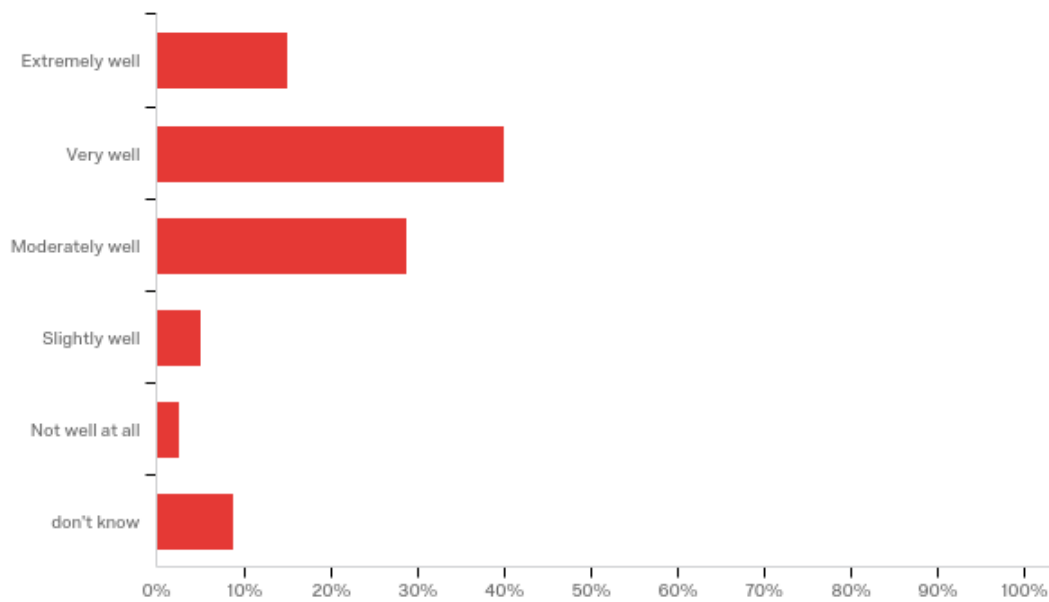
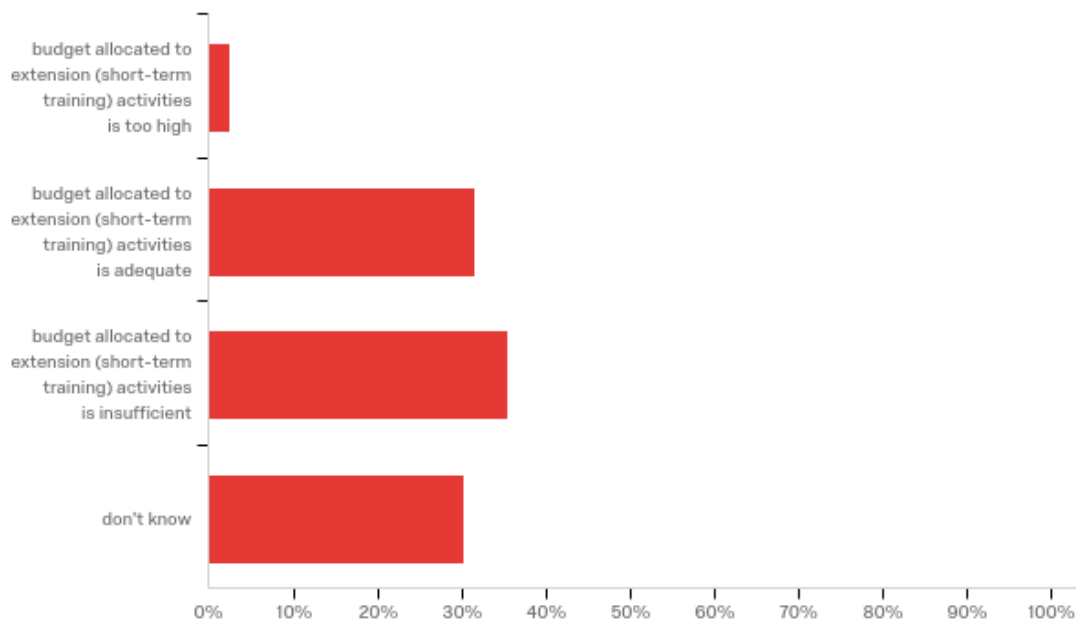


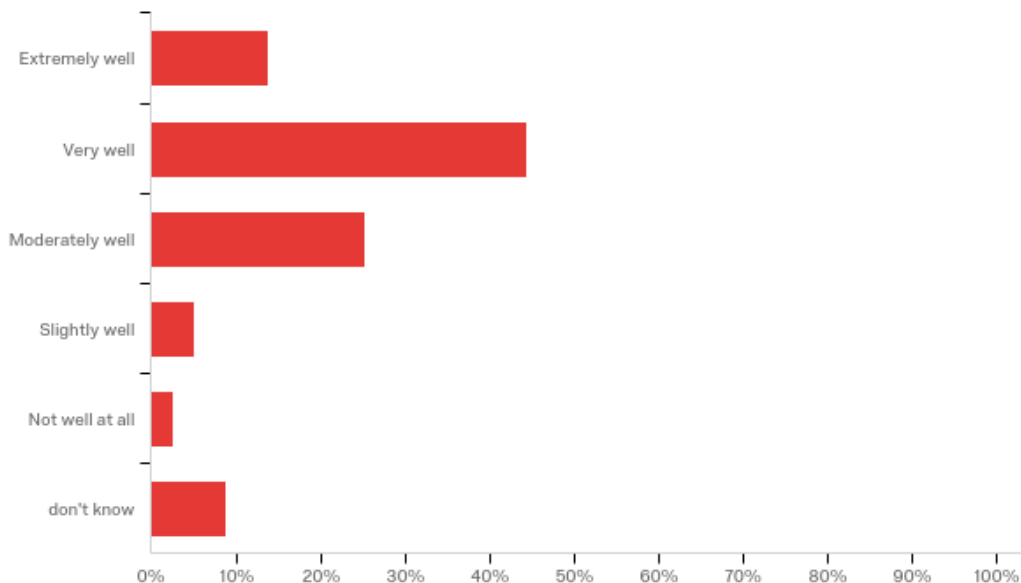
Figure A.3.12 suggest that 31% of respondents feel that the budget allocated to short-term/extension training is adequate, but 36% believe it is insufficient. This highlights the need to continue focusing and increasing budget on extension and short-term training for farmers, extension workers and other stakeholders in host countries.

Figure A.3.12: How adequate is the budget allocated to short-term/extension training of IPM technologies and practices in your IPM IL program?



Nearly 58% of collaborators believe that the short-term/extension components of the project have had an impact on the production practices of farmers (Figure A.3.13). Of this, 14% believe that it has worked extremely well, while 44% believe it has worked very well. About 26% say it has only worked moderately well, while 5% say it worked slightly well and 2% say it has not worked well at all.

Figure A.3.13: How well has the extension (short-term training) component of your IPM IL program reached, educated and improved production practices of farmers?



In addition, collaborators had specific comments on short-term/extension training of IPM technologies and practices. These comments indicate that there is strong consensus that short-term training and extension is crucial for the project. There is also a thread in the comments that there needs to be more attention and resources given to it. **In addition, there has been some success using WhatsApp to share information, but the project should look to use Information Communication Technology (ICT) to increase the reach of IPM technologies and practices in a broader and more cost-effective manner in the future. Continued emphasis on extension and dissemination of IPM technologies and practices is needed in the future.**

Collaborator responses to long-term training on the project

The IPM IL collaborator survey asked a series of questions about how they viewed *long* -term training in their individual programs and the IPM IL project as a whole. Figure A.3.14 assesses how well collaborators feel that long-term of IPM technologies and practices is integrated into their program. Results suggest that most people feel that long-term training is integrated into the project. Twenty percent of respondents feel that long-term training is extremely well integrated, 37% feel it is very well integrated, and 17% feel it is moderately well integrated. Only 5% feel it

is slightly well integrated and 5% feel it is not integrated at all.

Figure A.3.14: How well is long-term training of IPM technologies and practices integrated into your IPM IL program?

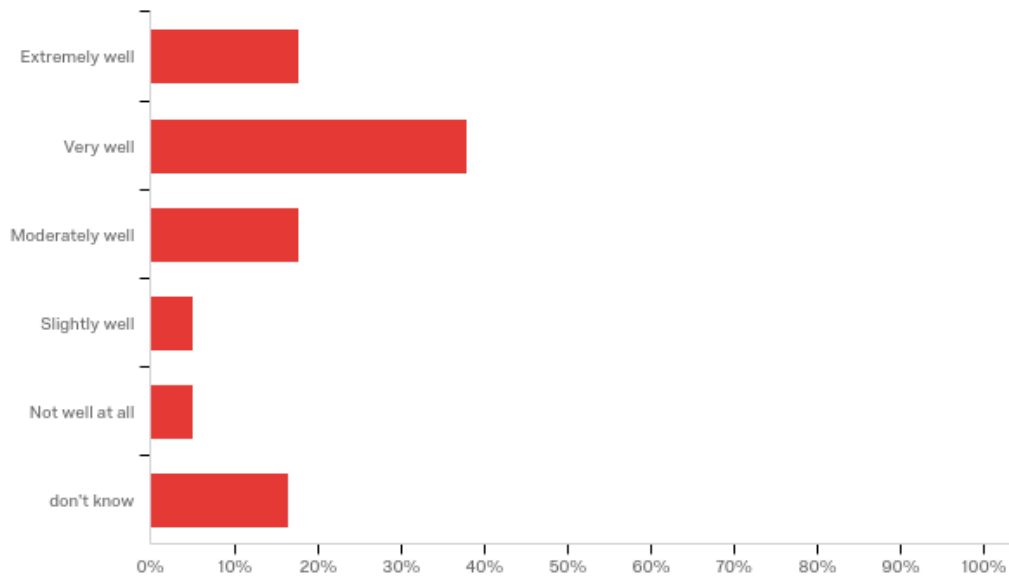
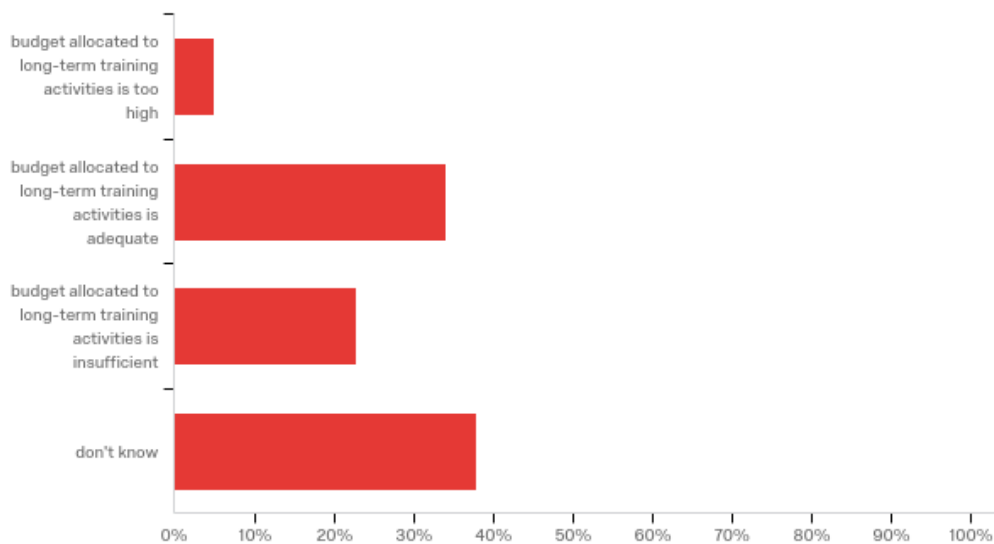


Figure A.3.15 suggest that 35% of collaborators feel the budget allocated to long-term training is adequate, while 24% feel it is insufficient. Just 5% feel it is too high and 37% do not know.

Figure A.3.15: How adequate is the budget allocated to long-term training of IPM technologies and practices in your IPM IL program?



Collaborators had specific comments on *long*-term training of IPM technologies and practices. These comments indicate that there is a clear desire for more long-term training on the IPM IL. This is likely reflective of the fact that collaborators want themselves and their colleagues to have the opportunity to enhance their education and subsequent advantages it provides.

IPM IL Collaborator views on scale-up and commercialization

The IPM IL collaborator survey asked a series of questions about how members of the project viewed scale-up and commercialization of IPM technologies and practices in their individual programs and the IPM IL project as a whole. Figure A.3.16 assesses how well collaborators feel that scale-up/commercialization of IPM technologies and practices is integrated into their program. Results suggest that the most common response is that it is moderately well integrated into their program (30%). The second most common answer is that it is very well integrated (25%). About 17% say that it is extremely well integrated, while 9% say it is slightly integrated and 6% say it is not well integrated at all.

Figure A.3.16: How well is scale-up / commercialization of IPM technologies and practices integrated into your IPM IL program?

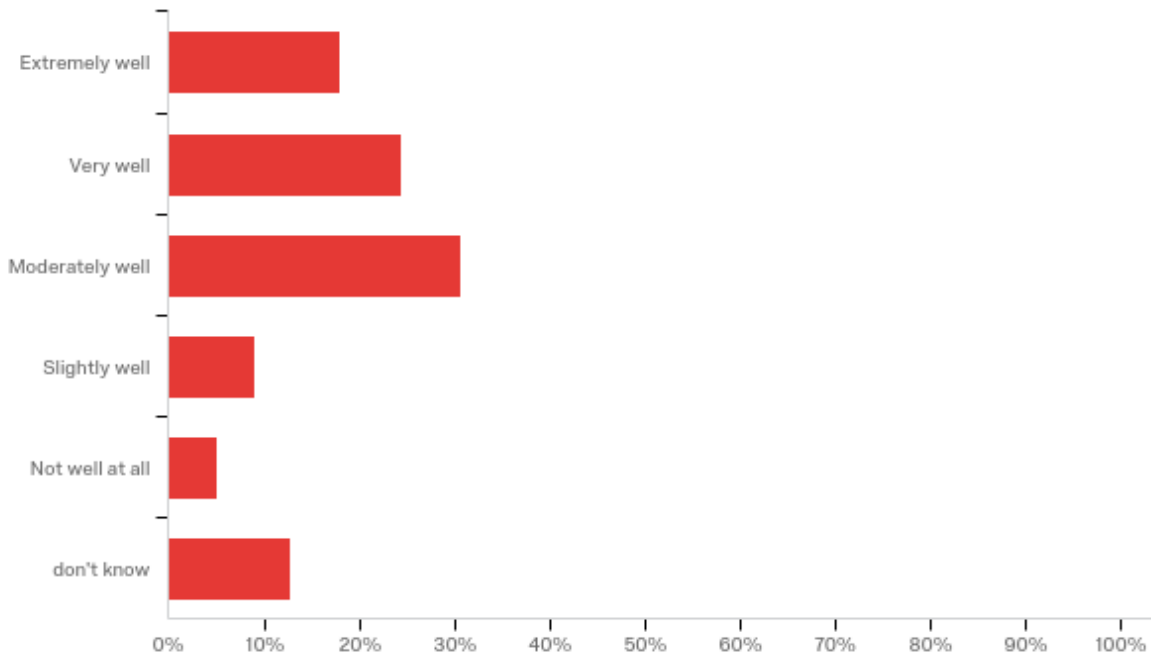
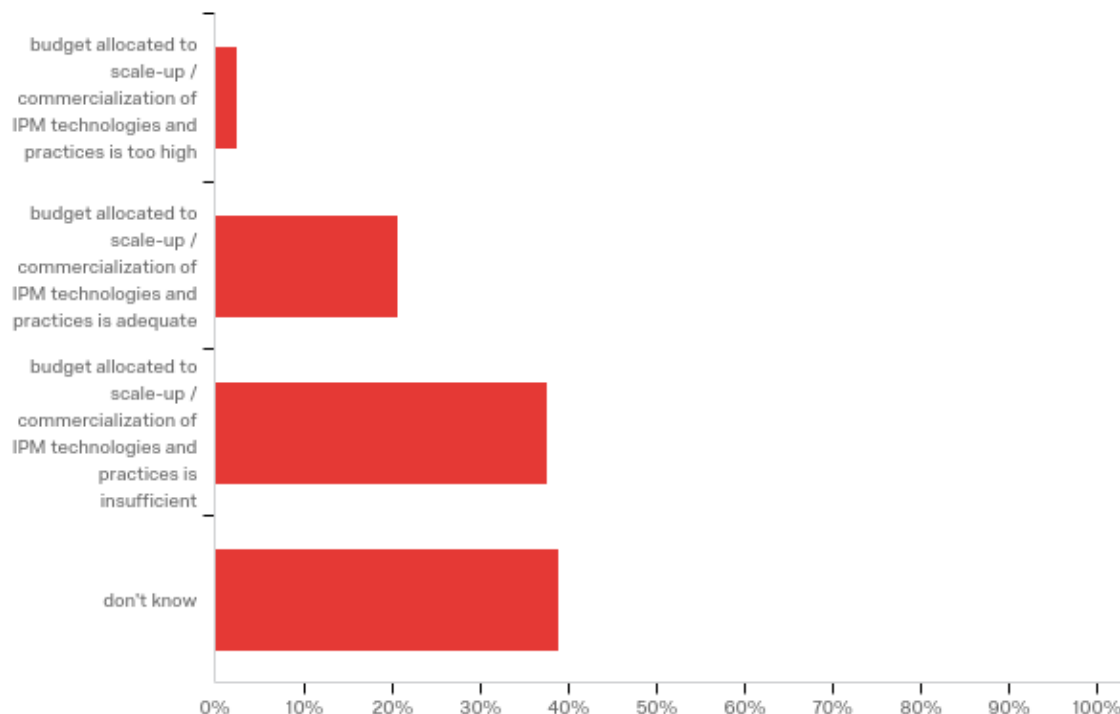


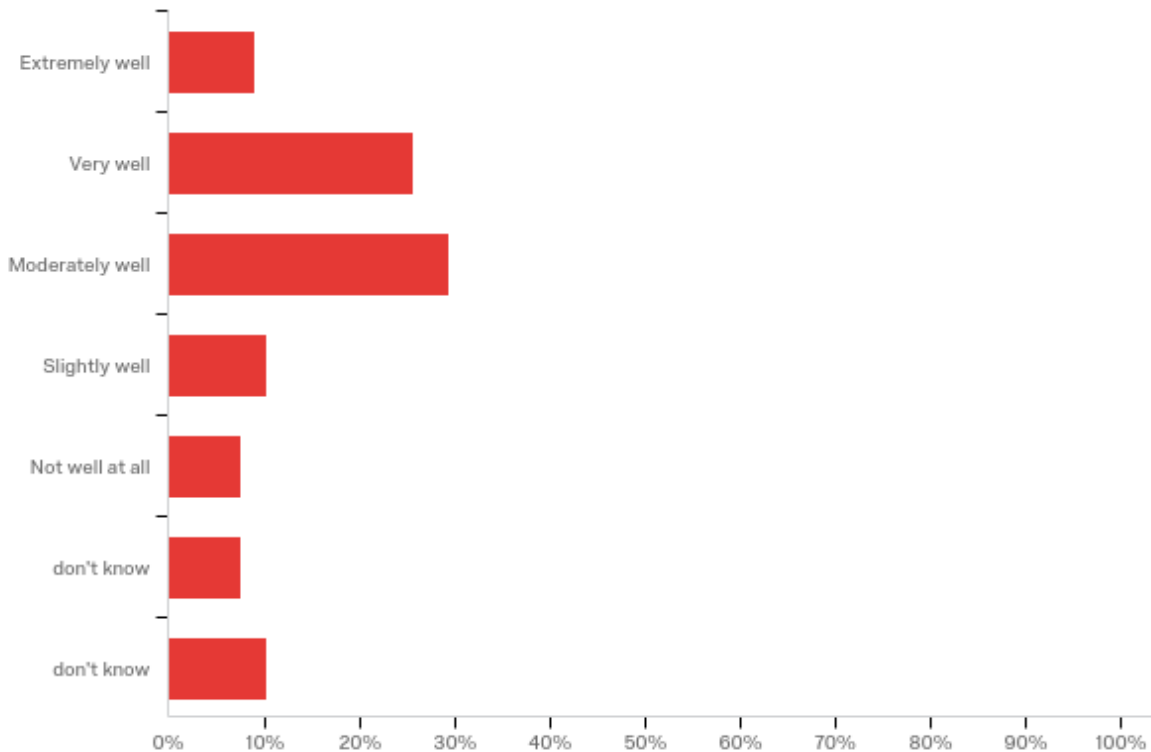
Figure A.3.17 suggest that 38% feel that the budget allocated to scale-up and commercialization of IPM technologies is not adequate, while 20% feel it is adequate and 39% do not know. This suggests that there is a belief among a significant number of collaborators that more resources should go to this endeavor.

Figure A.3.17: How adequate is the budget allocated to scale-up / commercialization of IPM technologies and practices in your IPM IL program?



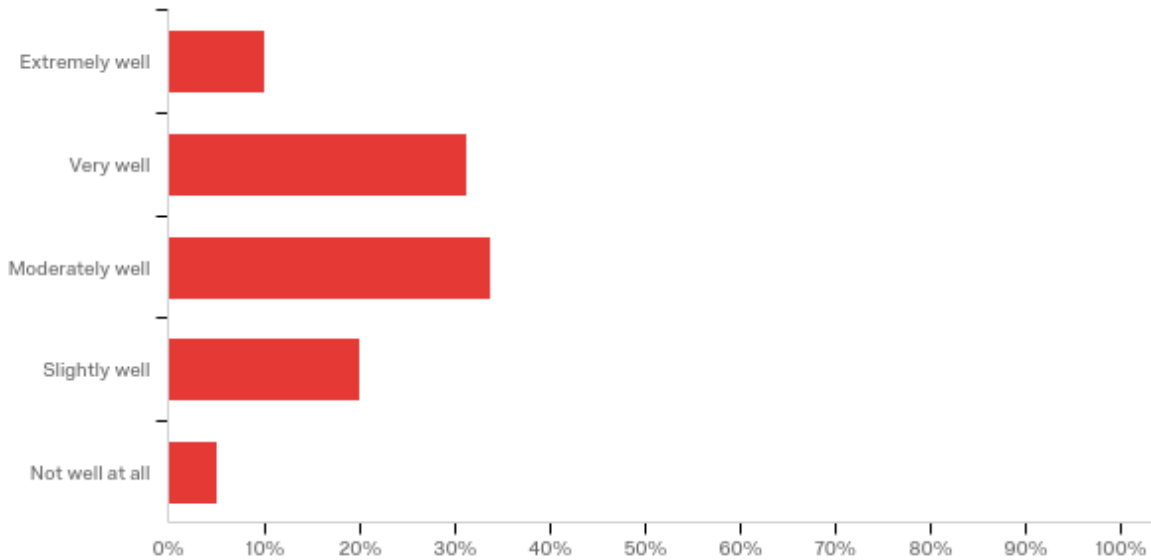
In order for scale-up and commercialization to occur, the private sector is an essential partner for selling and IPM technologies to farmers. Figure A.3.18 indicates collaborators' views on the level of engagement of private-sector partners in the IPM IL. The most common response is that the private sector is moderately well involved in their IPM program (29%). The second most common response was that the private sector is very well involved (25%). Nine percent say that the private sector is extremely well involved, and conversely, 10% say it is slightly well involved while another 10% say it is not involved at all.

Figure A.3.18: How well is the private sector engaged in your IPM IL program?



Local governments are another key partner for scale-up and long-term sustainability of the impacts on any project. Figure A.3.19 presents the collaborators' views on level of engagement with host country governments on the IPM IL. Nearly 40% say that local policy-makers are either extremely well engaged (10%) or very well engaged (30%). Conversely, 35% say that local policy makers are only moderately well involved, and 20% say that they are slightly well involved, while 5% say they are not involved at all.

Figure A.3.19: How well are policy-makers in host country governments engaged in your IPM IL program?



In addition, the IPM IL collaborators made the following specific recommendations about scaling-up and commercializing IPM technologies and practices. They suggest that scale-up does not receive as much attention as it possibly should on the project. Two of the programs are modeling based so do not directly have scale-up, but most of the others should consider scale-up and commercialization of IPM technologies and practices.

IPM IL Collaborator views on impact assessment

The IPM IL collaborator survey asked a series of questions about how they viewed impact assessment of IPM technologies and practices in their individual programs and the IPM IL project as a whole. Figure A.3.20 assesses how well collaborators feel that impact assessment is integrated into their program. Results suggest more than half of the participants (55%) of collaborators feel that impact assessment is either extremely well integrated or very well integrated into their program. About 28% say that it is moderately well integrated while 10% say it is only slightly well integrated. Only 1% say that impact assessment is not well integrated at all.

Figure A.3.20: How well is impact assessment integrated into your IPM IL program?

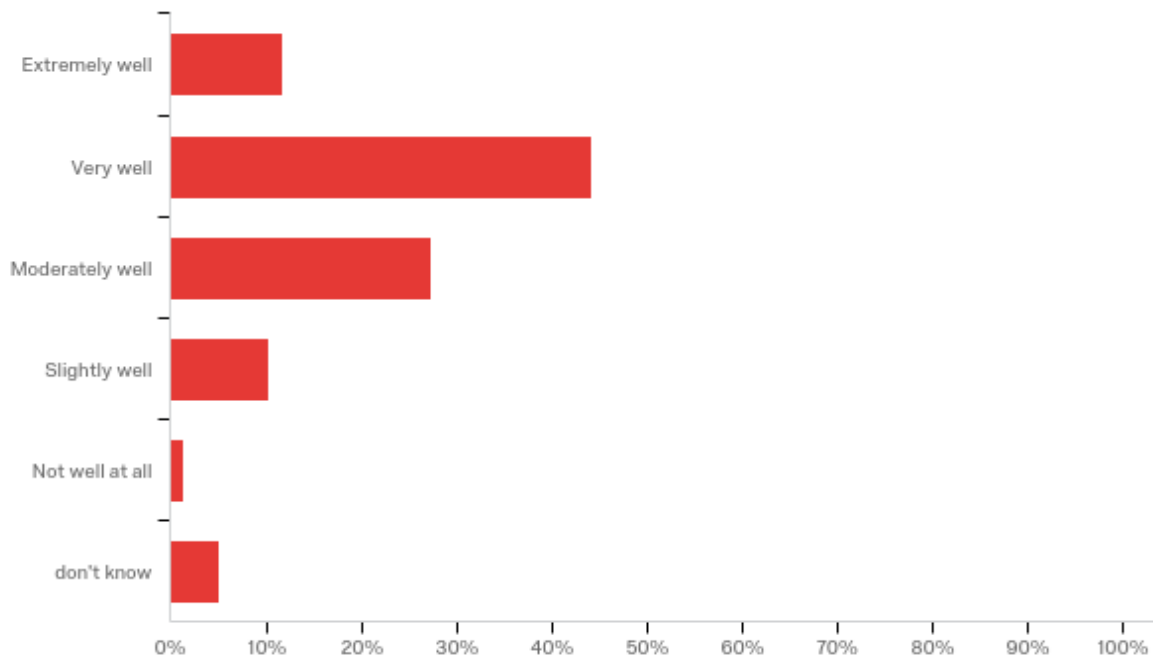
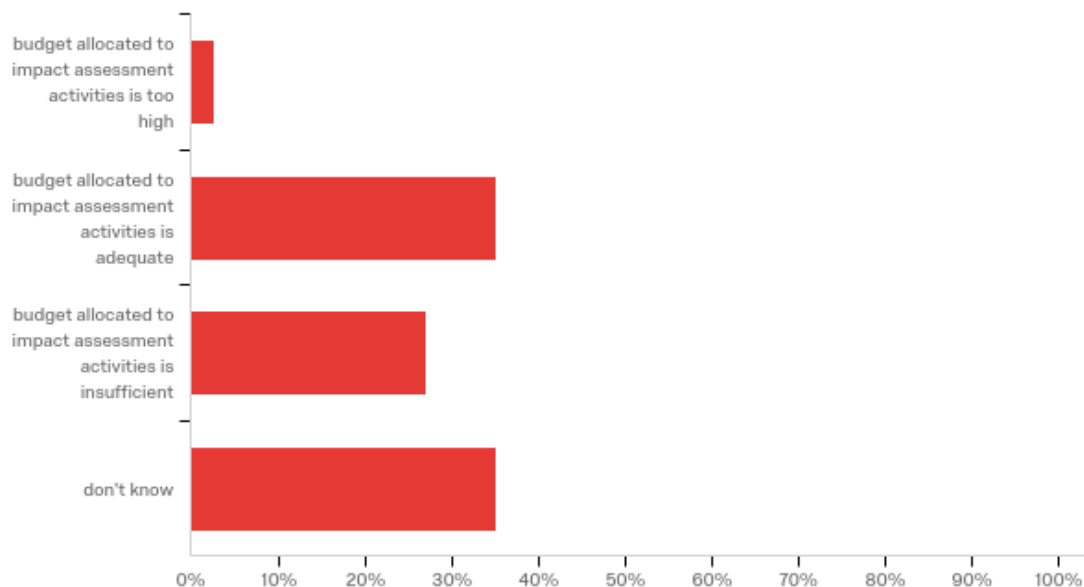


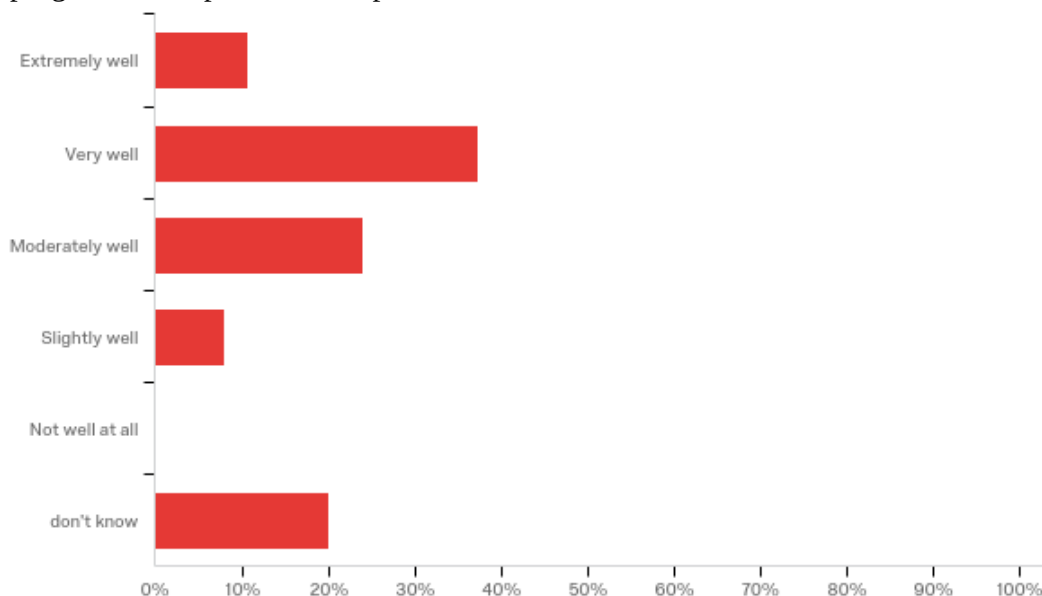
Figure A.3.21 suggests that the budget allocation for impact studies appear to be inadequate from survey participants point of view. **Therefore, the impact assessment needs to receive more attention moving forward.**

Figure A.3.21: How adequate is the budget allocated to impact assessment of IPM technologies and practices in your IPM IL program?



In principle, Impact assessment studies should add value to IPM IL program development and implementation. For example, help PI's make decisions about program modifications, and make recommendations to farmers and/or policy makers etc. Results from figure A.3.22 shows that nearly half of the participants agree that impact studies have done well.

Figure A.3.22: How well have the findings from impact assessment studies added value to your IPM IL program development and implementation?



In addition, IPM IL collaborators made the following specific recommendations about impact assessment of IPM technologies and practices. They suggest that some projects engage in impact assessment and others do not. Some feel that it is not well integrated and others feel it has added value. **It seems that some projects, such as vegetable IPM in Asia, have strong socio-economic component and do high quality impact assessment. Other projects lack such impact assessment. There should be some standardization of measuring impacts across the project. Regardless, impacts from the projects need to be highlighted more clearly.**

Collaborator survey responses to gender integration.

The IPM IL collaborator survey asked a series of questions about how they viewed gender integration in their individual programs and the IPM IL project as a whole. More than 90% feel that gender is well integrated in their IPM IL program (Figure A.3.23).

Figure A.3.23: How well is gender integrated into your IPM IL program?

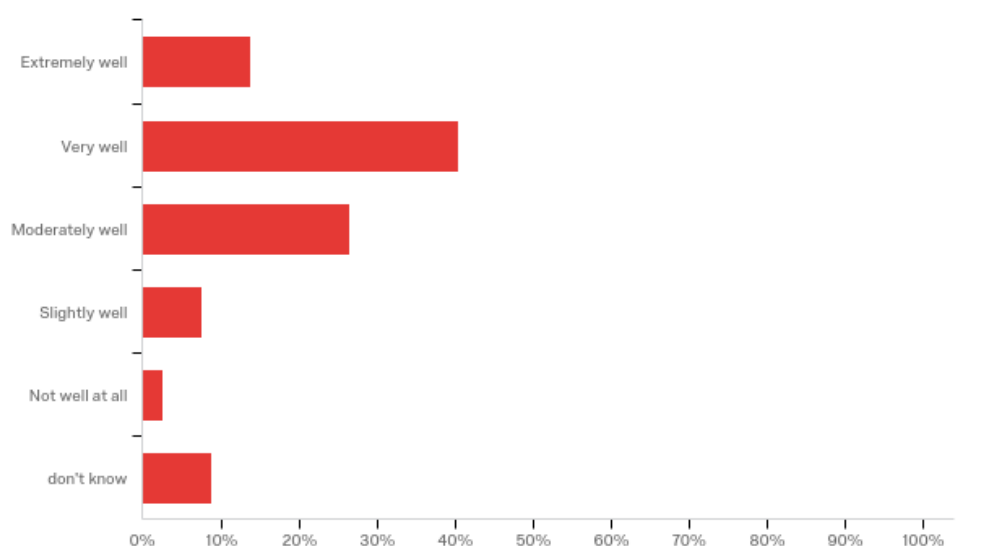
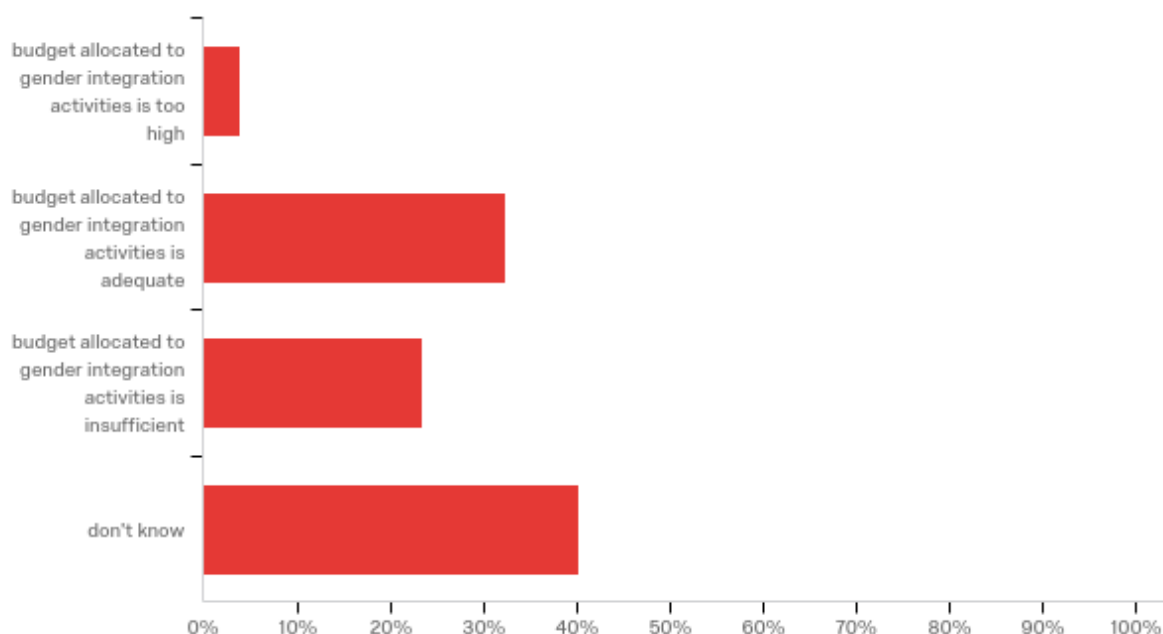


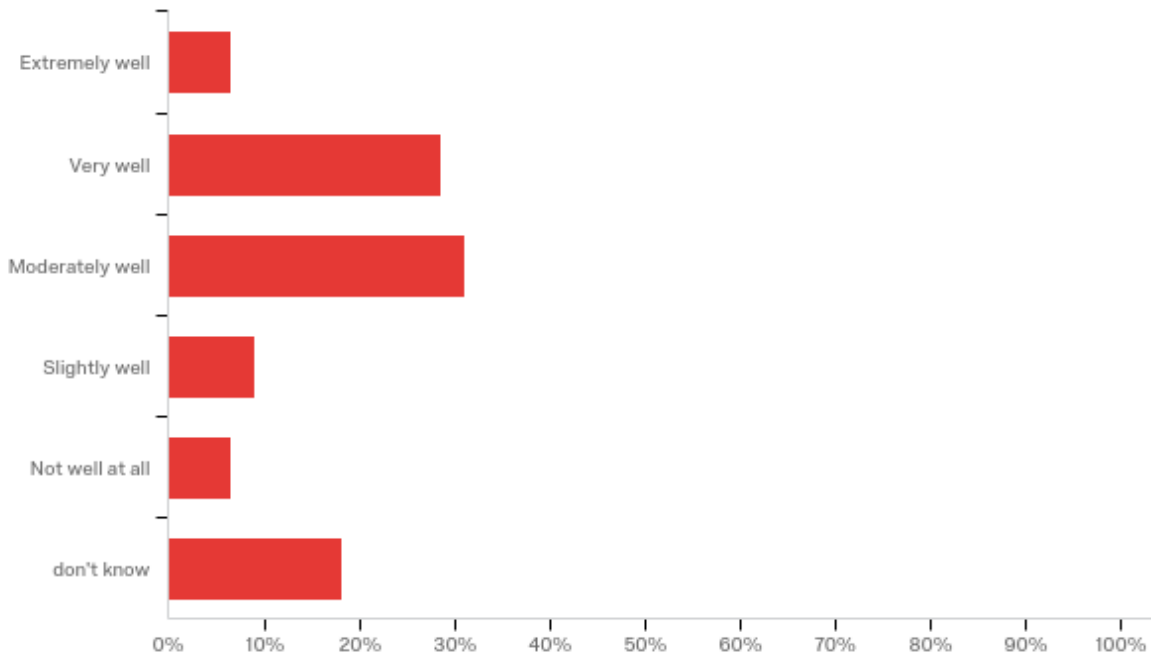
Figure A.3.24 suggests that 33% of collaborators feel that the budget for gender integration is adequate, while 23% feel that it is not adequate, and 41% do not know.

Figure A.3.24: How adequate is the budget allocated gender integration in your IPM IL program?



In principle, gender integration studies should add value to IPM IL program development and implementation. For example, to help us understand how households make decisions about technology adoption, labor allocation, food consumption etc. Results from Figure A.3.25 suggest that 31% of respondents feel that the gender integration studies have added moderate value to their program, while 29% feel that gender integration studies have done very well to add value and 8% feel that they have done extremely well. Conversely, 9% felt that gender integration studies have slightly added value and 6% feel they have not added value at all, while 18% do not know.

Figure A.3.25: How well have the findings from gender integration studies added value to your IPM IL program development and implementation?



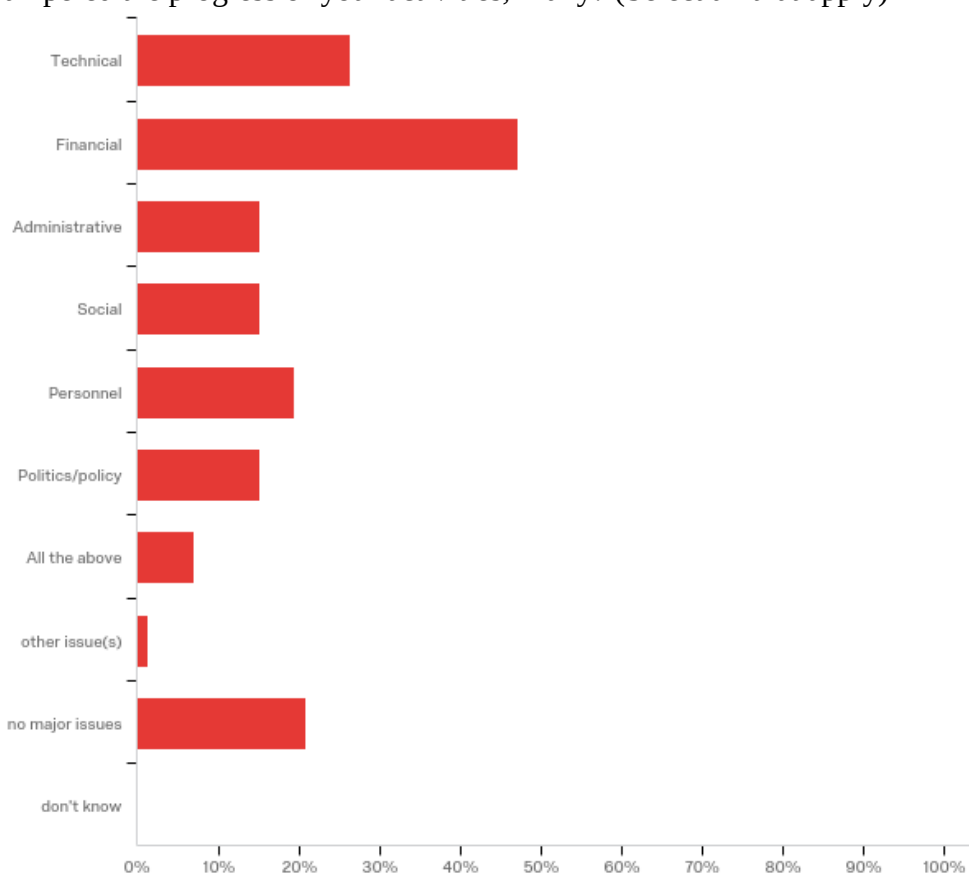
IPM IL collaborators made the following specific recommendations about gender integration. These comments suggest that women are involved with IPM training and vegetable and rice cultivation activities so there is integration in that aspect. There is some feeling that gender is given lip service but not really a focus. Many women are trained on the project with is a positive. **However, it is worth noting that many collaborators answered “don’t know” in response to the gender questions, suggesting that many collaborators are not engaged with it in their role on the program. It is also not clear what gender related studies have been published in the project, so moving forward gender should be more integrated across the project and gender differentiated impacts should be considered.**

Also, there should be some documentation about benefits to youth on the project. Can youth (and women) be involved in IPM technology scale-up?

Collaborator survey challenges and recommendations for future.

The IPM IL collaborator survey asked about major challenges they have encountered on the project. The major challenges that they encountered on the project were Financial (28%), followed by technical (15%) then personnel related (11%). Delays in funds coming from USAID and moving through the management entity to the sub-grantees is the main Issue (Figure A.3.26). It is worth noting that only 14% of collaborators state that they experienced no issues on the project.

Figure A.3.26: What are the major issues relating to the IPM IL that you encountered that hampered the progress of your activities, if any? (Select all that apply)



Appendix 4: IPM IL Publications provided by IPM IL ME to the External Evaluation Committee.

IPM Innovation Lab Publications: Phase V

Biological Control of the Invasive Weed <i>Parthenium hysterophorus</i> in East Africa	
Refereed Journal Articles	1. McConnachie, Andrew John. Host range tests cast doubt on the suitability of <i>Epiblema strenuana</i> as a biological control agent for <i>Parthenium hysterophorus</i> in Africa. <i>BioControl</i>. 2. McConnachie, Andrea John. Host range and risk assessment of <i>Zygogramma bicolorata</i>, a defoliating agent released in South Africa for the biocontrol of <i>Parthenium hysterophorus</i>. <i>Biocontrol Science and Technology</i>. 3. Mersie, Wondi, Alemayehu, Lidya, Strathie, Lorraine, McConnachie, Andrea, Terefe, Shitaye, Negeri, Mulugeta, Zewdie, Kassahun. Host range evaluation of the leaf-feeding beetle, <i>Zygogramma bicolorata</i> and the stem-boring weevil, <i>Listronotus setosipennis</i> demonstrates their suitability for biological control of the invasive weed, <i>Parthenium hysterophorus</i>. <i>Biocontrol Science and Technology</i>. 4. Mersie, W., Alemayehu, L., Strathie, L., McConnachie, A., Terefe, S. and Negeri, M. Host range evaluation of the leaf-feeding beetle, <i>Zygogramma bicolorata</i> and the stem-boring weevil, <i>Listronotus setosipennis</i> demonstrates their suitability for biological control of the invasive weed, <i>Parthenium hysterophorus</i> in Ethiopia. Submitted to <i>Biocontrol, Science and Technology</i> in 2018. \ 5. Dhileepan, K., McFadyen, R., Strathie, L. and Khan, N. 7. Biological Control. In: Editors S. Adkins. K. Dhileepan, A. Shabbir. <i>Parthenium Weed: Biology, Ecology and Management</i>. CABI Invasives Series. In press. 6. 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. <i>Parthenium Weed: Biology, Ecology and Management</i>. CABI Invasives Series. In press 7. Chidawanyika, F., Nyamukondiwa, C., Strathie, L., Fischer, K. 2017. Effects of Thermal Regimes, Starvation and Age on Heat Tolerance of the <i>Parthenium</i> beetle <i>Zygogramma bicolorata</i> (Coleoptera: Chrysomelidae) following Dynamic and Static Protocols. <i>PLoS ONE</i>12(1): e0169371.doi:10.1371/journal.pone.0169371
Other Journal Articles	1. Wondi Mersie, Lidya Alemayehu. Helping Workitu Eirgu and Other Rural Women in Ethiopia Tackle the Scourge of the Invasive Weed <i>Parthenium</i>. 2. Mersie, W. 2016. <i>Zygogramma bicolorata</i>, a biocontrol agent, established on <i>Parthenium</i> in Ethiopia. <i>Global Plant Protection News</i>. The International Association for the Plant Protection Sciences (IPPAS).
Conference Papers	1. Assema, B. (2017). Gauging women's interest and ability to participate in the adoption of biocontrol agents for control of <i>Parthenium</i> infestation in Tullo district, West Haraghe zone, Oromia regional state, Ethiopia. (Thesis Submitted for Master of Science Degree). Haramaya University, Haramaya, ET, June 2017.

	2. Alemayehu, Lidya and Mersie, W. 2018. Host specificity of the stem-boring weevil, <i>Listronotus setosipennis</i> (Hustache). Poster - Session 2-p6. XV International Symposium on Biological Control of Weeds. August 26-31, 2018. Engelberg, Switzerland. 3. Christie, M., Summer, 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. 4. Cowie, B., Venter, N., Strathie, L., Goodall, J., Witkowski, E. and Byrne, M. 2018. New insights and prospects into <i>Parthenium hysterophorus</i> biocontrol from South Africa. Poster - Session 2-p6. XV International Symposium on Biological Control of Weeds. August 26-31, 2018. Engelberg, Switzerland. 5. Gareeb, M., Strathie, L., Sambo, S. and Magoso, X. 2018. Techniques to rear three insect agents for the biological control of <i>Parthenium hysterophorus</i> in South Africa. 1st International Conference on Biological Control. Approaches and Applications. p. 208. September 27-29, 2018, Bengaluru, India. 6. Mersie, W. 2018. Host range evaluation of the leaf-feeding beetle <i>Zygogramma bicolorata</i> and the stem-boring weevil, <i>Listronotus setosipennis</i> demonstrates their suitability for biological control of the invasive weed <i>Parthenium hysterophorus</i> in Ethiopia. 1st International Conference on Biological Control. Approaches and Applications. p. 198. September 27-29, 2018. Bengaluru, India. 7. Molo, R., Winnifred, A., Strathie, L. and Mersie, W. 2018. Distribution and current efforts in biological control of <i>Parthenium hysterophorus</i> in Uganda: 1st International Conference on Biological Control. Approaches and Applications. p. 207. September 27-29, 2018. Bengaluru, India. 8. 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 <i>Parthenium hysterophorus</i> in South Africa. 1st International Conference on Biological Control. Approaches and Applications. p. 204. Bengaluru, India. September 27-29, 2018. 9. 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 <i>Parthenium hysterophorus</i> in South Africa. Poster - Session 9-P24. XV International Symposium on Biological Control of Weeds. August 26-31, 2018. Engelberg, Switzerland. 10. Assema, B., D. Kifle, L. Nigatu and M. Christie. <i>Gauging women's interest and ability to participate in the adoption of biocontrol agents for control of parthenium invasion in Tullo district, west Hararghe Zone, Oromia Regional State, Ethiopia</i>. Feed the Future: Innovation Lab for Integrated Pest Management Workshop on Management of Parthenium in East Africa, Addis Ababa, Ethiopia, 5 July 2017 11. Nigatu, L. and T. Tana. The impact of parthenium on the life of the Ethiopian farmers. Feed the Future: Innovation Lab for Integrated Pest
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Popular Articles	1. Biological Control of Parthenium (<i>Parthenium hysterophorus</i> L.) in Ethiopia. <i>IOBC Newsletter</i>. 12-1-18 2. Killer weed in East Africa no match for Virginia's land grant institutions. <i>Virginia Tech Magazine</i>. Spring 2018 3. Killer weed in East Africa no match for Virginia's land grant institutions. <i>Connected Africa</i>. 1-18-18 4. Killer weed in East Africa no match for Virginia land-grant institutions. <i>Augusta Free Press</i>. 1-20-18 5. Killer Weed in East Africa No Match for Virginia's Land-Grant Institutions. <i>CBS</i>. 1-18-18 6. An unexpected gift: IPM IL receives a grant from Haramaya University 7. Leveling the Playing Field in the Fight Against Parthenium 8. IPM Innovation Lab Awarded Ethiopian funding for Parthenium biocontrol. <i>International Association for the Plant Protection Sciences</i> 9. Gift from Ethiopian university helps combat crop-destroying weed. <i>Virginia Tech News</i>
Promotional Materials/Pamphlets	
Videos	1. Virginia Tech experts work to save Ethiopian farmlands 2. Taking Aim at a Bitter Weed
Posters/ Presentations	1. Christie, M.E., D. Sumner, L. Alemayhu, T. Amare, W. Mersie. (2018) Gender, household decision-making, and invasive pest management in a rural Ethiopian community. (Presentation) American Association of Geographers (AAG) Annual Meeting, New Orleans, LA, April 2018. 2. Sumner, D. (2017). Gender, Labor, and Livelihood: Invasive Pest Management in a Rural Ethiopian Community. (Presentation). Virginia Tech Women and Gender in International Development Discussion Series, Blacksburg VA, September 2017. 3. Abebe, M. 2015. Mass rearing of the biological control agent, <i>Zygogramma bicolorata</i> in Ethiopia. International Workshop on Biological Control of <i>Parthenium hysterophorus</i> in East Africa. Addis Ababa, Ethiopia, 13 December 2015. 4. Assefa, S. 2015. Parthenium distribution and socio economic impacts in Oromia. International Workshop on Biological Control of <i>Parthenium hysterophorus</i> in East Africa. Addis Ababa, Ethiopia, 13 December 2015. 5. Christie, E. 2015. Gender perspectives in the implementation of the Parthenium Project in East Africa. International Workshop on Biological Control of <i>Parthenium hysterophorus</i> in East Africa. Addis Ababa, Ethiopia, 13 December 2015.

	6. Mersie, W. 2015. Biological control of the invasive weed <i>Parthenium hysterophorus</i> in East Africa. International Workshop on Biological Control of <i>Parthenium hysterophorus</i> in East Africa. Addis Ababa, Ethiopia, 13 December 2015. 7. Mersie, W. 2015. Scaling-up the rearing and release of <i>Zygogramma bicolorata</i> and <i>Listronotus setosipennis</i> in <i>Parthenium</i>-infested areas of Ethiopia and Tanzania. International Workshop on Biological Control of <i>Parthenium hysterophorus</i> in East Africa. Addis Ababa, Ethiopia, 13 December 2015. 8. Muniappan, R. 2015. OIRED Overview. International Workshop on Biological Control of <i>Parthenium hysterophorus</i> in East Africa. Addis Ababa, Ethiopia, 13 December 2015. 9. Nigatu, L. 2015. The Impact of <i>Parthenium</i> on the Life of the Ethiopian Farmers. International Workshop on Biological Control of <i>Parthenium hysterophorus</i> in East Africa. Addis Ababa, Ethiopia, 13 December 2015. 10. Yitaferu, B. 2015. Brief overview of the Amhara National Regional State and the Amhara Agricultural Research Institute. International Workshop on Biological Control of <i>Parthenium hysterophorus</i> in East Africa. Addis Ababa, Ethiopia, 13 December 2015.
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Vegetable Crops IPM in East Africa	
Refereed Journal Articles	1. Coyne, D. L., L. Cortada, J. J. Dalzell, A. O. Claudius-Cole, S. Haukeland, N. Luambano, and H. Talwana. 2018. Plant-Parasitic Nematodes and Food Security in Sub-Saharan Africa, pp. 381-403. In J. E. Leach and S. E. Lindow (eds.), Annual Review of Phytopathology, Vol 56, vol. 56. 2. Kanyagha, H., F. Rotondo, A. L. Testen, and S. A. Miller. 2018. Survey and characterization of <i>Ralstonia solanacearum</i> in solanaceous crops in Tanzania. <i>Phytopathology</i> 108: 128-128. 3. Murunde, R., H. Wainwright. Miller. 2018. Bio-priming to improve the seed germination, emergence and seedling growth of kale, carrot and onions. <i>Global Journal of Agricultural Research</i>. 6: 26-34. 4. Testen, A. L., F. Baysal-Gurel, D. P. Mamiro, and S. A. Miller. 2015. First Report of Tomato Big Bud Caused by a 16SrII-C Phytoplasma in Tanzania. <i>Plant Disease</i> 99: 1854-1854. 5. Testen, A.L., Chala, A., Azerefegne, F. and Miller, S.A. 201x. First report of corky root rot of tomato caused by <i>Pyrenochaeta lycopersici</i> in Africa. <i>Plant Disease</i> (accepted).
Other Journal Articles	1. Coyne, D. L., J. M. Nicol, and B. Claudius-Cole. 2018. Practical plant nematology: A field and laboratory guide. 3rd edition. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 2. Kanyagha, H., Rotondo, F., Testen, A.L. and Miller, S.A. 2018. Survey and characterization of <i>Ralstonia solanacearum</i> in solanaceous crops in Tanzania. <i>Phytopathology</i> 108: S1.128.

	3. Testen, A.L. and Miller, S.A. 2016. Think locally, act globally: Meeting stakeholders' needs in developing countries. <i>Phytopathology</i> 106: S4.178.
Conference Papers	1. Miller, S. A. 2015. Biology and management of bacterial diseases of Solanaceous vegetables. Proceedings, INIAP First International Symposium on Integrated Pest Management of the Solanaceae: Knowledge for Healthy Food Production. Quito, Ecuador, October 7-8, 2015. 2. Ignatius S., Mwangi F. M., Mbaka J. 2015. Evaluation of grafting technology for management of bacterial wilt of tomato. 15th Workshop on Sustainable Horticultural Production in The Tropics: Strengthening the Experimental Research Environment – Field Experimentation. (Kalro), Kandara, Muranga County - Kenya, December 1-4, 2015. 3. Mbaka J., Waiganjo M. M., Amata R., Wepukhulu S. B., Kuria S., Gitonga J., Erbaugh M., and Miller S. 2015. Evaluation of onion accessions on bulb quality, yield and pest resistance. 15th Workshop on Sustainable Horticultural Production in The Tropics: Strengthening the Experimental Research Environment – Field Experimentation. (Kalro), Kandara, Muranga County - Kenya, December 1-4, 2015. 4. Njenga J. K., Gathungu G. K. and Mbaka J. N. 2018. Evaluation of plant extracts on egg hatching and juvenile mortality of French bean root-knot nematodes. 18th Workshop on Sustainable Horticultural Production in The Tropics: Strengthening Theoretical Research Methods - Systems Analysis. (Kalro), Kandara, Muranga County - Kenya, November 26-30, 2018. 5. Ngugi C. N., Haukeland S., Wachira P. M., Mbaka J. N., Sheila O., and Mburu H. M. 2018. Molecular characterization of entomopathogenic nematodes from Kenya. 18th Workshop on Sustainable Horticultural Production in The Tropics: Strengthening Theoretical Research Methods - Systems Analysis. (Kalro), Kandara, Muranga County - Kenya, November 26-30, 2018.
Popular Articles	1. Virginia Tech-led training creates greater crop yields in East Africa. <i>VT News</i> 2. Wainwright, H. 2018. Large-scale controlled environment agriculture globally, and its potential for Africa. <i>Agriculture for Development</i>, 34: 24-27. 3. Wainwright, H. 2018. Going vertical in Kenya. <i>Agriculture for Development</i>, 34: 34-35.
Promotional Materials/Pamphlets	1. Sseruwagi, P., J. Ndunguru. 2017. Major viral diseases of tomato and their management in Tanzania. Mikocheni Agricultural Research Institute (MARI). 2. Sseruwagi, P., J. Ndunguru, M. Njelekela, D. Kalekayo, N. Nyiti. 2016. Summary report of survey of viral diseases affecting vegetables in Tanzania. Mikocheni Agricultural Research Institute (MARI).
Videos	

Posters/ Presentations	1. Sseruwagi Peter, Macfadyen Sarina, Boykin M. Laura, and Luis Canas. 2018. Why it is critical to understand the biology and ecology of Bemisia tabaci in smallholder farming systems. 3rd International Whitefly Symposium (IWS3), Perth, Western Australia, 16 to 19th September 2018. 2. Testen, A.L. and Miller, S.A. 2017. Think locally, act globally: Meeting stakeholders' needs in developing countries. Fieldside Manner Webinar Series, American Phytopathological Society. 3. Miller, S. A. 2017. Challenges and opportunities for capacity building and IPM implementation in developing economies. APS North Central Division Meeting, Champaign, IL, USA. June, 2017. 4. Canas L. A. 2016. Insect pest and vector identification. Presented at Workshop on Diagnosis of Diseases and Identification of Insect Pests and Vectors in Vegetable Crops, Dar es Salaam, Tanzania, August 22-25, 2016. 5. Canas L. A. 2016. Internet resources for vector identification. Presented at Workshop on Diagnosis of Diseases and Identification of Insect Pests and Vectors in Vegetable Crops, Dar es Salaam, Tanzania, August 22-25, 2016. 6. Canas L. A. 2016. Using social media to share findings and ask questions. Presented at Workshop on Diagnosis of Diseases and Identification of Insect Pests and Vectors in Vegetable Crops, Dar es Salaam, Tanzania, August 22-25, 2016. 7. Canas L. A., A. L. Testen, P. Sseruwagi, F. Azerefegne, P. Mathenge, R. Murunde. 2018. How to put all together – IPM packages and examples to use to manage pests. Successful control stories. Presented at Integrated Pest Management Workshop: “From diagnosis to control: practical information to diagnose and manage key pests of vegetable crops”, Hawassa, Ethiopia April 19-21, 2018. 8. Canas L. A. 2018. Insect pest, vector identification and integrated pest management. Presented at Integrated Pest Management Workshop: “From diagnosis to control: practical information to diagnose and manage key pests of vegetable crops”, Hawassa, Ethiopia April 19-21, 2018. 9. Canas L. A., and P. Mathenge. 2018. Examples of use of IPM packages: Tomato IPM package and management of insect pests. Presented at Integrated Pest Management Workshop: “From diagnosis to control: practical information to diagnose and manage key pests of vegetable crops”, Hawassa, Ethiopia April 19-21, 2018. 10. Deogratus M. 2018. Sample collection, storage and molecular detection of plant viruses. Presented at Integrated Pest Management Workshop: “From diagnosis to control: practical information to diagnose and manage key pests of vegetable crops”, Hawassa, Ethiopia April 19-21, 2018. 11. Gilbertson R. L. 2016. Diagnosing virus diseases of vegetable crops symptoms, diagnostic methods, examples of important tomato viruses. Presented at Workshop on Diagnosis of Diseases and Identification of
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	21. Miller S. A. 2016. Diagnosing diseases of vegetable crops caused by bacteria and phytoplasmas. Presented at Workshop on Diagnosis of Diseases and Identification of Insect Pests and Vectors in Vegetable Crops, Dar es Salaam, Tanzania, August 22-25, 2016. 22. Miller S. A. 2016. Rapid serological tests. Presented at Workshop on Diagnosis of Diseases and Identification of Insect Pests and Vectors in Vegetable Crops, Dar es Salaam, Tanzania, August 22-25, 2016. 23. Mtui H. D. and E. R. Mgembe. 2017. Seedling Health Management. Presented at East African Vegetable Crops Integrated Pest Management - Innovation Lab Project Vegetable Seedling Health Management Workshop, Morogoro, Tanzania; February 14-16, 2017. 24. Ndunguru J., and Sseruwagi, P. 2016. Status of vegetable virus diseases, field symptoms, distribution, impact, associated vectors and their management in East Africa. Presented at Workshop on Diagnosis of Diseases and Identification of Insect Pests and Vectors in Vegetable Crops, Dar es Salaam, Tanzania, August 22-25, 2016. 25. Selamawit A., and D. Coyne. 2018. Nematodes affecting vegetable crops and their management. Presented at Integrated Pest Management Workshop: "From diagnosis to control: practical information to diagnose and manage key pests of vegetable crops", Hawassa, Ethiopia April 19-21, 2018. 26. Sibuga K. P. and D. Mamiro. 2017. Fundamentals of seedling production systems. Presented at East African Vegetable Crops Integrated Pest Management - Innovation Lab Project Vegetable Seedling Health Management Workshop, Morogoro, Tanzania; February 14-16, 2017. 27. Sseruwagi P. 2018. Status of vegetable virus diseases, field symptoms, distribution, impact, associated vectors and their management in East Africa. Presented at Integrated Pest Management Workshop: "From diagnosis to control: practical information to diagnose and manage key pests of vegetable crops", Hawassa, Ethiopia April 19-21, 2018. 28. Testen A. L. and Miller, S. A. 2017. Think locally, act globally: Meeting stakeholders' needs in developing countries. Fieldside Manner Webinar Series, American Phytopathological Society. 29. Testen A. L. and Miller, S.A. 2016. Think locally, act globally: meeting stakeholders' needs in developing countries. Presented at Annual Meeting of the American Phytopathological Society, Tampa, Florida, USA. July 2016. 30. Testen A. L. 2018. The disease diagnostic process, sampling, triage, imaging, resources. Presented at Integrated Pest Management Workshop: "From diagnosis to control: practical information to diagnose and manage key pests of vegetable crops", Hawassa, Ethiopia April 19-21, 2018. 31. Testen A. L. 2018. Common diseases of vegetable crops and recommendations for management. Presented at Integrated Pest Management Workshop: "From diagnosis to control: practical information to diagnose and manage key pests of vegetable crops", Hawassa, Ethiopia April 19-21, 2018.
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	32. Tibanyedera N., and G. Rwezaura. 2017. Seedling Irrigation. Fundamentals of seedling production systems. Presented at East African Vegetable Crops Integrated Pest Management - Innovation Lab Project Vegetable Seedling Health Management Workshop, Morogoro, Tanzania; February 14-16, 2017.
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Rice, Maize, and Chickpea IPM for East Africa	
Refereed Journal Articles	1. Fite Tarekegn, Tefera Tadele, Negeri Mulugeta, Damte Tebekew, Sori Waktole, Legesse, Hirpa. Farmers Status, Knowledge & Management Practices on Major Chickpea Insect Pests in Some Selected Zones of Ethiopia. <i>Journal of Agricultural Science</i>; 2019; Vol. 11 (1); p31-45. 2. Fite Tarekegn, Tefera Tadele, Negeri Mulugeta, Damte Tebekew, Sori Waktole. Management of <i>Helicoverpa armigera</i> (Lepidoptera: Noctuidae) by Nutritional Indices and Botanical Extracts of <i>Millettia feruginea</i> and <i>Azadirachta indica</i>. <i>Advances in Entomology</i>; 2018; Vol.6; p235-255. 3. Fite Tarekegn, Tefera Tadele, Negeri Mulugeta, Damte Tebekew, Sori Waktole. Comparative Performance of <i>Helicoverpa armigera</i> (Lepidoptera: Noctuidae) on Chickpea and Faba Bean. <i>International Journal of Biology</i>; 2019; Vol. 11 (1); p29-45. 4. Hashim Ibrahim, Mamiro Delphina P., Mabagala, Robert B., Tefera, Tadele. Smallholder Farmers' Knowledge, Perception, and Management of Rice Blast Disease in Upland Rice Production in Tanzania. <i>Journal of Agricultural Science</i>; 2018; Vol. 10(7); p137-145. 5. Hashim Ibrahim, Mamiro Delphina, Mabagala, Robert B., Tefera Tadele. In vitro and in vivo Evaluation of Microbial Agents for Management of Rice Blast Disease in Tanzania. <i>World Journal of Agricultural Sciences</i>; 2018; Vol. 14(4); p108-117. 6. January Bonaventure, Rwegasira Gration, Tefera Tadele. Lepidopteran Stem Borer Species Abundance and Associated Damages on Irrigated Kilombero Low Land Rice Ecosystem in Tanzania. <i>Journal of Entomology</i>; 2018; Vol. 15(1); p28-35. 7. January B., Rwegasira Gration M., Tefera Tadele. Farmers' Perceptions of Rice Production Constraints and Stem Borers Management Practices in Tanzania. <i>Journal of Agricultural Science</i>; 2018; Vol. 10(6); p57-71. 8. January B., Rwegasira G., Tefera T. Distribution of rice stem borers and their parasitoid in irrigated low land rice ecosystem in Kilombero valley, Morogoro, Tanzania. <i>Journal of Entomology and Zoology Studies</i>; 2018; Vol. 6(2); p237-242. 9. January B., Rwegasira Gration M., Tefera T. Efficacy of Selected Biopesticides and Botanical Extracts in Managing Rice Stem Borer, <i>Chilo partellus</i> (Swinhoe) (Lepidoptera: Crambidae) in Tanzania. <i>Journal of Agriculture and Ecology Research International</i>; 2018; Vol. 15(4); p1-16

	10. Sisay Birhanu, Tefera Tadele, Josephine Simiyu Malusi, Paddy L., Mendesil Esayas, Elibariki Nsami, Wakgari Mulatu, Ayalew Gashawbeza, Ayalew. First report of the fall armyworm, <i>Spodoptera frugiperda</i> (Lepidoptera: Noctuidae), natural enemies from Africa. <i>Journal of Applied Entomology</i>; 2018; Vol.142 (8); p800-804. 11. Kumela, T., Simiyu, J., Sisay B., Likhayo, P., Mendesil, E., Gohole, L., Tefera, T. Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (<i>Spodoptera frugiperda</i>) in Ethiopia and Kenya. <i>International Journal of Pest Management</i>; 2018.
Other Journal Articles	1. Tefera, Tadele and Desalegn Tadesse, eds. 2017. Working Document: Assessment of Pest Diagnostic Capacity in Plant Health Related Laboratories in Kenya. International Centre for Insect Physiology and Ecology (ICIPE) 2. Tefera, Tadele and Desalegn Tadesse, eds. 2017. Working Document: Assessment of Pest Diagnostic Capacity in Plant Health Related Laboratories for Maize and Rice in Tanzania. International Centre for Insect Physiology and Ecology (ICIPE). 3. Korir, J., G. Muricho, and M. Kassie. 2017. Farmers' Perceptions of Maize Stem Borer and Adoption of Integrated Pest Management Practices in Nakuru and Bomet Counties, Kenya. International Centre for Insect Physiology and Ecology (ICIPE). 4. Tefera Tadele and Tadesse Desalegne, eds. 2017. Assessment of Pest Diagnostics Capacity in Plant Health Related Laboratories in Ethiopia. International Centre for Insect Physiology and Ecology (ICIPE).
Conference Papers	1. T. Tefera. 2018. Developing IPM strategy for the invasive pest fall armyworm <i>Spodoptera frugiperda</i> in East Africa. Presented at International IPM symposium, Baltimore, Maryland, March 19-23. 2. T. Tefera. 2018. Biological control of fall armyworm: potential roles of predators and parasitoids, CIMMYT/USAID ToT, Nov 13-15, Addis Ababa. 3. T Tefera. 2018. Sex Pheromone monitoring of fall armyworm. UN/FAO ToT July 24, 2017, Addis Ababa. 4. T. Tefera. 2018. Grain Crops IPM for East Africa and fall armyworm Invasion. Harmony Hotel, July 14-15, Addis Ababa. 5. Kassie, Menale. Economic Analysis of FAW invasion in Africa: informing immediate and long-term action. Harmony Hotel, July 14-15, Addis Ababa. 6. G. Gezahegn. T. Tadele, Lemmessa, Fikre , Ahmed, Seid, Zewude, Asrat. Seed Quality and Mycoflora Associated with Chickpea (<i>Cicer arietinum</i> L.) Seed in Ethiopia. Chickpea Forum organized by ICRISAT (International Crops Research Institute for Semi-Arid Tropics) In collaboration with Ethiopian Institute of Agricultural Research (EIAR). Debrezeit / Dukem Lina Hote, May 10-11/2018.

	7. Kumela, Teshome. Farmers' Perception of Fall Armyworm, a case of Jima zone, Ethiopia. Harmony Hotel, July 14-15, Addis Ababa 8. Muniappan, R. Overview of Fall Armyworm, <i>Spodoptera frugiperda</i>. Harmony Hotel, July 14-15, Addis Ababa 9. Sisay, Birhanu. Evaluation of Different Management Options Against Fall Armyworm. Harmony Hotel, July 14-15, Addis Ababa 10. Simiyu, Josephine. Distribution and Biology of the Fall Armyworm in Kenya. Harmony Hotel, July 14-15, Addis Ababa 11. Hashim, I, Mamiro, D, Mabagala, R.B., Tefera, T. 2018. In vitro and in vivo evaluation of microbial agents for management of rice blast disease (<i>Pyricularia oryzae</i> Cav.) in Tanzania. International Congress of Plant Pathology (ICPP). Boston, Massachusetts.
Popular Articles	1. Not Just Maize: Africa's Fall Armyworm Crisis Threatens Sorghum, Other Crops, Too. <i>Prevention Web</i>. 11-21-18 2. Not Just Maize: Africa's Fall Armyworm Crisis Threatens Sorghum, Other Crops, Too. <i>Entomology Today</i>. 11-20-18 3. Training on <i>Trichoderma</i> and Plant Growth Promoting Rhizobacteria. <i>IAPPS</i>. 10-1-18 4. Virginia Tech researchers make small discovery that could keep millions from going hungry. <i>VT News</i>. 9-14-18 5. Fighting Nature with Nature: Scientists Mobilize Biological Control Against Devastating Fall Armyworm. <i>PreventionWeb</i>. 9-11-18 6. Fighting Nature with Nature: Scientists Mobilize Biological Control Against Devastating Fall Armyworm. <i>Entomology Today</i>. 9-11-18 7. Virginia Tech scientists rally international coalition to stop a pestilent 'army.' <i>Virginia Tech News</i>. 8. As corn pest ravages crops in Africa, Virginia Tech program leads the charge. <i>Virginia Tech News</i>. 9. <u>Push-Pull: One Simple Farming Technique Successfully Battles Africa's Key Agricultural Constraints</u> 10. <u>Push-Pull: for better future; Success stories of Push-Pull Maize IPM in Ethiopia, Kenya and Tanzania, 2017-by Desalegne Tadesse</u> 11. <u>Integrated management methods change the landscape of chickpea production in Ethiopia-blog story by Desalegne Tadesse; 2018.</u> 12. <u>icipe Push-Pull Technology in Ethiopia- icipe news, 2017.</u>

	13. Ethiopia: Maize farmers grow special plants to manage Fall armyworm- News, 2018-wire radio-Ethiopia 14. Maize pest meets its match in desmodium and napier grass- News-Kenya's nation, 2017.
Promotional Materials/Pamphlets	1. Push-Pull Technology Flyer 2. Push-Pull Technology Booklet 3. IPM Annual Review and Meeting Proceedings Booklet 4. IPM Brochure 5. Chickpea Flyer 6. Rice Flyer 7. Chickpea Banner 8. Maize Banner 9. Rice Banner 10. Trichoderma and Plant Growth Promoting Rhizobacteria Training Flyer 11. Proceedings of Farmer Field Day and Annual Review Meeting of Rice (July 2018) 12. Training Workshop on Indigenous Biological Control Agents of the Fall Armyworm: Techniques in field collection, mass rearing, and release 13. Stickers
Videos	1. Push-Pull Technology from pest control to livestock feed and natural resource management in Hawassa 2. The glories of Push-Pull Technology in Kericho-Kenya
Posters/ Presentations	1. Tefera, T. Rice, Maize & Chickpea IPM for East Africa: An overview of the project in the 3 countries. Annual Planning Meeting and external evaluation (July 2017 and 2018) 2. Tefera, T. Rice, Maize & Chickpea IPM for East Africa: Overview. Stakeholders meeting, Dar Es Selam, October 2017. 3. Kassie, Menale. The push-pull farming system in Kenya and Ethiopia: Implications for economic and social welfare. Annual Planning Meeting, Nairobi, July 24-27, 2018. 4. Kassie, Menale. Baseline survey results, Tanzania. Annual Planning Meeting, Nairobi, July 24-27, 2018. 5. Kassie, Menale. Gender and grain IPM project in number. Annual Planning Meeting, Nairobi, July 24-27, 2018.

	6. Kassie, Menale. Socioeconomic component: Key achievements. Annual Planning Meeting, and external evaluation (July 2017 and December 2018). 7. R. Muniappan. IPM Innovation Lab -An Overview. Annual Planning Meeting, Nairobi, July 24-27, 2018 8. R. Muniappan. Trichogramma and telenomus for management of Fall Armyworm and other Lepidopteran pests in East Africa. Annual Planning Meeting, Nairobi, July 24-27, 2018 9. Fayad, Amer. IPM Innovation Lab: Renewed Commitment to Africa and Asia. Annual Planning Meeting, Hawassa 17-19 July 2017. 10. Likhayo, Paddy. Promotion of Push - Pull Technology for the control of stem borers in Bomet, Kericho and Nakuru counties in Kenya. Annual Planning Meeting, (July 2017 and 2018). 11. Chuwa, Charles. 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, Tanzania. Annual Planning Meeting, (2017 and 2018). 12. Chuwa, Charles. Training: RICE DISEASES. For Extension officers and lead farmers, Mvomero-Tanzania, 12 June 2017 13. Sisay, Birhanu. Evaluation of Different Management Options against Fall armyworm, <i>Spodoptera frugiperda</i> (Lepidoptera: Noctuidae) and Assessment of Their Parasitoids Enemies in Some Parts of Ethiopia. Annual Planning Meeting (July 2017 and 2018). 14. Sisay, Birhanu Management of Maize Stem borers using Push- Pull technology in Hawassa, Ethiopia. Annual Planning Meeting, Nairobi, July 24-27, 2018 15. January, Bonaventure. Management options for rice stem borers in irrigated low land rice ecosystem in Tanzania. Annual Planning Meeting, Nairobi, July 24-27, 2018. 16. January, Bonaventure. Efficacy of different mycopesticides and botanical extracts in control of Rice stem borers in Irrigated low land rice ecosystem in Tanzania. Annual Planning Meeting, Hawassa 17-19 July 2017. 17. January, Bonaventure. Species abundance and damages associated with Lepidopteran stem borers in Irrigated low land rice Eco system in Tanzania. Stakeholders meeting. Dar Es Selam, 31st October 2017 18. Josphat Kiplang. Economics of Maize, Rice and Chickpea IPM in Kenya, Ethiopia and Tanzania PhD Presentation. Annual Planning Meeting, Hawassa 17-19 July 2017. 19. Kebede, Denberu. Pathogenecity of Maize endophytes and selected EPF isolates against the spotted stem borer <i>Chilo partellus</i>. Annual Planning Meeting, Nairobi, July 24-27, 2018.
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	20. Kebede, Denberu. Endophytes Associated with Maize and Pathogenicity of Selected Entomopathogenic Fungi against the Spotted Stem Borer <i>Chilopartellus</i>. Annual Planning Meeting, and external evaluation (2017 and 2018). 21. Kumela, Teshome. Farmers' Perception of Fall Armyworm, a case of Ethiopia. Annual Planning Meeting, Hawassa 17-19 July 2017. 22. Hashim, Ibrahim. Rice blast disease (<i>Pyricularia oryzae</i> Cav.) incidence, severity, genotype reaction and management in Tanzania. Annual Planning Meeting, Nairobi, July 24-27, 2018. 23. Hashim, Ibrahim. Evaluation of microbial-fungicides (<i>Trichoderma asperellum</i> and <i>Bacillus subtilis</i>) for the control of rice blast disease in Tanzania. Annual Planning Meeting, Hawassa 17-19 July 2017. 24. Getaneh, Gezahegne. Integrated Chickpea diseases management for <i>Fusarium</i> wilt and <i>Ascochyta</i> blight. Annual Planning Meeting, Nairobi, July 24-27, 2018. 25. Getaneh, Gezahegne. In vitro evaluation of bio-agents against chickpea <i>Fusarium</i> wilt disease. Annual Planning Meeting, Hawassa 17-19 July 2017. 26. Simiyu, Josephine. Distribution, Damage and Preliminary Biology of the Fall Armyworm in Kenya. Annual Planning Meeting, (July 2017 and 2018). 27. Elibariki, Nsami. MAIZE STEM BORERS AND STRIGA MANAGEMENT IN TANZANIA USING PUSH- PULL TECHNOLOGY. Annual Planning Meeting (2017 and 2018). 28. Elibariki, Nsami. Major maize pests and diseases in trial sites. Training on Integrated Management of Maize Stemborers and Striga weed using Push-Pull Technology 14th June 2017. 29. Muricho G., Kassie M., Diro G. and B. Muriithi . Impact of women empowerment and PPT adoption on women nutrition and farm labour. Annual Planning Meeting, Hawassa 17-19 July 2017 30. Amiri, Nana. Endophytic fungi associated with rice in Tanzania and their interaction with rice stem borers. Annual Planning Meeting, Hawassa 17-19 July 2017. 31. Fite, Tarekegn. Management of Chickpea Pod Borer in Ethiopia. Annual Planning Meeting, (2017 and 2018). 32. Tadesse, Desalegne. IPM Approach for Communications. Annual Planning Meeting, (2017 and 2018). 33. Zewdie, Asrat. On-farm verification and demonstration of integrated wilt/ root rot and pod borer management method on chickpea in East Shewa Zone. Annual Planning Meeting, Nairobi, July 24-27, 2018
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	34. Korir, Josphat Kiplangat. Potential Demand for IPM Technologies and Practices in East Africa. Annual Planning Meeting, Nairobi, July 24-27, 2018. 35. Diro, Debela.and Demissie, Girma. Integrated Termite Management in maize in Western Ethiopia. Annual Planning Meeting, Nairobi, July 24-27, 2018.

Vegetable Crops and Mango IPM in Asia	
Refereed Journal Articles	1. Rahman, Sadique Md., Norton, George, Rashid, M. Harun-Ar. Economic impacts of integrated pest management on vegetable production in Bangladesh. <i>Crop protection</i>. 2. Spangler, K. and M.E. Christie. The feminization of agriculture beyond the household: Impacts of migration and changing cultivation practices in the Nepali mid-hills. (Paper Under Review) <i>Geoforum</i>. 3. Spangler, K. (2018). "When he comes home, then he can decide": Male Out-Migration, the Feminization of Agriculture, and Integrated Pest Management in the Nepali Mid-Hills. (Thesis Submitted for Master of Science Degree). Virginia Tech, Blacksburg, VA, May 2018. 4. Nagendran, K., Karthika, C., Parthasarathy, S., Mohan Kumar, S., Karthikeyan, G. Molecular evidence for the occurrence of <i>Tomato leaf curl New Delhi virus</i> on bottle gourd in Tamil Nadu, India. <i>Vegetable Science</i>. 5. Nagendran, K., Kumar, S. Mohan., Priyanka And, R., Karthikeyan, G. Molecular Evidence for the Occurrence of <i>Tomato Leaf Curl New Delhi Virus</i> and <i>Squash Leaf Curl China Virus</i> on Volunteer Pumpkin Plants in Tamil Nadu. <i>Trends in Biosciences</i>. 6. Nagendran, K., Kumar, S. Mohan., Manoranjitham And, S.K., Karthikeyan, G. Molecular Detection and Characterization of Tomato Leaf Curl New Delhi Virus Causing Mosaic Disease on Bitter Gourd in Tamil Nadu, India. <i>Trends in Biosciences</i>. 7. Nagendran, K., Aravintharaj, R., Mohankumar, S., Manoranjitham, K., Naidu, R.A., Karthikeyan, G. First Report of <i>Cucumber green mottle mosaic virus</i> in Snake Gourd (<i>Trichosanthes cucumerina</i>) in India. <i>Plant Disease</i>. 8. Nagendran, K., Balaji, C.G., Mohankumar, S., Manoranjithan, S.K., Naidu, R.A., Karthikeyan, G. First report of <i>Zucchini yellow mosaic virus</i> in Snake Gourd (<i>Trichosanthes cucumerina</i>) in India. <i>Plant Disease</i>. 9. Nagendran, K., Priyanka, R., Keerthana, U., Mohankumar, S., Karthikeyan, G. First report of <i>Zucchini Mosaic Virus</i> on <i>Cucurbita Moschata</i> in India. <i>Journal of Plant Pathology</i>.

	10. Akhtar, N., Nayab, M., Sattar, N., Qurashi, F. First report of <i>Alternaria Alternata</i> Causing Leaf Spot of <i>Polyalthia Longifolia</i> in Pakistan. <i>Journal of Plant Pathology</i>. 11. Nagendran, K., Mohankumar, S., Mohammed Faisal, P., Bagewadi, B., Karthikeyan, G. Molecular evidence for the occurrence of tomato leaf curl New Delhi virus on chayote (<i>Sechium edule</i>) in southern India. <i>VirusDis</i>. 12. Nagendran, K., Mohankumar, S., Aravintharaj, R., Balaji, C.G., Manoranjitham, S.K., Achuit, K. Singh, Rai, A.B., Singh, B., Karthikeyan, G. The occurrence and distribution of major virus infesting cucurbits in Tamil Nadu state, India. <i>Crop Protection</i>. 13. Nagendran, K., Satya, V.K., Mohankumar, S., Karthikeyan, G. Molecular characterization of a distinct bipartite <i>Begomovirus</i> species infecting ivy gourd (<i>Coccinia grandis L.</i>) in Tamil Nadu, India. <i>Virus Genes</i>. 14. Nagendran, K., Priyanka, R., Aravintharaj, R., Balaji, C.G., Prashant, S., Basavaraj, B., Mohankumar, S., Karthikeyan, G. Characterization of <i>Cucumber mosaic virus</i> infecting snake gourd and bottle gourd in India. <i>Physiological and Molecular Plant Pathology</i>. 15. Nagendra, K., R. Aravintharaj, S. Mohankumar, S. K. Manoranjitham, R. A. Naidu, and G. Karthikeyan. 2015. First Report of Cucumber green mottle mosaic virus in Snake Gourd (<i>Trichosanthes cucumerina</i>) in India. <i>Plant Disease</i>. 99:4, 559. 16. Nagendran, K., S. Mohankumar, R. Aravintharaj, C.G. Balaji, S.K. Manoranjitham, Achuit K. Singh, A.B. Rai, B. Singh, and G. Karthikeyan. 2017. The occurrence and distribution of major viruses infecting cucurbits in Tamil Nadu state, India. <i>Crop Protection</i>. 99, 10-16. 17. Singh, A., Sah, L.P., G.C., Y. Dhoj, Devkota, M., Colavito, L.A., Rajbhandari, P., Norton, G., Rajotte, E.G., Muniappan, R. Evaluation of pest exclusion net to major insect pest of tomato in Kavre and Lalitpur. <i>Nepalese Journal of Agricultural Sciences</i>. 18. Bhandar, A., Sah, L.P., G.C., Y. Dhoj, Devkota, M., Colavito, L.A., Rajbhandari, B.P., Norton, G., Millet, S., Muniappan, R. Evaluation of carbon sources for anaerobic soil disinfestation in tomato production in Lalitpur district. <i>Nepalese Journal of Agricultural Sciences</i>. 19. Hossain, M.S., M.Y. Mian and R. Muniappan. 2016. First record of <i>Tuta absoluta</i> (Lepidoptera: Gelechiidae) from Bangladesh. <i>J. Agric. Urban Entomol</i>. 32: 101-106. 20. Bagewadi, Basavaraj, Naidu, Rayapati. First report of Tomato yellow leaf curl Kanchanaburi virus in eggplant and tomato in Cambodia. <i>Plant Disease</i>. 21. 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. 22. 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
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	advanced lines for high yield, multiple disease resistance and long shelf life in Bangladesh. <i>Acta Hort.</i> (ISHS) 1179:311-316. 23. 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. <i>Acta Hort.</i> (ISHS) 1179:299-304. 24. 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).
Other Journal Articles	
Conference Papers	
Popular Articles	1. Professor awarded for research contributions and four decades of service. <i>VT News</i>. 10-2-18 2. Male Out-Migration: A Change in Households, a Change in Public Spaces. <i>Agrilinks</i>. 9-19-18 3. Two Sides of the Same Life: Controlling Pests in Cambodia. <i>Global Plant Protection News</i>. 3-1-18 4. Two Sides of the Same Leaf: Controlling Pests in Cambodia. <i>Feed the Future Newsletter</i>. 2-1-18 5. Bangladesh: Women entrepreneurs produce <i>Trichoderma</i>. <i>Global Plant Protection News</i>. 4-17-18 6. Bangladesh: Women entrepreneurs produce <i>Trichoderma</i>. <i>Global Plant Protection News</i>. 4-17-18 7. Early measures to save tomato harvest. <i>The Daily Star</i> 8. Virginia Tech Leads Research on Tomato Leafminer. <i>VT News</i> 9. Virginia Tech programs assist earthquake recovery in Nepal. <i>WSLS</i> 10. <u>Women Find Work with the Help of an Entrepreneur and a "Fighting Fungus"</u> 11. <u>After IPM Innovation Lab trainings, Bangladesh and Nepal confirm tomato-pest invasion</u> 12. <u>IPM Innovation Lab training in Nepal changes lives of merchants and farmers</u> 13. <u>Fighting Fruit Flies: Bangladesh uses Common Materials against a Common Pest</u>
Promotional Materials/Pamphlets	1. <u>IPM Brochure</u> 2. <i>Tuta Absoluta</i> <u>Booklet</u> 3. <u>Fruit Bagging Booklet</u>

	4. Vegetable Seedling Brochure (1) 5. Vegetable Seedling Brochure (2) 6. Fruit Fly Control on Cucurbit Crops Brochure (1) 7. Fruit Fly Control on Cucurbit Crops Brochure (2) 8. IPM for Cabbage Brochure (1) 9. IPM for Cabbage Brochure (2) 10. Grafting Technology on Eggplant and Tomato Brochure (1) 11. Grafting Technology on Eggplant and Tomato Brochure (2)
Videos	1. IPM IL's workshop in Cambodia invokes power of the 'fighting fungus' 2. The Tiny Fungi Playing a Giant Role 3. Video documentary: Colavito, B.R., L.P. Sah, K Pradhan, LA Colavito (2017) Video on outbreak of Tuta absoluta in Nepal, its damage and way forward. 4. Tuta Materials Webpage 5. IPM Vegetable Package Materials Webpage
Posters/ Presentations	1. Christie, M.E., K. Spangler, D. Sumner. (2018). Gendered knowledge, roles, and spaces: IPM cultivation and social change in the Nepali mid-hills. (Presentation) 2. Sustainability and Development Conference at the University of Michigan, Ann Arbor, MI, November 2018. 3. Spangler, K., M.E. Christie. (2018). "When he comes home, then he can decide:" Feminization of agriculture and male out-migration in the Nepali mid-hills. (Presentation) American Association of Geographers (AAG) Annual Meeting, New Orleans, April 2018. 4. Spangler, K., M.E. Christie. (2018). What's in a household? Male out-migration, community spaces, and empowerment in the Nepali mid-hills. (Presentation) 7th Annual Dimensions of Political Ecology (DOPE) Conference, Lexington, KY, February 2018. 5. Christie, M.E., J.M. Alam, and D. Sumner. (2018) Gendered space and subjective indicators of impacts in an integrated pest management (IPM) project in Bangladesh. (Presentation) 7th Annual Dimensions of Political Ecology (DOPE) Conference, Lexington, KY, February 2018. 6. Christie, M.E., M. Nahar, and J.M. Alam. (2015). Agriculture and pest management in Bangladesh: Gendered perspectives from the house-lot garden. (Presentation) 5th Annual Dimensions of Political Ecology Conference, University of Kentucky, Lexington, KY, February 2015.

	7. 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, <i>Tuta absoluta</i>, and its management in Nepal. Presentation at ESA's 65th Annual Meeting, November 5-8, Denver, Colorado. 8. 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, <i>Tuta absoluta</i> and its management in Nepal. Presentation at 9th International IPM Conference, March 18-22, 2018, Baltimore, Maryland. 9. 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, <i>Tuta absoluta</i> in Nepal. Oral Presentation at 1st International Conference on Biological Controls, September 27-29, 2018, Bengaluru, Karnataka, India 10. Devkota, M, Sah. L.P. and L. Colavito. 2017. Designing IPM solutions for vegetable pests and management of <i>Tuta absoluta</i> in Nepal, presentation at 11th National Organic Fair organized at Rupandehi Butwal, February 15 to 19, 2018. 11. Seng, Kim Hian and Megan O'Rourke, IPM Cucumber Package in Cambodia, Presentation at ESA's 65th Annual Meeting, November 5-8, Denver, Colorado. 12. Seng, Kim Hian, Lessons learned from IPM trials, presented at the dissemination workshop on the Prakas of BCAs, jointly organized by the government & GIZ, December, 2017, Phenom Penh, Cambodia. 13. 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. 14. Norton, George W., Why IPM Makes a Difference, Plenary presentation at 9th International IPM Conference, March 18-22, 2018, Baltimore, Maryland. 15. 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. 16. Hossain, Shahadath, Development of bio-rational based management approach against mango hopper, <i>Idioscopus naggpurensis (pruthi)</i>, First International Conference on Biological Control Approaches and Applications, September 27-29, 2018, Bengaluru, India. 17. Bagewadi, B., Nagendran, K., Khadka, R.B., Karthikeyan, G., Hossain, Md. S., Shah, L., Fayad, A., and Naidu, R.A. (2017). Zucchini tigré mosaic virus, an emerging potyvirus in cucurbit vegetables in South Asian
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	countries. Paper presented at 2017 American Phytopathological Society Annual Meeting, San Antonio, TX, August 5-9. 18. Christie, M.E., K. Spangler, I. Sereno. (2017). Challenges using Qualitative Methods to Integrate Gender into Research-for-Development Projects with Biophysical Scientists in Asia, Africa, and Latin America. Paper presented at the annual meeting of the American Association of Geographers (AAG), Boston, MA, April 7. 19. Colavito, L. and L. Sah. (2017). Tuta absoluta Orientation Workshop, Presentation at Café Lalitpur, Nepal to 37 representatives from MoAD, MoLD, NARC, PPD, iDE Nepal, various USAID-funded projects and the private sector, March 9. 20. Colavito, L. and L. Sah. (2017). Developing IPM Packages for Vegetable Crops and its Dissemination in FtF Disticts of Nepal and IPM Learning Center: Knowledge Depository for Visitors. Paper and Poster presentations at Asia Pacific workshop on Empowering Farmers through Integrated Pest Management organized in Kathmandu from February 27, 2017 to March 2. 21. Koy, C. (2017). Varietal screening of tomato in bacteria wilt (<i>Ralstonia solanacearum</i>) disease, presentation at RUA, January. 22. Sah, L.P., Ajay Pratap Giri, Luke A Colavito, Shiva yendyo, Yubraj Dhakal, Dilli R Sharma, George Norton, Edwin G Rajotte, R Muniappan, and Sulav Paudel (2017). Occurrence, Distribution and Management Practices of South American Leaf miner (Tuta absoluta) in Nepal. Presentation at the International Conference on Biodiversity, Climate change Assessment and Impact on Livelihood, Kathmandu Nepal , January 10-12.(Abstract: ICBCL 52, pp22-23). 23. Sah. L.P., Ajay Pratap Giri, Luke A Colavito, Shiva yendyo, Yubraj Dhakal, Dilli R Sharma, George Norton, Edwin G Rajotte, R Muniappan, and Sulav Paudel (2017). IPM Learning Center : Knowledge Depository for Visitors. Presented at APPPC/FAO Workshop on Empowering Farmers through FFS IPM {Training}in Support of Sustainable Intensification of Crop Production within context of Climate, February 27 to March 2, Kathmandu, Nepal. 24. Sah. L.P. and L. Colavito. (2017). Pest Management Technology and Tuta absoluta in Nepal. Presented at 10th National Organic Fair organized in Kanchanpur District from February 3 to 6. 25. Spangler, K. (2017). Exploring the gendered implications of the adaptation of integrated pest management practices in Nepal. Paper presented at Dimensions of Political Ecology Conference, Lexington, KY February 3. 26. Bhusal, K., B.P.Bhattraai and L.Sah, (2017). Pest and disease surveillanve of vegetable crops and farmer's pest management practices in Banke and
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	Surkeht districts. Nepalese Journal of Agricultural Sciences, Vol. 15. pp. 160-165. 27. Hossain, M.S., M.Y. Mian, GMA Halim and R. Muniappan. (2016). Bangladeshe Tuta leafminer er abirvab ebong amader karaniya (Bengali) pp.1-14. 28. Hossain, MS, B.C. Sarker and M.M. Hossain. (2017). Fruit bagging: An effective and eco-friendly approach for controlling fruitfly (In Bangla). IPM IL, Bangladesh Site Horticulture Research Center, Bangladesh Agricultural Research Institute, Gazipur. 12 pp. 29. Joshi, J., B.P. Rajbhandari and L.Sah, (2017). Management practices adopted by commercial tomato growers against Tuta absoluta. Nepalese Journal of Agricultural Sciences, Vol. 15. pp. 93-97. 30. Mian, Md.Y, Md. S. Hossain, and A.N.M.R. Karim. (2016). Integrated Pest Management of Vegetable Crops in Bangladesh. Chapter 11 in R. Muniappan and E.A. Heinrichs (eds.). Integrated Pest Management of Tropical Vegetable Crops. Springer, 235-250. 31. Norton, G.W., J. Alwang and M.S. Issa. (2016). Impacts of IPM on vegetable production in the tropics. Chapter 14 in R. Muniappan and E.A. Heinrichs (eds.). Integrated Pest Management of Tropical Vegetable Crops. Springer, 289-304 32. Paudel. S, L.P. Sah, K Pradhan, LA Colavito, BP Upadhyay, EG Rajotte, R Muniappan, (2016). Development and dissemination of Vegetable IPM Practices and Packages in Nepal. Chapter 12 in R. Muniappan and E.A. Heinrichs (eds.). Integrated Pest Management of Tropical Vegetable Crops. Springer, 251-269. 33. Sah, L. and others. (2017). Tuta and IPM protocols for tomato were developed utilizing the latest international research and preliminary research conducted in Nepal since the outbreak. The protocols were developed in coordination with Department of Agriculture, Plant Protection Directorate, and NARC in both English and Nepali script. 34. Sah. L.P., Ajay Pratap Giri, Komal Pradhan and Luke A Colavito. (2017). Tuta and IPM protocols for tomato developed in coordination with Department of Agriculture, Plant Protection Directorate, and NARC in both English and Nepali script.
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IPM for Exportable Fruit Crops in Vietnam	
Refereed Journal Articles	1. Hanh T.T.M., Hieu N.T., Dao Thi Be Bay, Hoa N.V., Hoat T.X., 2016. Evaluation of Susceptibility to witches' broom of longan varieties grown in Mekong Delta. <i>Journal of Vietnam Agricultural Science and Technology</i> 14 (6): 843-851.

	2. Hanh T.T.M. and Hoa N.V., 2018. Morpho-biological characteristics of predatory mite (<i>Amblyseius</i> sp.), a biological control agent of <i>Eriophyes dimocarp</i> on longan. <i>Journal of Vietnam Agricultural Science and Technology</i> 1 (86): 64-68 3. Uyen D.T.K., Tran Nhan Dung and Hoa N.V. 2018. Primary results of construction of phylogenetic tree of <i>Colletotrichum</i> spp. causing anthracnose diseases on dragon fruit in Southern provinces. <i>Journal of Vietnam Agricultural Science and Technology</i> 1 (86): 68-72 4. Uyen D.T.K., Phen T.V. and Hoa N.V., 2018. Identification of <i>Colletotrichum truncatum</i> causing anthracnose on dragon fruit and effect of botanical extracts on fungus growth. <i>Journal of Vietnam Agricultural Science and Technology</i> 1 (86): 83-88 5. Tuong L.T., Uyen D.T.K., Hieu N.T. and Hoa N.V. 2018. Study on the antagonism of actinomycetes to causing anthracnose and canker disease on dragon fruit in vitro. <i>Journal of Vietnam Agricultural Science and Technology</i> 1 (86): 78-82. 6. Hanh T.T.M., Giang N.T.C., Hoa N.V. and Rangaswamy Muniappan, 2018. Study on morphology, biology of <i>Thrips palmi</i> and efficiency of different concentration of neem leaf extract on dragon fruit. <i>Journal of Vietnam Agricultural Science and Technology</i> 1 (3): 108-113 (in English).
Other Journal Articles	
Conference Papers	1. Hanh T.T.M., Thoa N.T.K. and Hoa N.V., 2016. Management of <i>Eriophyes dimocarp</i> on Longan in Vietnam using safe and biological approaches. International Congress of Entomology XXV, Orlando, Florida, USA, September 25-30: 202 (Oral presentation and Abstract) 2. Hieu N.V., Hoa N.V., Hanh T.T.M, Dien L.Q., Uyen D.T.K., Thu N.N.A. and Linh D.T., 2017. Apply of biological control and SAR chemicals for management of fruit and vegetable pests. 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, No. 16/2017: 31-40 3. Hanh T.T.M. and Hoa N.V., 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, No. 16/2017: 54-60 4. Hanh T.T.M., 2017. Effect of Pyraclostrobin to Longan Witches's Broom syndrome in Vietnam at TOP CIENCIA workshop hold at Malang, Indonesia, March 14th (Oral presentation) 5. Hoa N.V., Hieu N.T., Hanh T.T.M., Uyen D.T.K., Munippan Rangaswamy, 2017. Prospects and challenges of applying IPM in fruit production in the southern of Vietnam at the Workshop on Agroecological

	Crop Protection hold at SOFRI, Vietnam, August 29-31th (Oral presentation) 6. Duyen L.T. and Hoa N.V., 2017. Survey on composition of natural enemies (lady bird) on some fruit trees (dragon fruit, longan, mango) in the Mekong Delta. SOFRI Annual Scientific Reporting Conference, SOFRI, 22-24/1/2018 7. Duyen L.T., Hanh T.T.M. and Hoa N.V., 2017. The result of building up a IPM model on longan in Vinh Long province. SOFRI Annual Scientific Reporting Conference, SOFRI, 22-24/1/2018 8. Hanh T.T.M., Chuong D.Q. and Hoa N.V., 2017. Evaluation of parasitic ability of entomopathogenic fungi to control Eriophyid mite <i>Eriophyes dimocarp</i> on longan. SOFRI Annual Scientific Reporting Conference, SOFRI, 22-24/1/2018 9. Hanh T.T.M., Chuong D.Q. and Hoa N.V., 2017. Study on management of fruit borers on Edor longan by fruit bagging in Vinh Long province. SOFRI Annual Scientific Reporting Conference, SOFRI, 22-24/1/2018 10. Tuong L.T., Ni T.T.O., Uyen D.T.K. and Hoa N.V., 2017. Collection, identify and selection strains of Trichoderma fungi to control pathogenic microorganisms on fruit trees. SOFRI Annual Scientific Reporting Conference, SOFRI, 22-24/1/2018 11. Thu N.N.A., Thanh N.T.K., Uyen D.T.K., Hieu N.T. and Hoa N.V., 2017. Initial use of beneficial bacteria to control canker disease on dragon fruit. SOFRI Annual Scientific Reporting Conference, SOFRI, 22-24/1/2018 12. Uyen D.T.K., Hoa T.M. and Hoa N.V., 2017. Results of identification of <i>Collettotrichum</i> spp. cause of dragon fruit anthracnose by using ITS, Enzyme MvnI, ACT and RAPD marker. SOFRI Annual Scientific Reporting Conference, SOFRI, 22-24/1/2018 13. Thu N.N.A., Cuong N.H., Thanh N.T.K., Uyen D.T.K., Hieu N.T. and Hoa N.V., 2017. Results of building up IPM demonstration to control canker disease on dragon fruit in Tien Giang and Long An provinces. SOFRI Annual Scientific Reporting Conference, SOFRI, 22-24/1/2018 14. Hieu N.T., Hanh T.T.M. and Hoa N.V., 2018. Pest and disease management to promote sustainable. Agriculture for Fruit and Vegetable. Theme: Solution of sustainable development for fruit crops in Southern provinces. @ Agricultural extension forum. National Agricultural Extension Center. Ministry of Agriculture and Rural Development, Vinh Long, 12/2018: 23-33
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	15. Hieu N.T., Thu N.N.A., Linh D.T., Thanh N.T.K., Hoa N.V. and Muniapan Rangaswamy, 2018. Effect of various degree of canopy pruning on plant growth, yield and control of canker disease (<i>Neoscytalidium dimidiatum</i>) of dragon fruit crop. <i>International Conference on Tropical Fruit Pests and Diseases (TROPED 2018)</i>, Sabah, Malaysia, September 24-29, 2018 (Oral presentation and abstract) 16. Thoa, N.T.K., 2018. Abundance of mesofauna on mango (<i>Mangifera indica</i> L.) ecosystem in Bengaluru, Karnataka, India. <i>International Conference on Tropical Fruit Pests and Diseases (TROPED 2018)</i>, Sabah, Malaysia, September 24-29, 2018 (Oral presentation and abstract) 17. Loc H.T., 2018. Validation of Artificial Diets for Rearing of <i>Galleria mellonella</i> Larvae and Mass Multiplication of Entomopathogenic Nematodes for Use in the Control of Fruit Flies. <i>International Conference on Tropical Fruit Pests and Diseases (TROPED 2018)</i>, Sabah, Malaysia, September 24-29, 2018 (Oral presentation and abstract) 18. Hoa N.V., Uyen D.T.K., Muniapan Rangaswamy, 2018. Effect of <i>Bacillus</i> spp. and plant extracts from <i>Impatiens balsamina</i> L. on anthracnose disease caused by <i>Colletotrichum</i> spp. on mango in Vietnam. The First International Conference of Biological Control Approaches and Applications, at Bengaluru, India, September 27-29, 2018 (Oral Presentation and abstract) 19. Uyen D.T.K., Muniapan Rangaswamy, Phen T.V. and Hoa N.V., 2018. The efficacy of <i>Streptomyces</i> spp., <i>Bacillus</i> spp and extract of <i>Impatiens balsamina</i> on the mycelial growth of the fungi <i>Colletotrichum truncatum</i>, <i>C. gloeosporioides</i> causing anthracnose disease on dragon fruit. The First International Conference of Biological Control Approaches and Applications, at Bengaluru, India, September 27-29, 2018 (Poster presentation and abstract)
Popular Articles	1. Entomologist from Vietnam gains global perspective at Virginia Tech. <i>VT News</i>. 11.27.18 2. Agrilinks Young Scholars Blog Contest: We Have a Winner! <i>Agrilinks</i>. 10-16-18 3. Virginia Tech's simple fix for Vietnam cuts pesticide use, sends bugs packing. <i>VT News</i>. 7-30-18 4. <u>Dragon Fruit Sleeving: Farmers Find Relief with Simple Technologies</u> 5. <u>Mango Bagging: Farmers Stay Happy, Fruit Flies Stay Away</u> 6. <u>Longan Bagging: Multi-purpose Bags Give Farmers More Fruitful Futures</u>

	7. IPM on longan 8. IPM on dragon fruit, mango, longan
Promotional Materials/Pamphlets	1. Mango Brochure 2. Longan Brochure (1) 3. Longan Brochure (2) 4. Dragon Fruit Brochure (1) 5. Dragon Fruit Brochure (2) 6. Poster for Strengthening Production and Export of Vietnamese Fruit Crops Through Innovative and Market-Oriented IPM 7. Poster for Mango Management 8. Poster for Longan Management 9. Poster for Longan Witches' Broom 10. Poster for Dragon Fruit Management (1) 11. Poster for Dragon Fruit Management (2) 12. Training manual: Dragon fruit IPM technological process 13. Training manual: Longan IPM technological process 14. Training manual: Mango IPM technological process 15. Training manual: Lychee IPM technological process 16. Training manual: Canopy and branch pruning for pest and diseases management on dragon fruit 17. Training manual: Canopy and branch pruning for pest and diseases management on mango 18. Training manual: Using safe and effective pesticides according to VietGAP standard 19. Training manual: Production process according to VietGAP standard
Videos	1. Four (04) TV talk shows on the term of “Dragon fruit canker management” at TV channel of Binh Thuan, Tien Giang, Long An province, 2017. 2. Two (02) TV talk show on the term of “Longan Witches’ broom management” at TV channel of Tien Giang province and “IPM fruit crop production” at TV channel of Vinh Long province, 2017. 3. IPM on dragon fruit

Posters/ Presentations	1. Russell F. Mizell, 2017. Seminar: An overview of trapping crop (Training workshop presentation), My Tho, VN, February 22th 2. Naidu Rayapati, 2017. Serminar: An Overview of Virus Diseases (Training workshop presentation), My Tho, VN, March 3rd 3. Hieu N.T. 2017. Training of Dragon fruit IPM technological process (Training presentation), Cho Gao district, Tien Giang province, September 14th 4. Thu N.N.A. 2017. Training of Dragon fruit IPM technological process (Training presentation), Chau Thanh district, Long An province, September 14th 5. Hieu N.T. 2017. Training of Production process according to VietGAP standard on dragon fruit (Training presentation), Cho Gao district, Tien Giang province, September 21st 6. Hanh T.T.M., 017. Training of Longan IPM technological process (Training presentation), Long Ho district, Vinh Long province, July 12th 7. Hanh T.T.M., 2017. Training of Production process according to VietGAP standard on longan (Training presentation), Cai Lay town, Tien Giang province, September 15th 8. Hanh T.T.M., 2017. Training of Production process according to VietGAP standard on longan (Training presentation), Cai Lay district, Tien Giang province, July 17th 9. Duyen L.T., 2017. Training of Using safe and effective pesticides according to VietGAP (Training presentation), Cai Lay district, Tien Giang province, July 21st 10. Cuong N.H., 2017. Training of Longan IPM technological process (Training presentation), Cai Lay town, Tien Giang province, September 29th 11. Loc H.T., 2017. Training of Production process according to VietGAP standard on longan (Training presentation), Long Ho district, Vinh Long province, July 31st 12. Vi B.X., 2017. Training of Longan IPM technological process (Training presentation), Hung Yen town, Hung Yen province, March 2nd 13. Vi B.X., 2017. Training of Longan IPM technological process and Production process according to VietGAP standard on longan (Training presentation), Hung Yen town, Hung Yen province, June 12th
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	14. Hong D.T.C., 2017. Training of Canopy and branch pruning for pest and diseases management (Training presentation), Cao Lanh city, Dong Thap province, August 7th 15. Uyen D.T. K., 2017. Training of Mango IPM technological process (Training presentation), Cao Lanh city, Dong Thap province, August 17th 16. Loc H.T., 2017. Training of Production process according to VietGAP standard on mango (Training presentation), Cao Lanh city, Dong Thap province, September 15th 17. Loc H.T., 2017. Training of Using safe and effective pesticides according to VietGAP standard (Training presentation), Cao Lanh city, Dong Thap province, September 25th 18. Vi, B.X., 2017. Training of Lychee IPM technological process (Training presentation), Luc Ngan district, Bac Giang province, April 4th 19. Vi, B.X., 2017. Training of Production process according to VietGAP standard on lychee (Training presentation), Luc Ngan district, Bac Giang province, July 10th 20. Hieu N.T., 2017. Training courses on canker management (Training presentation), Cho Gao district, Tien Giang province, December 20th 21. Thu N.N.A., 2017. Training courses on canker management on dragon fruit (Training presentation), Chau Thanh district, Long An province, December 20th 22. Cuong N.H., 2017. Training courses on canker management on dragon fruit (Training presentation), Ham Thuan Bac district, Binh Thuan province, December 20th 23. Vi B.X., 2018. Training of Production process according to VietGAP standard on longan (Training Presentation), Hung Yen town, Hung Yen province, March 20th 24. Hanh T.T.M., 2018. Training of Longan IPM techlonogical process (Training presentation), Cai Lay district, Tien Giang province, April 5th 25. Hanh T.T.M., 2018. Training of VietGAP standard new version TCVN 11892-1: 2017 date October 10, 2017 (Training Presentation), Long Ho district, Vinh Long province, May 25th 26. Hanh T.T.M., 2018. Training of VietGAP standard new version TCVN 11892-1: 2017 date October 10, 2017 (Training Presentation), Cai Lay district, Tien Giang province, June 20th
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	27. Dien L.Q., 2018. Training of Canopy and branch pruning for pest and diseases management on mango (Training presentation), Dinh Quan district, Dong Nai province, September 6th 28. Dien L.Q., 2018. Training of IPM mango technological process (Training Presentation), Dinh Quan district, Dong Nai province, September 13th 29. Dien L.Q., 2018. Training of Production process according to VietGAP standard on mango (Training presentation), Dinh Quan district, Dong Nai province, September 20th 30. Dien L.Q., 2018. Training of Using safe and effective pesticides according to VietGAP standard, Dinh Quan district, Dong Nai province, September 21th 31. Uyen D.T.K., 2018. Training of Management of pests on mango (Training presentation), Cao Lanh city, Dong Thap province, September 28th 32. Loc H.T., 2018. Training of Using safe and effective pesticides according to VietGAP standard (Training presentation), Cao Lanh city, Dong Thap province, October 4th 33. Vi B.X., 2018. Training of Lychee IPM technological process (Training presentation), Luc Ngan district, Bac Giang province, March 13-14th 34. Vi B.X., 2018. Training of Production process according to VietGAP standard on lychee (Training presentation), Luc Ngan district, Bac Giang province, April 25-26th 35. Sumner, D., Hanh T.T.M., T. Ngo Thi Thanh, M.E. Chrstie, Hoa N.V. (2019). Gender-responsive Integrated Pest Management (IPM) approaches in Vietnam: Lessons learned and insights to promote and strengthen gender integration (Poster). Seeds of Change Conference at the University of Canberra, Canberra, ACT, AU, April 2019. 36. Sumner, D., Hanh T.T.M., Truc N.T.T., M.E. Christie, Hoa N.V. (2019). Developing gender-responsive Integrated Pest Management (IPM) approaches in Vietnam: Lessons from a mixed-methods impact evaluation. Women and Gender in Development Conference 2019 – Out of the Theory & Into the Field at Virginia Tech, Blacksburg, VA, February 2019. 37. Sumner, D. (2018). Gender-focused Evaluation in the IPM Innovation Lab: The Most Significant Change Technique and Agricultural Technology Assessment. (Training Workshop Presentation). Gender-focused evaluation Training Workshop, My Tho, VN, December 2018.
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Modeling for Biodiversity and Climate Change	
Refereed Journal Articles	1. Bhattacharjee, Aishwarya, Anadon, Jose D., Lohman, David J., Doleck, Tenzing, Lakhankar, Tarendra, Shrestha, Bharat Babu, Thapa, Praseed, Devkota, Durga, Tiwari, Sundar, Ajay, Jha, Siwakoti, Mohan, Devkota, Naba R., Joha, Pramod K., Krakauer, Nir Y. The Impact of Climate Change on Biodiversity in Nepal: Current Knowledge, Lacunae, and Opportunities. <i>Climate</i>. 2. Bhandar, G., Thapa, R.B., Giri, Y.P., Manandhar, H.K. Effect of Planting Dates of Maize on the Incidence of Borer Complex in Chitwan, Nepal. <i>Journal of Agriculture and Forestry University</i>. 3. Giri, H.N., Sharma, M.D., Thapa, R.B., Pande, K.R., Khatri, B.B. Growth, Yield and Post-Harvest Quality of Late Season Cauliflower Grown at Two Ecological Zones of Nepal. <i>Journal of Agriculture and Forestry University</i>. 4. Luitel, Dol Raj, Siwakoti, Mohan, Jha, Pramod, K. Relationship between Climatic Variables and Finger Millet Yield in Syangja, Central Nepal. <i>Journal of Forest and Livelihood</i>. 5. Mandal, Ram Asheshwar, Jha, Pramod K., Krakauer, Nir, Jha, Ajay, Lakhankar, Tarendra. Assessing Cost Effective Management Options of Eichhornia Crassipes in Ecotourism Ramsar Sites, Nepal. <i>International Journal of Agricultural Science, Research and Technology in Extension and Education Systems</i>. 6. Luitel, Dol Raj, Siwakoti, Mohan, Jha, Pramod, K., Jha, Ajay Kumar, Krakauer, Nir. Climate, Distribution and Cropping Pattern of Finger Millet in Nepal: A review. <i>International Journal of Agriculture and Environmental Research</i>. 7. Bhandari, Ghanashyam, Jha, Shiva Kumar, Giri, Yagya Prasad, Manandhar, Hira Kaji, Jha, Pramod K., Devkota, N., Thapa, Praseed, Thapa, Resham Bahadur. Performance evaluation of locally developed black light trap for maize insects monitoring in Chitwan, Nepal. <i>Journal of Maize Research and Development</i>. 8. Luitel, Dol Raj, Siwakoti, Jha, Pramod, K., Jha, Ajay Kumar, Krakauer, Nir. An Overview: Distribution, Production, and Diversity of Local Landraces of Buckwheat in Nepal. <i>Advances in Agriculture</i>. 9. Sharma Poudel A., Pramod Kumar Jha, Muniappan Rangaswamy and Bharat Babu Shrestha: Biology and management of invasive weed <i>Ageratina adenophora</i>(Asteraceae): current state of knowledge and prospect for future research. <i>Weed Research (Accepted for publication in 2019)</i>. 10. Luitel, D R, M Siwakoti and P K Jha. 2019. Climate change, yield of finger millet and perception of small holders farmers in Chitwan Annapurna landscape area. (Paper submitted after final revision to <i>Journal of Mountain Science</i>). 11. Maharjan, S., Anjana Devkota, Pramod K. Jha, Nir Y. Krakauer, Rangaswamy Muniappan and Bharat B. Shrestha. Temporal and spatial

	patterns of research on a globally significant invasive weed <i>Parthenium hysterophorus</i> L.: A bibliographic review. <i>Crop Protection</i> , (Under Review Process)
Other Journal Articles	
Conference Papers	
Popular Articles	1. Mapping Climate Change, Invasive Species, and Semblances of Hope. <i>Agrilinks</i>. 4-27-18 2. “Tuta absoluta: tomato killer” in New Spotlight, 2017. Vol 10 (1):28-29. 3. “Alien Invasion” in New Spotlight, 2017. Vol 10(12):21-24. 4. “A dangerous Pest is on its way to Nepal” New Spotlight, 2018. Vol 12(10):19-20.
Promotional Materials/Pamphlets	
Videos	
Posters/ Presentations	1. Mandal, R. A., Jha, P.K., Lakhankar, T., Jha, A.K., and Krakauer, N. 2017. Infestation of <i>Eichhornia crassipes</i> in Ramsar sites of Nepal: Searching for management. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 29. 2. Maharjan, S., Devkota, A., Shrestha., Jha, P.K., Anadon, J.D., Mandal, R. A., and Krakauer, N., Jha, A. K. 2017. Variation in the Life History Traits of an invasive weed <i>Parthenium hysterophorus</i> L. along the elevation gradient in central Nepal. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 32. 3. Khadka, S., Jha, S.K., Jha, P.K., Anadon, J.D., Mandal, R. A., Jha, A.K., and Krakauer, N. 2017. Management of water hyacinth (<i>Eichhornia crassipes</i>) in Chitwan-Annapurna Landscape, Nepal. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 33. 4. Dangol, P., Shrestha, B.B., Lakhankar T., Siwakoti, M., Jha, P.K., Mandal, R. A., Jha, A.K., and Krakauer, N. 2017. Changes in Life history traits of invasive Alien Weed <i>Lantana camara</i> L. along elevation gradient in Nepal. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 34. 5. Poudel, A., Shrestha. B.B., Jha, P.K., Lohman, D., Krakauer, N., Jha, A.K. 2017. <i>Ageratina adenophora</i> (Asteraceae) invasion: current state of knowledge and prospect for future research. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 60. 6. Bhattacharjee, A., Anadon, J.D., Lohman, D., Lakhankar T., Krakauer, N., Jha, A.K., Tiwari, S., Thapa, S., Devkota, D., Devkota, N.R., Doleck, T., Pokharel, M.R., Luitel, D.R., Mandal, R. A., Sharma, M.P., Siwakoti, M., Jha, P.K. 2017. A review of impacts of climate change on biodiversity in Nepal. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 80.

	7. Giri, H.N., Sharma, M.D., Thapa, R.B., Thapa, S., Devkota, N.R., Jha, P.K., Mandal, R. A., Krakauer, N., Jha, A.K. 2017. Effect of organic and non-organic fertilizers as climate smart practices on growth and yield of cauliflower (<i>Brassica oleracea</i> L. var. botrytis). International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 94. 8. Panthy, A., Jha, P.K., Shrestha, B.B., Devkota, N.R., Krakauer, N., Jha, A.K. 2017. As assessment on the impact of climate change on cropping system and biodiversity in Chitwan District of Nepal. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 96. 9. Sapkota, S., Thapa, R.B., Lohman, D., Regmi, R., Krakauer, N., Jha, A.K., Devkota, N.R., Jha, P.K., Thapa, S. 2017. A review of monitoring of dung beetle's diversity and evaluation of its role in nutrient cycling. Proceedings of ICBCCL 2017. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 174. 10. Luitel, D.R., Siwakoti, M., Jha, P.K., Krakauer, N., Jha, A.K. 2017. Distribution, production and cropping pattern of finger millet in Nepal. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 187. 11. Bhandari, G., Anadon, J.D., Thapa, R., Giri, Y.P., Manandhar, H.K., Lohman, D., Krakauer, N., Jha, A.K., M., Jha, P.K., Devkota, N.R., Thapa, P., Mandal, R. A., Sharma. 2017. Maize stem borer <i>Chilo partellus</i> (Swinhoe) distribution along elevational variation and climatic variability. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 220. 12. Ghimire, M.S., Khanal, P., Krakauer, N., Jha, A.K., M., Jha, P.K., Devkota, N.R., Thapa, P. 2017. A review on management options for <i>Stemphylium</i> Blight of Lentil. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 222. 13. Shrestha, B.M., Jha, P.K., Siwakoti, M., Jha, A.K., Mandal, R. A. and Krakauer, N. 2017. Assessing livelihood vulnerability of small holder in Nawalparasi, Lamjung and Kaski districts, Central Nepal. International Conference on Biodiversity, Climate Change and 14Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 319. 14. Bhandari, S., Siwakoti, M., Anadon, J.D., Lohman, D., Jha, P.K., Mandal, R. A., Jha, A.K., and Krakauer, N. 2017. Fodder grass for livestock production to enhance people's income and enriching biodiversity at Puranchor village, Kaski district, Nepal. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 322. 15. Devkota, D., Devkota, N.R., Sharma, M.P., Jha, P.K., Krakauer, N., and Jha, A.K. 2017. Gender roles and needs of women's enterprise promotion. International Conference on Biodiversity, Climate Change and Livelihood. 10-12 January 2017, Kathmandu, Nepal. Page 334. 16. Luitel, D R, Siwakoti, M, Jha, P K, Jha, A K, Mandal, R A and Krakauer, N. 2017. Trend of climatic variables and impacts on yield of
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	finger millet in Chitwan-Annapurna Landscape, Nepal. International Conference of Wild Harvest, Governance and Livelihood in Asia (Nov 30- Dec. 2, 2017, Kathmandu, Nepal). 17. Maharjan,S, Shrestha,B B, Devkota,A and Jha,P K.2018.Variation in plant functional traits of an invasive weed <i>Parthenium hysterophorus</i> along elevation gradients in central Nepal”in “The 3rd International Conference on Mountains in the Changing World, held on October 9-10, 2018 in Kathmandu, Nepal. 18. Sharma, A.....2018.Plant functional traits variation of an invasive weed, <i>Ageratina adenophora</i> (Asteraceae) along elevation gradients in Chitwan-Annapurna Landscape, Nepal”. International Conference on “Mountains in the Changing World” held on 9th-10th October 2018 at Hotel Radisson. 19. Maharjan,S, Devkota,A, Shrestha,B B, Jha,P K, Anadon,J D, Mandal,RA, Krakauer,N and Jha,A.2017Life history traits variation of an invasive weed <i>Parthenium hysterophorus</i> L. along the elevation gradient in Central Nepal”in “The 9th HOPE Meeting” held on February 26-March 2, 2017, Japan(⁵Poster presentation). 20. Jha P K. and Siwakoti,M.2018.Invasive plant species in Nepal. in “First International Conference on Biological Control” held on September 27-29,2018 in Bengaluru, India. 21. Maharjan,S, Shrestha,B B, Devkota,A, Muniappan,R and Jha,P K.2018-Impact of <i>Zygogramma bicolorata</i> on growth of <i>Parthenium hysterophorus</i> in Nepal” in “First International Conference on Biological Control” held on September 27-29,2018 in Bengaluru, India. 22. Sharma A.,Shrestha, B B and Jha , P K.2018.Functional traits variation of an invasive weed, <i>Ageratina adenophora</i> (Sprengel) R. King and H. Robinson along elevation gradient in Chitwan-Annapurna Landscape, Nepal. .International Conference on Biological Control held on 27th-29th September 2018 at Hotel Le Meridian, Bangalore 23. Luitel,D R, Siwakoti,M and Jha,P K.2018.Yield variation of finger millet and buckwheat local landraces along elevation gradient in Chitwan-Annapurna Landscape, Nepal. International conference on Climate change, Biodiversity and Sustainable Agriculture(ICCBSA-2018) (Dec 13-16, 2018), Jorhat, ASSAM, India. 24. Sharma,A,Shrestha, B B and Jha , P K.2018.Functional traits variation of an invasive weed <i>Ageratina adenophora</i> (Sprengel) R. King and H. Robinson along elevation gradients in Chitwan-Annapurna Landscape, Nepal. Tenth HOPE Meeting with Nobel Laureates organized by Japan Society for the Promotion of Science held on 11th-15th March 2018 in Japan(Poster Presentation). 25. Bhandari,G.S, Thapa,R B, Giri,Y P, Manandhar,H K, Jha,P K and Devkota, N R.2018.Effect of planting dates of maize on the incidence of borer complex in inner terai, Nepal. 13th Asian Maize Conference and Expert Consultation onMaize for Food, Feed, Nutrition and Environmental Security,Ludhiana, India,October 8-10, 2018.
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	26. Maharjan,S,Shrestha,B B, Joshi,M D, Devkota.A, Muniappan,R, Jha,P K:2018-2019.Potential suitable habitat of <i>Parthenium hysterophorus</i> under climate change scenario in Chitwan Annapurna Landscape, Nepal” in “National Climate Conference held on December 31, 2018- January1, 2019 in Guphadanda, Sindhupalchok, Nepal) (Poster presentation). 27. Luitel,D R, Siwakoti,M and Jha ,P K. 2018-2019.Potential suitable habitat of <i>Eleusine coracana</i> (L) Gaertn (Finger millet) under the climate change scenarios in Nepal using Maxent model”. National Climate Change Conference (31 Dec 2018-1 Jan 2019,Guphadanda, Sindhupalchok, Nepal(Poster presentation). 28. Sharma, A.,Shrestha,B B, Joshi, M D, Jha,P K and Muniappan,R. 2018-2019.Predicting the potential distribution of an invasive weed <i>Ageratina adenophora</i> under climate change scenarios in Chitwan-Annapurna Landscape, Nepal. National Climate Conference held on 31st Dec-1st Jan 2019 at Guphadanda, Sindhupalanchowk, Nepal.
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Invasive Species Modeling for South American Tomato Leafminer and Groundnut Leafminer	
Refereed Journal Articles	1. Venkatramanan, S., Wu, S., Marathe, A., Marathe, M., Eubank, S., Sah, L., Giri, A.P., Colavito, L., Nitin, K.S., Sridhar, V., Asokan, R., Muniappan, R., Norton, G., Adiga, A. Towards robust models of food flows and their role in invasive species spread. <i>IEEE</i>. 2. Venkatramanan, S., Wu, S., Shi, B., Marathe, A., Marathe, M., Eubank, S., Sah, L. P., Giri, A.P., Colavito, L.A., Nitin, K.S., Sridhar, V., Asokan, R., Muniappan, R., Norton, G., Adiga, A. Study of <i>Tuta absoluta</i> in Nepal. <i>Virginia Tech</i>. 3. 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. <i>International Journal of Tropical Insect Science</i>, 38, 243-253. 4. Sylla S, Seydi O, Diarra K, Brévault T (2018) Seasonal decline of the tomato leafminer, <i>Tuta absoluta</i>, in the shifting landscape of a vegetable-growing area. <i>Entomologia Experimentalis et Applicata</i> (doi 10.1111/eea.12722). 5. 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. <i>Entomologia Generalis</i> (in press). 6. Campos, M.R., A. Biondi, A. Adiga, R.N. Guedes and N. Desneux. 2017. From the Western Palearctic region to beyond: <i>Tuta absoluta</i> 10 years after invading Europe. <i>Journal of Pest Science</i> 1-10. 7. Sylla, S., T. Brevault, A.B. Bal, A. Chailleux, M. Diatte, N. Desneux and K. Diarra. 2017. Rapid spread of the tomato leafminer, <i>Tuta absoluta</i> (Lepidoptera: Gelechiidae), and invasive pest in Sub-Saharan Africa. <i>Entomologia Generalis</i>, 269-283. 8. Sylla, S., T. Brevault, J.C. Streito and K. Diarra. 2016. First record of <i>Nesidiocoris tenuis</i> (Reuter) ((Heteroptera: Miridae) as potential predator

	of the tomato leafminer, <i>Tuta absoluta</i> (Meyrick) (Lepidoptera: Gelechiidae), in Senegal. Egyptian Journal of Pest Control, 26: 851-853. 9. Diatte M, Brévault T, Sylla S, Tendeng E, Sall-Sy D & Diarra K (2017) Arthropod pest complex and associated damage in field-grown tomato in Senegal. International Journal of Tropical Insect Science (in press). 10. Mateus R Campos, Antonio Biondi, Abhijin Adiga, Raul N.C. Guedes, Nicolas Desneux. 2017. From the Western Palearctic Region to Beyond: <i>Tuta Absoluta</i> ten years after its Europe invasion. Journal of Pest Science. 11. Sichao Wu, Henning Mortveit and Sandeep Gupta. 2017. A Framework for Validation of Network-based Simulation Models: an Application to Modeling Interventions of Pandemics. Accepted by SIGSIM-PADS '17, May 24–26, 2017. doi: http://dx.doi.org/10.1145/3064911.3064922. 12. Sichao Wu, Henning Mortveit, Abhijin Adiga and Srinivasan Venkatramanan. 2017. A Framework for Validation of Network-based Simulation Models: An Application to Modeling Interventions of Pandemics. GENEUS & Application in Pest Diffusion. Poster session presented at the Workshop on Uncertainty Quantification and Data-Driven Modeling, Austin, March 23-24, 2017. 13. Srinivasan Venkatramanan, Sichao Wu, Bowen Shi, Abhijin Adiga, Madhav Marathe, Stephen Eubank, Achla Marathe. 2017. Hybrid Models for Ecological and Anthropogenic Drivers of Pest Invasion: Case Study of <i>Tuta absoluta</i> in Nepal, International conference on biodiversity, climate change assessment and impacts on livelihood (ICBCL), Kathmandu, 2017. 14. Sylla S, Brévault T, Bal AB, Chailleux A, Diatte M & Desneux N. 2017. Rapid spread of the tomato leafminer, <i>Tuta Absoluta</i> (Lepidoptera, Gelechiidae), an invasive pest in subSaharan Africa. Entomologia Generalis (accepted with minor revisions). 15. Sylla S, Brévault T, Diarra K, Bearez P & Desneux N (2016) Life-history traits of <i>Macrolophus pygmaeus</i> with different prey foods. Plos One 11:e0166610. 16. Sylla S, Brévault T, Streito J-C & Diarra K (2016) First Record of <i>Nesidiocoris tenuis</i> (Reuter) (Heteroptera: Miridae), as a predator of the tomato leaf miner, <i>Tuta Absoluta</i> (Meyrick) (Lepidoptera: Gelechiidae), in Senegal. Egyptian Journal of Biological Pest Control 26:851- 853. 17. Sylla S, Seydi O, Diarra K, Brévault T (2018) Seasonal decline of the tomato leafminer, <i>Tuta absoluta</i>, in the shifting landscape of a vegetable-growing area. Entomologia Experimentalis et Applicata (doi 10.1111/eea.12722).
Other Journal Articles	
Conference Papers	1. Sylla S, Diarra K, Desneux N, Brévault T (2016) Invasion of the tomato leafminer, <i>Tuta Absoluta</i>, in West Africa: Spatial dynamics, ecological niche, and potential for biological control. International Congress of Entomology (ICE), Orlando, USA, 25-30 September 2016. doi: 10.1603/ICE.2016.108757

	2. 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). 3. V. Sridhar, K. S. Nitin, R. Asokan and A. Adiga. 2017. Use of CLIMEX to identify the potential areas for spread of Tuta absoluta under climate change, International conference on biodiversity, climate change assessment and impacts on livelihood (ICBCL), Kathmandu, 2017.
Popular Articles	1. Countries Get Heads Up About Leafminer Invasion Thanks to Virginia Tech. <i>Growing America</i>. 3-9-18 2. Countries get heads up about tomato leafminer thanks to Virginia Tech VT News. 3-7-18 3. Countries get heads up about tomato leafminer thanks to Virginia Tech. <i>HortiDaily</i>. 3-12-18 4. Scientific Modeling Helps Defend Tomatoes Against Flying Foe. <i>Feed the Future Newsletter</i>. 5. Invasive Pest Modeling for <i>Tuta absoluta</i>. <i>Virginia Tech Biocomplexity Institute</i>
Promotional Materials/Pamphlets	
Videos	1. Virginia Tech's Biocomplexity Institute and IPM Innovation Lab collaborate on specialized online project management tool
Posters/ Presentations	

Ecologically-based Participatory IPM Packages for Rice in Cambodia (EPIC)	
Refereed Journal Articles	1. Flor, Rica, Kraus, Emily, Then, Rathmuny, Kong, Parameas, Stuart, Alexander. Working with Cambodian rice farmers to combat a plague of rodents. <i>Rice Today</i>. 2. Flor, Rica Joy, Chhay, Kry, Sorn, Vichet, Maat, Harro, Hadi, Buyung Asmara Ratna. The Technological Trajectory of Integrated Pest Management for Rice in Cambodia. <i>Sustainability</i>. 3. Stuart, A.M., Kong, P., Then, R., Flor, R.J., Sathya, K. (in press) Tailor-made solutions to tackle rodent pests of rice through community-based management approaches in Cambodia, Crop Protection 4. Flor, R.J., H. Maat, B.A.R. Hadi, V. Kumar and N. Castilla. xxxx. Do field-level practices of Cambodian farmers prompt a pesticide lock-in? Field Crops Research (accepted, minor revision)
Other Journal Articles	1. (Book) Heinrichs, E.A., F. Nwiline, M. Stout, B.A.R. Hadi, and F. Thais. 2017. Rice insect pests and their management. Burleigh-Dodds.
Conference Papers	1. Flor, R. Lock in mechanisms affecting Integrated Pest Management in Cambodia. Paper presented at the 5th International Rice Congress, Singapore. October 2018.

	2. Stuart, A.M., Kong, P., Then, R., Flor, R., Sathya, K. 2018. Stuart, A.M., Kong, P., Then, R., Flor, R., Sathya, K. 2018. Reducing rodent damage to rice in Cambodia through ecologically-based rodent management approaches tailored to local conditions. 4th International Rice Congress, Singapore. 15-17 October, 2018. 3. Stuart, A.M., Kong, P., Then, R., Flor, R., Sathya, K. 2018. Reducing rodent damage to rice in Cambodia through ecologically-based rodent management approaches tailored to local conditions. 6th International conference on rodent biology and management, Potsdam, Germany. 3-7 September, 2018. 4. Flor, R., Then, R., Hadi, B.A.R. 2018. Can Adaptive Research approach facilitate innovation process for Integrated Pest Management in Cambodia? Paper presented at the 1st International CESAIN Conference. Phnom Penh. 10-11 January 2018. 5. Flor, R. Hadi, B., Maat, H. 2018. Convergence and divergence of IPM and Agroecology: Implications for further development of IPM in Cambodia. Paper presented at the Sustainability and Development Conference. Ann Arbor, Michigan, 9-11 November 2018. 6. Flor, R. 2017. Developing Ecologically based participatory IPM package for rice in Cambodia. Presented at the ALISEA Conference, Siem Reap Cambodia. November 2017. 7. Flor, R., Chhay, K., Sorn, V., Maat, H., and Hadi BAR. Analysis of lock in mechanisms. Paper Presented at the 23rd European Seminar on Extension and Education, Chania, Greece. July 2017.
Popular Articles	1. Flor, Rica, Kraus, Emily, Then, Rathmuny, Kong, Parameas, Stuart, Alexander. 2018. Working with Cambodian rice farmers to combat a plague of rodents. <i>Rice Today</i>. 2. Giving Cambodian Youth a taste of rice science. News article at IRRI News. 13 March 2018.http://news.irri.org/2018/03/giving-cambodia-youth-taste-of-rice.html 3. IRRI. 2017. Cambodian farmers participate in cross-site visits to learn about Integrated Pest Management practices. IRRI News 22 November 2017. 4. IRRI. 2016. On-farm research trials ramped up in Cambodia to reduce pesticide use in rice farming. IRRI News, 7 December 2016. 5. IRRI. 2016. Biological control agents are farmers' friends. IRRI News 29 September 2016. 6. IRRI. 2018. EPIC: A new partnership for rice pest management in Cambodia. Rice Today November 2016.
Promotional Materials/Pamphlets	
Videos	

Posters/ Presentations	1. Sumner, D. (2018). Gender-focused Evaluation in the IPM Innovation Lab: The Most Significant Change Technique and Agricultural Technology Assessment. (Training Workshop Presentation). Gender-focused evaluation Training Workshop, Phnom Penh, KH, December 2018. 2. 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. 3. 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. 4. 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. 5. <u>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.</u> 6. 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 7. “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. 8. 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 9. Buyung Hadi, EPIC Adaptive research platform, presentation at EPIC annual meeting, Phenom Penh, December 2016. 10. Buyung Hadi, EPIC: A new partnership on participatory development of rice IPM in Cambodia, presentation in front of H.E. Ty Sokhun, Cambodian secretary of state and delegates, IRRI, Los Banos, February 21 2017. 11. Chou Cheythirith, Training program and extension materials on rice IPM – GDA perspective, presentation at EPIC annual meeting, Phenom Penh, December 2016.
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	12. Harvey Reissig, Sydni Jackson, Kean Makarady, Alpy Math, and George Norton, Preliminary Summary of Results from Rice Baseline and Pesticide Survey, presentation at EPIC annual meeting, Phenom Penh, December 2016. 13. Keam Makarady, Training program and extension materials on rice IPM – NGO perspective, presentation at EPIC annual meeting, Phenom Penh, December 2016. 14. Khay Sathya, Nancy Castilla, Rice Crop Health Survey: Preliminary Results, presentation at EPIC annual meeting, Phenom Penh, December 2016. 15. Rica Flor, Baseline survey for impact assessment, presentation at EPIC annual meeting, Phenom Penh, December 2016. 16. Rica Flor, Developing an Ecologically based Participatory (IPM) Package for Rice in Cambodia (EPIC) Project and partnership with GIZ, presentation at GIZ operational meeting, February 28 2017 17. Rica Flor, Developing Ecologically-based Participatory IPM package for rice in Cambodia: Participatory approaches, presentation at ALISEA general meeting, March 21 2017 18. Rica Flor, EPIC learning alliances, presentation at EPIC annual meeting, Phenom Penh, December 2016. 19. Hadi, B.A.R., Flor R., Stuart A., Kumar, V., Castilla, N. 2018. Opportunities and constraints for ecologically-based pest management of rice in Cambodia. Agroecology Futures Regional Forum, 2018, Siem Reap, Cambodia. 20. Hadi, B.A.R. 2018. Start at the end: co-designing conservation biocontrol scheme with SE Asian Farmers. IV Annual Food Security Symposium at University of Illinois, Urbana-Champaign, 2018. Urbana-Champaign, IL, USA. 21. Then, R. 2018. Safe use of pesticides. Training on pesticide safety and PERSUAP for all project cooperating farmers and extension partners. Battambang, Prey Veng, Kampong Thom and Takeo. October 2018. 22. Flor, R. 2018. Social Research Methods. Training provided to staff of GDA, Phnom Penh, 23-24 May 2018 23. Flor R., Then R. 2017. Participatory Impact Pathways Assessment (PIPA): Sharing on EPIC and EPIC Technologies. Slides presented as part of PIPA workshop in Battambang, K.Thom, Prey Veng and Takeo. May 2017 24. Hadi, B.A.R. 2017. Ecological engineering in tropical rice systems. Entomological Society of America annual meeting, 2017. Denver, CO, USA. 25. Hadi, B.A.R. 2016. Designing pest-resilient rice ecosystems”. International Congress of Entomology, 2016. Orlando, FL, USA.
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	26. Kraus, E. Life cycle of (hemimetabolous and holometabolous) insects. Posters presented at the STEM Conference organized by USAID Cambodia Mission. Phnom Penh, 1-3 March 2018. 27. Hadi, B., Cheythirith, C. 2018. Entomopathogenic fungi and botanical insecticide for rice insect pest management. Poster presentation for the CESAIN Conference, January 2018. 28. Sathya, K., Castilla, N.P., Hadi, B., Stuart, A., Somany, S., Kumar, V. 2018. Characterization of cropping practices, pest constraints, and yield variation in irrigated lowland rice of Cambodia. Poster presented during the 5th International Rice Congress, October 10-15, 2018. Singapore. 29. Hadi, B.A.R., Flor R., Stuart A., Kumar, V., Castilla, N. 2018. Ecologically-based, Participatory IPM for rice in Cambodia. Poster presented during the 5th International Rice Congress, October 10-15, 2018. Singapore.
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Management Entity	
Newsletters/ Reports	1. Fall 2018 Newsletter 2. Summer 2018 Newsletter 3. Spring 2018 Newsletter 4. Winter 2017 Newsletter 5. Fall 2016 Newsletter 6. Summer 2016 Newsletter 7. Spring 2016 Newsletter 8. Fall 2015 Newsletter 9. Pest Risk Assessment of the Fall Armyworm, <i>Spodoptera frugiperda</i>, in Egypt. A document prepared by the IPM IL team to the USAID mission, Egypt. 10. IPM Innovation Lab 10-Year Special Report. 11. 3 Year Book 12. IPM Innovation Lab Annual Report (FY 2018) 13. IPM Innovation Lab Semi Annual Report (FY 2018) October 1 2017-March 31 2018 14. IPM Innovation Lab Annual Report (FY 2017) October 2016-September 2017

	15. IPM Innovation Lab Semi Annual Report (FY 2017) October 2016-April 2017 16. IPM Innovation Lab Spring 2016-Fall 2016 (FY 2016) Semi-Annual Report 17. IPM Innovation Lab Fall 2015-Spring 2016 (FY 2016) Semi-Annual Report 18. IPM Innovation Lab Fall 2014-Spring 2015 (FY 2015) Semi-Annual Report 19. IPM Innovation Lab Work Plan 2017-2018 20. IPM Innovation Lab Work Plan 2016-2017 21. IPM Innovation Lab Work Plan 2015-2016 22. IPM Innovation Lab Work Plan 2014-2015 23. Eggplant Package 24. Onion Package 25. Tomato Package 26. Crucifers Package 27. Pepper Package 28. Beans Package 29. POPs Manual
Refereed Journal Articles	1. Rahman, M., B. Bagewadi, A. Fayad, A. V. Karasev, and R. Naidu. 2018. Molecular characterization of viruses in country beans (<i>Lablab purpureus</i>) in Bangladesh. International Congress of Plant Pathology, July 2018, Boston, MA, USA. (Abstract). 2. Das, S., B. Bagewadi, L. Sah, K H. Seng, A. Fayad, A. Karasev, and R. Naidu. 2018. Host-specific lineages of <i>Bean common mosaic virus</i> in Bangladesh, Cambodia, and Nepal. International Congress of Plant Pathology, July 2018, Boston, MA, USA. (Abstract). 3. Fayad, A. 2018. Overview of barriers and successes to transfer of agricultural technology. International Congress of Plant Pathology, July 2018, Boston, MA, USA. (Abstract). 4. Fayad, A. and C. E. Morris. Innovative pest control technologies for smallholder farmers: Cases from the field. International Congress of Plant Pathology, July 2018, Boston, MA, USA. (Abstract). 5. Fayad, A. and R. Muniappan. 2018. IPM Packages for Tropical Crops: How the IPM Innovation Lab help achieve food security in the developing

	world. Proceedings of the 9th International IPM Symposium., March 2018, Baltimore, MD, USA. (Abstract). 6. Fayad, A. and R. Muniappan. 2018. The spread and management of the South American tomato leafminer, <i>Tuta absoluta</i>. Proceedings of the 9th International IPM Symposium., March 2018, Baltimore, MD, USA. (Abstract). 7. Tefera, T., B. Sisay, J. Simiyu, R. Muniappan, and A. Fayad. 2018. Developing an IPM approach to the new invasive pest of the fall armyworm in Africa. Proceedings of the 9th International IPM Symposium., March 2018, Baltimore, MD, USA. (Abstract). 8. Rayapati, N. and A. Fayad. 2018. Managing virus diseases in vegetable and legume crops in Bangladesh, Cambodia, and Nepal. Proceedings of the 9th International IPM Symposium., March 2018, Baltimore, MD, USA. (Abstract). 9. Fayad, A. and A. Adhiga. 2017. Monitoring the spread and management of <i>Tuta absoluta</i>. (Meeting Report). Current Science 113: 844-845. 10. Fayad, A., R. Muniappan, and L. Sah. 2017. A model for sustainable IPM technology transfer in Nepal (Abstract and Poster, APS 2017 Annual Meeting). 11. Bagewadi, B., K. Nagendran, R.B. Khadka, G. Karthikeyan, Md. S. Hossain, L. Shah, A. Fayad, and R. Naidu. 2017. <i>Zucchini tigré mosaic virus</i>, an emerging potyvirus in cucurbit vegetables in South Asian countries (Abstract and Poster, APS 2017 Annual Meeting). 12. Rayapati, N. and A. Fayad. 2016. Management of emerging plant virus diseases for food and nutritional security in subsistence agriculture. The Emerging Plant Disease and Global Food Security Symposium. North Carolina State University, Raleigh, NC (Abstract and Digital Poster). 13. Fayad, A. 2015. IPM Innovation Lab: Renewed commitment to Africa and Asia. Entomological Society of America Annual Meeting, Minneapolis, MN (Abstract). 14. Fayad, A. and R. Muniappan. 2015. Integrated pest management for developing countries in Africa and Asia. Entomological Society of America Annual Meeting, Minneapolis, MN (Abstract). 15. Rayapati, N., B. Bagewadi, N. Krishnan, S. Paudel, M. S. Hossain, K. Gandhi, and A. Fayad. 2015. Emerging vegetable and legume viruses in subsistence agriculture. Proceedings of the 5th conference of the International Working Group on Legume and vegetable Viruses. August 2015, Haarlem, The Netherlands. (Abstract) 16. Fayad, A and R. Muniappan. 2015. IPM Innovation Lab's IPM components and packages for tropical agriculture. Proceedings of the 8th International IPM Symposium., March 2015, Salt Lake City, Utah, USA. (Abstract) 17. Fayad, A., R. Muniappan, and G. Norton. 2015. Feed the Future Innovation Lab for Integrated Pest Management: ecological systems-based
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Posters/ Conference	1. The IPM Innovation Lab won the XVIII International Plant Protection Congress in Excellence Award.

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	2. Global Agricultural Productivity Report enables Virginia Tech College of Agriculture and Life Sciences to expand its global reach. <i>VT News</i>. 12-2-18 3. Virginia Tech teams up with researchers in Niger to improve livelihoods. <i>VT News</i>. 11-26-18 4. Virginia Tech to host gender and international development conference. <i>VT News</i>. 10-29-18 5. Value-Added Food and Processes: Biocontrol Opens New Prospects in the Sahel. <i>Agrilinks</i>. 10-24-18 6. Center for International Research, Education, and Development names communications director. <i>VT News</i>. 10-17-18 7. How Science and Extension Services Benefit from International Collaboration. <i>Agrilinks</i>. 9-24-18 8. Fall Armyworm's Arrival in India Sparks Fear of its Spread Through Asia. <i>Earth Island Journal</i>. 8-20-18 9. March of the Armyworm. <i>Earth Island Journal</i>. 6-6-18 10. IPM Innovation Lab Presents Webinars on Neem and <i>Trichoderma</i>. <i>IAPPS Newsletter</i>. 9-1-18 11. BIFAD Award for Scientific Excellence. <i>IAPPS Newsletter</i>. 9-1-18 12. Student from Niger with ties to Virginia Tech wins major award. <i>VT News</i>. 3-15-18 13. Virginia Tech provides key intel in U.S. an Egyptian-led battle against a major pest. <i>VT News</i>. 3-30-18 14. Using Integrated Pest Management to Reduce Pesticides and Increase Food Safety <i>Agrilinks</i>. 3-6-18 15. Virginia Tech scientist edits new integrated pest management book. <i>Virginia Tech News</i>. 16. Virginia Tech program leads international workshops on destructive tomato pest. <i>Virginia Tech News</i>. 17. Helping the World Grow Better. <i>Virginia Agriculture</i> 18. Virginia Tech expert tapped for United Nations work in Saudi Arabia. <i>Virginia Tech News</i>. 19. Virginia Tech scientist works to control insects that attack Niger's most important food crop. <i>Virginia Tech News</i>. 20. Tomato pest devastating to crops. <i>News-press.com</i> 21. You say tomato, these moths say dinner. <i>The New York Times</i>
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	22. The Coming Tomatocalypse: Could a Tiny Moth Make Ketchup Scarce? <i>Civil Eats</i> 23. Why We Love Science. <i>The Huffington Post</i> 24. Muniappan: Note to Virginia agriculture: Invasive pests edge closer to America's shores. <i>Richmond Times-Dispatch</i> 25. Africa's Big Tomato Pickle: Miner Grubs are Wiping Them Out. <i>Bloomberg</i> 26. Virginia Tech Researcher Sounded Alert on Nigeria's 'Tomato Emergency.' <i>VT News</i> 27. 7 Tips to Keep Pests –and Pesticides–out of Your Garden. <i>Growing Virginia</i> 28. Ag Life: Moths threatening tomato crops. <i>Virginia First</i>. 29. Innovation Lab Launches Preemptive Strike Against Destructive Insect in Nepal. <i>Agrilinks</i>. 30. Virginia Tech Gets Jump on Destructive Pest in Nepal. <i>August Free Press</i>. 31. Invasion of the Tomato Leafminer. <i>Scientific American "Food Matters" Blog</i>. 32. Sowing the Future. <i>Virginia Tech Research magazine</i>. 33. Virginia Tech program receives grant to improve agriculture in developing countries. <i>WSLS10</i>. 34. Virginia Tech awarded \$18 million to implement integrated pest management program in developing countries. <i>Digest Project – Feed the Future Innovation Labs and Collaborative Research Support Program</i>. 35. Virginia Tech Feed the Future Lab awarded \$18 million in funding. <i>Collegiate Times</i>. 36. Virginia Entomologist Honored for Work in Tropical Agriculture. <i>India West</i>. 37. "Fresh" News from the World Vegetable Center
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Appendix 5: Trip Report of S. Shanmugasundaram (Sundar) and Jacob Ricker-Gilbert to Virginia Tech; Blacksburg, VA.

DATE: December 9 to 12 (including travel dates). Meeting dates Dec. 10 and 11.

LOCATION: IPM IL office at VT, Blacksburg

On Dec. 9 I was supposed to travel from Newark to Charlotte, NC and then from there to Roanoke, VA. Due to heavy snow and bad weather flights to Charlotte, NC was cancelled. So, I flew from Newark to Dulles, Washington. The flight to Roanoke was cancelled and rescheduled to mid-day. But around noon the airlines cancelled that flight as well due to bad weather and re-booked me for a flight the next day morning. I checked in to a hotel for the night and the following day the flight left on time and arrived around 10 am. My review team member, Jake arrived about an hour earlier and was waiting at the airport so that we can take the same taxi to Blacksburg and got settled in the hotel. Around noon Muni came to the hotel and picked us up and went to CIRED office for the meeting. Due to bad weather, the offices of VT were closed for the morning. The meeting started at around 1:00 pm.

The list of people who participated in the meeting in person and through conference call:

Dr. Van Crowder, Executive Director, CIRED, Virginia Tech Univ. (VT).

Dr. Rangaswamy Muniappan, Director, IPM IL

Dr. Amer Fayad, Associate Director, IPM IL

Dr. Lawrence Datnoff, Chair, TAC, IPM IL (Conference call)

Dr. Dely Gapasin, Member TAC, IPM IL

Dr. Hanh Tran, Co-PI Fruit crops IPM in Vietnam

Dr. Abhijin Adiga, PI, Invasive species modeling project, VT

Ms. Zara Shortt, Finance Coordinator, IPM IL

Dr. Wondie Mersie, PI *Parthenium* project (Conference call)

Dr. George Norton, PI Vegetable crops IPM for Asia

Mr. Daniel Sumner Gender

Ms. Sara Hendery, Communications Coordinator, IPM IL

Dr. Jacob Ricker-Gilbert, External Review Team member

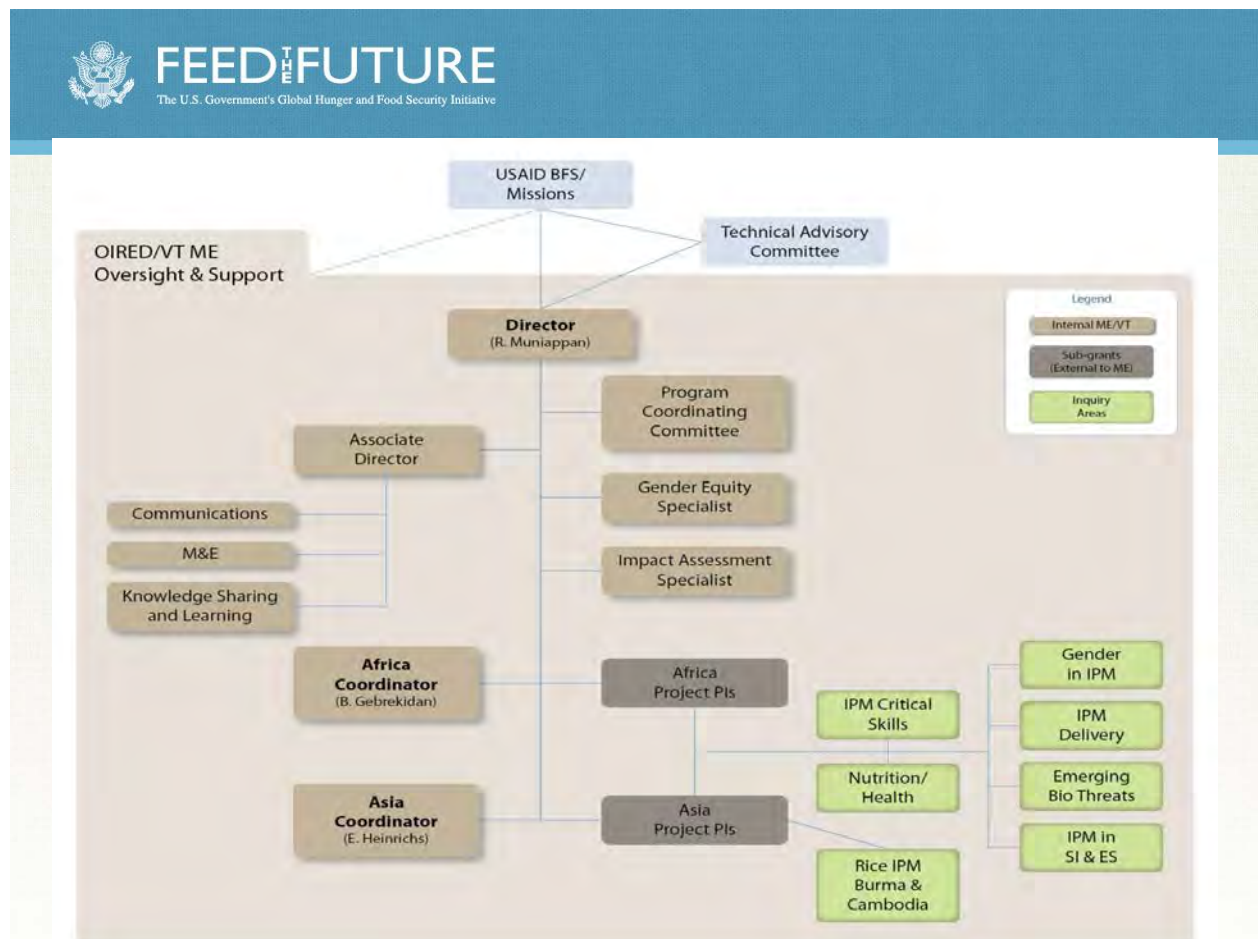
Dr. S. Shanmugasundaram, External Review Team Member and Leader.

Presentations and discussions:

1. Dr. Van Crowder, Executive Director for Center for International Research, Education and development (CIRED) opened the meeting and welcomed all the participants. Dr. Crowder has worked in the US State Millennium Challenge Corporation and has considerable experience in handling international research, education and development activities. Previously CIRED was Office for International Research, Education and development (OIRE). His office handles \$77 million worth of 37 global projects in 17 countries. Some of the large projects are in: Senegal, Afghan Agricultural Innovation, USAID Honduras, (Youth), and MCC Vegetables in Guatemala. IPM IL is one such global projects supported by USAID since 1993 (when it

was called IPM Collaborative Research Support Program (CRSP). CIRED provides office facilities, administrative (including fiscal management) and logistical support for IPM IL. CIRED also lobbies for the IPM IL both within Virginia Tech University (VT) system and outside. The upper echelon of the VT (Vice President for Outreach and International Affairs) is also very supportive of IPM IL. For example, VP for Outreach and International Affairs has provided US\$50,000/- for IPM IL to enhance its activities. Dr. Crowder is very proud and enthusiastic about the project and he participated in the one and half day review exercise and was very helpful in answering the reviewers' questions and comments. In the structure of IPM IL (Fig. 1) CIRED is connected with a dotted line which appears as if it has minor relations with IPM IL. However, the reviewers feel that CIRED is an integral part of IPM IL. CIRED helps in the effective and efficient administration of IPM IL by providing their infrastructure and personnel resources. **Therefore, the reviewers recommend a solid line from CIRED to the IPM IL. The current structure in Fig. 1 is complicated by the inclusion of inquiry areas and projects. Furthermore, in the light of termination of Asia and Africa Managers the review team recommends a revised structure.**

Fig. 1. Original Structure of IPM IL



2. Dr. Rangaswamy Muniappan, Director, IPM IL presented a historical perspective of IPM IL. The first phase of IPM CRSP ran from 1993-1998, followed by the second phase 1999-2004; third phase from 2005 -2009 was competitive followed by the fourth phase 2009-2014; and the current fifth phase from 2014-2019 was competitive. The current phase initially included 7 countries (Fig. 2).

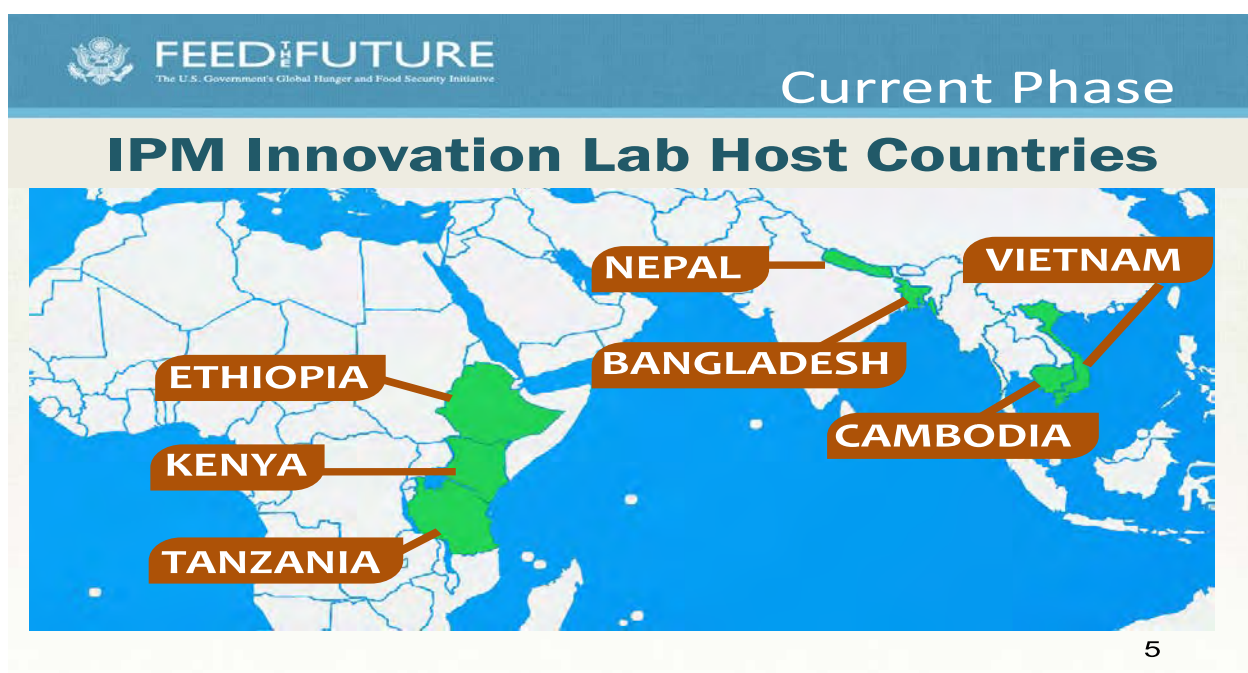


Fig. 2. IPM IL host countries in the current phase.

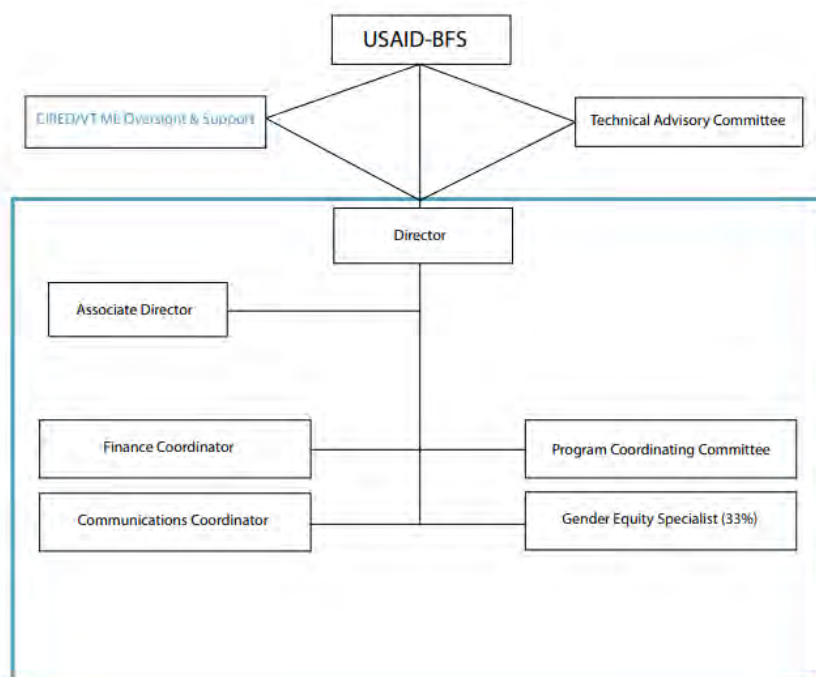


Fig. 3. Revised structure of IPM IL ME

The structure of the Management Entity (ME) shown in Fig. 1 appears to be all inclusive. The review team would like to suggest a simple organogram of the current status of the ME as shown in Fig.3.

The agreement officer's representative (AOR) for USAID is Dr. John Bowman. AOR is constantly in touch with the Director of IPM IL, reviewing, monitoring, advising and assisting in the progress as well as the smooth operation of the IPM IL. A technical advisory committee (TAC) has been instituted whose task is to provide clear guidance and direction for the research and development activities based on the goal and objectives of the project. They help the ME in the development of their work plans, review the awards, review and recommend project proposals from various collaborators for potential sub-awards, review the ongoing projects, participate in the annual meetings and provide suggestions to improve the implementation of the projects to achieve the objectives. The TAC consists of five members with diverse expertise and from diverse institutions. The current TAC members are:

Dr. Lawrence Datnoff, Chair, Dr. Dely Gapasin, Dr. Glen Hartman, Dr. Sunday Ekasi and Dr. R. Srinivasan. The ME and the AOR are happy and pleased with the current group of TAC members and their contribution to the success of the IPM IL.

Currently, the ME of IPM IL consists of Director (Dr. Rangaswamy Muniappan), Associate Director (Dr. Amer Fayad), Ms. Zara Shortt (Finance Coordinator), Ms. Sara Hendery (Communications Coordinator) and Mr. Daniel Sumner (Gender Coordinator).

The following are the current eight projects of IPM IL:

<u>Projects</u>	<u>Principal Investigators</u>
1. Exportable fruit crops IPM-Vietnam	Hoa Nguyen Van
2. <i>Parthenium</i> biocontrol-East Africa	Wondi Mersie
3. Biodiversity and climate change-Nepal	Pramod Jha
4. Vegetable crops and mango IPM-Asia	George Norton
5. Modeling of invasive species dispersal	Abhijin Adiga
6. Rice IPM-Cambodia	Buyung Hadi
7. Vegetable crops IPM-East Africa	Luis Cañas
8. Rice, maize and chickpea IPM-East Africa	Tadele Tefera

Of the above, three projects are for Africa and four projects are for Asia and one project is global. The following four Principal Investigators (PI) are from US institutions: Wondie Mersie from Virginia State University, George Norton and Abhijin Adiga are from Virginia Tech University, and Luis Canas from Ohio State University who replaced John Cardina from the same university. Two PIs from International institutions are: Buyung Hadi, International Rice Research Institute (IRRI) and Tadele Tefera, International Center for Insect Physiology and Ecology (*icipe*). Two PIs are from the partner country institutions: Hoa Nguyen Van, Southern Horticultural Research Institute (SOFRI) and Pramod K. Jha, Tribhuvan University, Nepal. Each of the projects have sub-awardees in the U.S. as well as in collaborating countries with Co PIs and collaborators.

Basic and applied research are conducted by the project scientists, research scientists from US institutions and National partner country scientists. The development and adoption of technologies

developed have been moved for adoption by farmers with the help of extension agents, private sector and lead farmers.

Crops and countries are chosen by the USAID for IPM IL. If the ME needs to change crops or countries then they have to discuss with AOR and get his/her approval. The IPM IL addresses the IPM of the following crops: Maize, rice, chickpea, (grain crops), tomato, onion, African eggplant, cabbage, cauliflower, cucurbits, chilies, and beans (vegetable crops), dragon fruit, mango, longan and lychee (fruit crops).

The following two projects focus on participatory biodiversity and climate change assessment for IPM in Nepal and invasive species modeling for South American Tomato leafminer and groundnut leafminer.

IPM packages include a whole range of recommendations beginning with good agricultural practices (GAP), resistant varieties, grafting to resistant root stock, use of vesicular arbuscular mycorrhiza (VAM), Trichoderma, pheromones, predators, parasites, Nuclear Polyhedrosis Virus (NPV), *Metarhizium* and *Beauveria*, *Bacillus thuringiensis* (BT), “greener pesticides” such as neem seed oil extract, pyrethrum extracts, nicotine, rotenone, etc., and trap crops, yellow sticky traps, repellent crops, staking, mulching, protected cultivation and any other method that will be environmentally friendly, ecologically viable, economically attractive and user friendly are all included. The IPM packages are crop specific, location and season specific and therefore there is no one universal solution for any one crop or a group of crops. Therefore, the IPM packages need to be tailored to meet the needs of specific location, season and crop. They also need to be modified to adjust to the situations. Farmers may not use all the recommendations. The IPM IL recommends the judicious use of the IPM technologies to control the specific pests. The main focus of the current IPM IL is regionalization and globalization of the IPM packages for grain crops, vegetables and fruits.

The Africa Manager (Coordinator) and Asia Manager (Coordinator) positions were terminated in 2016 and 2017 respectively due to budgetary reasons. The IPM IL has also terminated a sub-award to the City University of New York in September 2017 due to non-performance.

IPM IL terminated a collaborating retired scientist from University of Florida 2017 since he was not familiar with the subject matter and another Collaborating scientist from University of Minnesota, in 2018, who is too busy to get involved in the project. Although the IPM IL commenced in 2014, termination of the CUNY sub-award also took three years. Similarly, the termination of the retired Univ. of Florida scientist took three years. It was clarified that in 2015 RFAs for sub-awards were released and it took a year or more to evaluate the performance of projects and individuals. The ME also has to follow the protocol and get the approval of TAC, AOR and AO before a project can be terminated

IPM IL activities include long-term (B.S., M.S., and Ph.D. degree and post doc training) both within the country and outside the country, and short-term training for extension agents, technicians, private sector, lead farmers and farmers. The review team commends the ME in making serious efforts to increase the scientifically and technically trained manpower at all levels in various countries in large numbers who will help to sustain the IPM IL in the long run.

IPM IL has also brought awareness of the pests such as Tomato leafminer, *Tuta absoluta*, *Parthenium* weed, papaya mealybug, groundnut leafminer, witches' broom of Longan through workshops and trained the local people the IPM packages to manage the above pests. Awareness was also created through national, regional and international workshops and symposia on the threat of invasive species such as *Parthenium* and Fall Armyworm (FAW) and the need to address the IPM solution to these threats before it is too late. Webinars were also conducted. By organizing various workshops, national, regional and international conferences IPM IL has brought awareness at appropriate time to take proper action to address the serious problem of invasive pests, diseases, and weeds problem.

Pesticide Evaluation Report and Safer Use Action Plans (PRESUAP) have been established for *Tuta absoluta*, fall army worm, fruit crop pests in Vietnam, rice in Cambodia, vegetable crops in Bangladesh, Cambodia Nepal in Asia and Ethiopia, Kenya and Tanzania in Africa.

Ten impact assessment studies were conducted in various countries in Asia, Africa and Central America and the net returns vary from 3 to 6 million in Bangladesh for pheromone traps for cucurbits to an impressive, 500 to 1340 million for the mealy bug control in papaya, cassava and mulberry in India.

There was a buy-in from Egypt and an award from the Vice president for International Affairs for the IPM IL. There is also an award from the President of the Haramaya University in Ethiopia. A number of questions to Dr. Muniappan clarified a number of points. Some suggestions were made by the reviewers and they will be included in the review report.

The IPM IL team has published high quality research papers in reputed international refereed journals, national refereed journals, popular magazines, newspapers and local media in the US and within the countries. The IPM IL has an excellent web page, publishes Newsletter and periodic success stories through pamphlets. These are excellent.

9. Abhijin Adiga, PI Invasive species modeling project.

This project is implemented from VT. It aims to produce a high resolution, interaction based approach to modeling which includes diverse environmental and biological interactions. The system is expected to provide reasons for pest spread, early detection, early warning, informing prevention and mitigation efforts, crisis options in near real time and economic impact which will impact policies and control measures. They will also help identify hot spots. The economic impact will also focus on direct and indirect loss, consumer surplus, producer surplus, and social cost. The team has multi-disciplinary expertise and has sought the cooperation of and data from INRA, CIRAD (France), ICAR (India), and North Carolina State university. Modeling was aimed at two invasive species, South American Tomato Leafminer (*Tuta absoluta*) and Groundnut Leafminer (*Aproaerema modicella*). The team has published a number of quality papers in reputed journals which will be valuable for the scientific community. It will be interesting and valuable if the modeling can predict the movement of the pest, forecast and warn the arrival of the pest, so that the countries can be forewarned and they can prepare to take necessary actions to prevent catastrophic damage to the crops. In order to make such predictive modeling a large volume of data, from various agro-ecological zones, on weather, pest dynamics, hosts' presence, alternative hosts, predators and parasites of the pests, pesticide use, are all needed. They are not easily

available and most of the times they are not there. Therefore, the computer modeling has to assume a lot of things. As a result, the robustness and value of the model is questionable.

One of the key questions was whether the team has the required amount of data to develop a meaningful model which can provide a reliable and predictable information. The team stated that is one of the problems in this type of study. Under this pretext, one need to question the use of such studies under this project. The review team also learned that the whole research team from this unit has moved from VT to University of Virginia. As a result, the IPM IL ME is processing to transfer the project from VT to UV. **The review team recommends that if the IPM IL continues for the next phase the modeling project should be critically reviewed and its usefulness to meet the goals and objectives of the IPM IL be carefully evaluated before the project is considered for inclusion.**

10. Hahn Tran, Co-PI fruit crops IPM in Vietnam.

The major exportable fruit crops in Vietnam are: dragon fruit, mango, longan and lychee. Pests and diseases are major problems and farmers spray pesticides and therefore, pesticide residue is the key problem. IPM IL aims to manage the pests, diseases and weeds through ecologically-based IPM package of practices.

Dragon fruit is grown in about 36,000 ha producing 14,000 t per year. The fungus *Neocytalidium dimidiatum* (fungus) causes canker. The problem is serious during the wet season. White plastic sleeves are used to cover the fruits and it is very effective. Each sleeve costs around 300 VND (US one cent) and can be reused three or four times. Other bags cost around 800 to 5000 VND per bag. The number of insecticide sprays in 52 to 55 days were reduced from 35 sprays to 5 sprays. Bagging also reduces the infestation by stink bugs and fruit flies. The yield is 67% more than the un-bagged trees. Mangoes were also bagged to manage the canker and fruit flies. Mangoes are grown in about 90,000 ha in Vietnam.

In 2015 Vietnam earned \$100 million by exporting Longan. It is the second most important exportable fruit crop after Dragon fruit. Longan is susceptible to fruit borer, stink bugs and fruit flies. Ninety per cent farmers use pesticides. One gallon mesh plastic bags are used to cover the fruits 15 days after fruit set. Farmers reduced the pesticide sprays to only 3 or 4 times. Profit increased by 7%. Most plastic bags attached to lights serve as light traps to attract fruit borers and stem borers as well as to monitor the pests. In Lychee, a pesticide approved by USDA has been used and the yield increased by 11.2%. Wax paper bagging is recommended for pre-harvest insects such as fruit flies, leaf hoppers, fruit borers and thrips and diseases such as anthracnose.

Ms. Hahn came to VT IPM IL to improve her English communication so that she can communicate better and write better scientific papers in reputed journals. Further she can improve the research techniques. Along with Dr. Muniappan she was able to identify for the first time the cause of the witches' broom disease as an *Eriophid* mite which is a new species and they have named the species after her. A lot of women are involved in fruit production and export in Vietnam.

Based on the observations in Vietnam and other countries there are a number of private sector agents such as seed dealers, pesticide companies, fertilizer distributors and even lead farmers are becoming small entrepreneurs in undertaking the multiplication and distribution of IPM components. Empowering the private sector including the enterprising farmers (a lot of them are women farmers) to take the leadership and ownership in extending the appropriate IPM technology will speed up the adoption and lead to sustainability. **Therefore, the review team**

recommends that the IPM IL serve as a catalyst to encourage and bring together all the private IPM component producers and distributors in Asia and Africa and enable them to organize an Association of IPM Component Producers and Distributors in Asia/Africa. The name of the association can be flexible as long as it can be established in the same lines as the Asia Pacific Seed Association (APSA) which was started in 1993 from a small group by Dr. Morgan Lamonius from Denmark who worked for FAO in Bangkok. But APSA today has a large membership and they also support research by National and International institutions.

11. Dely Gapasin, TAC member

The perspective of IPM IL from the Technical Advisory Committee (TAC) member's views were presented. The IPM IL has evolved over time based on changing environment. She emphasized the need for partnership with small businesses, need to encourage and involve more women. The reviewers asked about the terms of reference, the role, the issues encountered, specific recommendations of the TAC for the future of IPM IL, TAC's frequency of meeting, travel and participation and the future role of TAC based on past experience. She explained that the role of TAC is advisory. They participate in annual review and undertake site reviews. Except some minor issues such as the termination of some projects, termination of regional managers there are no serious issues. Receipt of timely funding from the USAID is mentioned as one of the serious issue at all levels that affect the whole implementation of IPM IL. She has undertaken a review of East Africa and the report highlights the findings. She has also given recommendations. The Push-Pull technology has large women participation in Ethiopia and Kenya. Since 2014 the CGIAR and NARS compete for the sub-awards. The economic analysis should be conducted by projects. The impact should be by commodity and adoption of technologies should be at national level, policy level and farmers' level. It appears that modeling project benefits USA. Otherwise it is rather difficult to justify the modeling project in the IPM IL. Reactions to reviews are discussed and adjustments in the work plans are made accordingly. TAC spends about 20 to 25 days in a year for the IPM IL. A policy manual as a guide to the PIs and collaborators will be useful. **The review team concurs with Dr. Dely Gapasin and recommends that the ME make aware of the availability of a policy manual as a guide to the PIs, and all collaborators.**

12. Zara Short, Web Portal

IPM IL web portal v 2.0 for subscribers only is organized to have the Program, Proposals, sub-proposals, trip reports, travel requests, approval, annual report, and data set submission and sharing. Each location has a maximum space allocation. It is in word, Excel and pdf.

PIs submit the draft report to IPM IL. IPM IL collate PI report and submit to AOR/USAID. Trip report is available to anyone. Semi-annual report is ready in October and April. TAC reviews the work plan. Development of Data library and it goes to the USAID's repository of research data.

Request for Assistance starts with a concept note followed by call for the full proposal and selected full proposals are approved. Portal is funded by IPM IL project funds at a cost of US\$200,000 initial funding in 2014 and yearly operational expenses of approximately US \$30,000. The contact person is mandiwil@virginia.edu

13. Wondi Mersie PI *Parthenium* project, East Africa.

Parthenium is a serious weed in maize, sorghum, in wild life parks and in homestead areas in Ethiopia, Kenya, Tanzania, Uganda and South Africa. South Africa has done a lot of work and

used biocontrol agents effectively. Traditionally hand weeding is done to get rid of them. But the labor is scarce. People are also allergic to the weed and they get sick with respiratory problems. The weed releases toxic chemicals which causes mutagenicity and it has allelopathic effect on crops. The cattle that feed on this weed have off-flavor milk which fetches poor price and the meat is also of poor quality. IPM IL has identified two biocontrol agents- *Zygogramma bicolorata*, a beetle from Mexico that lays eggs underneath the leaves and the larvae feed on the leaves defoliating the plants; the second one is *Listronotus setosipennis*, which lays eggs on the flower buds and the larvae bore through the stem and the whole plant wilts and dies. IPM IL is also evaluating the following biocontrol agents as potential ones for future use: *Smicronyz lutulentus*, (a seed feeding weevil), *Carmenta* sp. (a day flying clear-winged moth), *Epiblemma strenuana* (a stem galling insect), and *Conotrachal* sp. *Zygogramma* is suitable for high rainfall areas while *Listronotus* is adapted to harsh conditions. Each *Zygogramma* beetle can eat about four to five leaves a day and in one month cycle they can devour the whole plant. In Ethiopia, the biocontrol agents have been released in four regions. Monitoring and evaluation is being conducted in released areas. It appears that a fungus attacks the *Zygogramma* which needs to be carefully examined. Initial studies have shown that the biocontrol agents have moved 100 meters from the released site.

Drought reduces the larvae production. The biocontrol agents do not completely destroy the weed. Instead the biocontrol agents and the weed co-exist keeping a balance and the weeds are kept at a very low level to cause any significant economic loss.

In the future, they would like to see Ethiopia to be the hub for sub-Saharan Africa region for *Parthenium* biocontrol research, training and development. Kenya and Uganda have diverse ecological zones. Diversity in biocontrol agents are yet to be studied. The Minister for Agriculture in Ethiopia strongly supports the *Parthenium* biocontrol program. Biocontrol rearing nurseries need to be established close to the problem areas. Six weeks after the release of the biocontrol agents in homesteads the grass comes back with only a few weeds. The biocontrol agent weakens the weed.

The review team recommends that diversity in biocontrol agents may be examined. The enemies of biocontrol agents may also be studied so that the biocontrol agents are not decimated by the enemies.

14. George Norton, PI Vegetable crops IPM for Asia

Nepal, Bangladesh and Cambodia are the three countries in Asia where this project has activities. The project also partners with Penn State University, Ohio State University, and Washington State University. The cooperators in Cambodia include Royal University of Agriculture (RUA), International Development Enterprise (IDE), and AVRDC- The World Vegetable Center. In Bangladesh, the collaborator is Bangladesh Agricultural Research institute (BARI), Mennonite Central Committee (MCC). In Nepal, it works with IDE.

The project focuses on tomato, eggplant, cabbage, cauliflower, beans, cucurbits, and onions. It also included mango in Bangladesh.

The major objectives are adoption of resistant varieties, different IPM practices, human resources and capacity building, evaluation of outcome and impact of gender, policies and regulations, conduct of short-term training, field days, bringing awareness of invasive species such as *Tuta absoluta*, tomato leafminer and *Spodoptera frugiperda*, the Fall Army Worm (FAW). The project conducts annual meeting in January-February when the crops are in the field.

Tuta absoluta workshop monitors the arrival of the pest. There are 12 farmer cooperators and 6 to 9 undergraduate students use the components of the study for their thesis. The pest is already in Bangladesh and Nepal. *Trichoderma* is imported from India but it goes bad due to transport, heat and other factors. In Nepal students survey 400 farmers who adapt at least two practices in the IPM package. IN Cambodia 400 farmers are used for a baseline survey. BAU has two Ph.D. students in Bangladesh. Maria Elisa Christie and her M.S. student Kaitlyn studied the households to determine who makes the decision within the households. Out of 2886 trainees 1563 are women. Therefore, the women participation is impressive.

Although, there are some difficulties the Sandwich studies program with BAU in Bangladesh benefits students from coming to US universities. In Nepal, the Sandwich program is not successful-the student took a job outside. One possibility is to train the students in India and South Africa. Tamil Nadu Agricultural University (TNAU) is one example.

For the future, Dr. George Norton feels that sticking with vegetables is better. He wonders whether we need to get involved with grains and fruits. The project should try to bring in more young people, infuse new blood and have a participatory approach with stakeholders in prioritizing the activities. Regulatory issue of bio-pesticides is a problem area. For example, it took four years to get Government regulation approved for pheromones (female hormone to attract males) in Bangladesh and Nepal. GTZ is working on the regulatory issue in Cambodia.

The review team sees merit in Dr. Norton's thoughts on the crops and recommends that the IPM IL ME and the AOR seriously consider focusing and concentrating on selected vegetable crops instead of diluting their efforts on other crops.

15. Lawrence Datnoff, Chair, IPM IL TAC

Through conference call the review team had discussion and briefing with Dr. Datnoff. *Parthenium* project is making good progress. Uganda has problem with the weed. He suggests that IPM IL regroup and expand the activity to Uganda. The TAC meets once a year to review the progress. TAC also helps in reviewing and screening project proposals and makes recommendations to the ME. He travelled with Dr. Norton to Bangladesh, Nepal, and Cambodia to observe and review the projects. In Nepal, the research plots are very well managed. They follow the guidelines and the IPM vs the control plots are very clear.

In Bangladesh, the presentations by the Ph.D. students were of very high quality. In the IPM package they are using grafting technology effectively, *Bacillus thuringiensis* (Bt), sticky trap, and biocontrol for various pests. Observed the students trained for research projects targeted for specific pests and crops. In Cambodia observed rice blast. Dr. Datnoff is happy with the diversity of TAC membership. He would like to see more travel for the TAC members. The CUNY project was dropped and it was a big one. The Tribhuvan University project in Nepal collaborates with Bio-complexity Institute. Biocontrol should develop specific business models with private enterprise as partners. He feels that there are lots of Innovation Labs but there is no formal mechanism for synergy.

Based on the observations and discussions the Review Team recommends that if possible in the formative stages of Innovation Labs, provisions and mechanisms may be formally included to enable synergy and collaboration between related ILs such as Hort IL, Sustainable IL, IPM IL, and Food Processing and Postharvest IL.

16. Amer Fayad, Associate Director, IPM IL Monitoring and Evaluation

IPM IL has a performance and monitoring plan in place. They have a policies and operating procedures manual (POPS). There is a proposal management system in the portal. Semi-annual and annual reports are required from all the projects. In the annual meeting the progress of the work is reviewed and measures were taken by the ME to correct or resolve the issues related to work plan and progress. Based on the progress made the new annual work plans are prepared and approved for the following year. The TAC meets once a year and reviews the progress and makes recommendations for the new work plans in the annual meetings. There are Feed the Future (FtF) indicators given by USAID and the performance evaluations are based on the FtF indicators. The capacity building includes the short-term training, long-term training, workshops and conferences. A gender specialist specifically assesses the gender impact. A variety of publications are constantly produced to update the scientific community, technicians, extension people, national partners, local community, traders, donors and policy people. The IPM IL web portal is also maintained and it provides all the information and it is frequently updated.

17. Ms. Paige Selvey, Senior Associate Director of Post award, The Office of Sponsor Program (Conference call)

The Office of Sponsor Programs (OSP) handles restricted, non-restricted contracts, pre-awards and post awards. OSP looks after both Federal and non-Federal awards. There is a negotiating team which is responsible overseeing the negotiation of awards. The system has an award review and set up phase. Then the accounting system and budget is set up so that the project can get going. There are budgeting guide lines.

Zara Shortt, financial coordinator of IPM IL works closely with CIRED and OSP at VT and Zara is very knowledgeable about the system and enables the system to run smoothly. VT applies an off campus overhead rate of 26% across their budgets which is based on their NICRA; each of the cooperating national partners applies either their own NICRA, a de minimum rate of 10%, or has chosen to direct charge expenses as applicable. OSP and IPM IL developed invoicing templates for 3 categories of sub-awards including US based, Host country based, and USAID delineated Public International Organizations (PIO). Depending on the type of sub-award the required expenditure documentation varies. For host country institutions, all receipts are required. For US and PIO sub-awards Zara does receipt sampling based on the invoices submitted. International travel is pre-approved with approval numbers being submitted for any invoices including international travel expenditures. This system serves as a check that international travel has been approved and included in the USAID approved travel matrix. Zara handles the receipts of the partners, sub-award invoices and submits to CIRED for approval and then passes on to OSP administrator at VT who reviews and raises questions if there are any. So, there are two sets of eyes for checks and balances. Statements are prepared on a monthly basis. Use of consultants and purchase of equipment are based on the terms of the contract. For international travel, approval to specific country is required based on federal requirement and global security. OSP reviews, asks questions and Zara clarifies. Zara provides quarterly expense break down report by country to John Brown and Charles Jackson. The US and PIO invoice template includes a section to report the expenditures by country. Expenditure is on a cost reimbursable basis. IPM IL provides guidelines for all the partners specifying expenditure categories, allowable and acceptable receipts, dates, description of the vendor and VT OSP includes these within the sub-award agreements. For countries in Asia and Africa where the language is different the receipts are a challenge and

educational. Translations are made with English descriptions either on backup documentation itself or in a detail listing included in the Host country and PIO invoice template.

VT provides a one time working capital advance to IPM IL collaborators when needed for typically for up to 60 days. The system is working very good as long as the USAID advances the funds in a timely fashion. This year there are delays which has complicated the partners research plans and affected the timely implementation of activities.

The reviewers congratulate and appreciate the efficient financial management of IPM IL with the help of experienced people at OSP at VT and excellent coordination from Zara at IPM IL.

18. Ms. Zara Shortt, IPM IL Budget. (Financial Coordinator IPM IL)

The budget flow is from USAID OSP and then to IPM IL. There is currently a total of 22 sub-awards and 11 sub-funds.

The total USAID funding for IPM IL is US\$18,000,000

The total for IPM IL ME 5,540,000

Program Total 12, 210,000

Africa and Asia 7,750,000

Rice in Cambodia 2,360,000

Biodiversity and modeling 2, 100,000

VT cost share 495,115

USAID usually allocates the funds based on the proposed budget. The annual allocation is around US\$3.6 million. There was a deficit of around US\$1.2 million in 2014-2015 and around UDS\$1.5 million in 2016-2017. The program is yet to receive funds for 2018-2019. Taking 2019 out of the picture the cut for the Program is around US\$2.6 million. It is unclear when the funds for 2018-2019 will be coming and how much will be cut. This causes uncertainty at the ME level and at the partners' level without funding the season is lost for planting the crops and conducting the trials.

In March 2018 due to restriction of funds for Ethiopia and Cambodia activities were cut but salaries were not cut. In Nepal, they have to let workers know two months in advance whether they will be paid. USAID wants the work done with or without funding. Excluding FY2019, the Management Entity is operating with a 30% cut in their original budget. Again, excluding FY2019, the overall project has taken a 20% cut to funding. Travels are reduced to tide over the cuts. Budget is linked with the work plan and aligned every year. Within projects adjustments are made for redistribution.

The review team once again congratulates Zara for her excellent management of the finances and budget enabling smooth operation and implementation of the work plan of IPM IL.

The review team recognizes the difficulties encountered by the IPM IL due to the budget cut of US\$1.2 million in the first year and US\$2.6 million so far, and as a result the program activities unduly suffered. The review team recommends that AOR and USAID appreciate the difficult circumstances the IPM IL implemented the activities in spite of budget constraints. Even under funding shortage both IPM IL and their partners have made significant progress and impact in Asia and Africa.

19. Dr. Amer Fayad presented on Gender

Increased recognition of women's contribution to agriculture is critical to achieve global food security (FtF 2012). The project tries to identify gender-based constraints, the women's ability to do various jobs, and the role of women in agricultural and household decision making. It also examines the inter-relationship between gender and IPM IL. The women of today are more empowered, more knowledgeable, and willing to take more responsibilities in household and agricultural activities as well as decision making. Due to the training provided by IPM IL to women farmers they are now armed with better technology which are less burdensome. There are some enterprising women farmers who have entered in to producing bio-pesticides and market them to other farmers. Women are able to make decision in IPM IL technology management to have a better return from the farm. IPM IL has enlisted a large number of trainees and nearly 50% of them are women. It shows the willingness of women to participate in learning to implement modern technology based pest control with health and environmental concern. In terms of institutional capacity building IPM IL has included a number of women for short-term and long-term degree training empowering with advanced knowledge and administrative as well as leadership abilities. There are exceptions to the above in some countries due to socio-cultural reasons which may change over time.

The review team recommends that IPM IL take a pro-active approach recognizing that the women of today are more advanced and progressive and they are making significant contribution to improve agricultural productivity, income generation and poverty alleviation working hand in hand with men both on-farm and off-farm activities and household decision making. IPM IL may like to analyze and capture the impact made by them in the impact analysis.

20. Ms. Sara Hendery, Communications Coordinator

IPM IL is in Facebook, Twitter, and has its own website. An IPM IL Newsletter is published 4 times a year and it provides informal updates of IPM IL activities. Periodical press releases are made with the approval of the Director of IPM IL. Articles are also published in local, regional and international Newspapers and magazines to have visibility. Magazines and Newspapers include, Scientific American, New York Times, Science Daily, Entomology Today. IPM IL participates in Agrilinks, conducted webinars (*Tuta*, *Trichoderma* and *Neem*) and produced videos and blogs. IPM IL also participated in international women's month March and has videos of it. The success stories of Nepal and Vietnam are publicized in local news spotlight in those countries. "Whatsapp" is used as a communication tool to help farmers identify the pest and adopt IPM Package of practices.

The review team appreciates the diverse avenues through which the information from IPM IL are disseminated and communicated to a wide array of audiences. **The review team recommends and encourages the communications office to tailor some eye-and attention-catching popular, brief, easy to read write ups on selected success stories specifically targeted to the donor agencies to attract funding for future research and development efforts.**

Other discussions:

For the future IPM IL would like to place emphasis on FAW. IRRI's US\$2.6 million project is aiming to decrease the use of pesticides in rice and rat control with traps in rice in Cambodia but the review team has not seen any meaningful output from this project. Successful technology

development award to University of California at Davis UC Davis) for the development of *Trichoderma* in Nepal and grafting in Bangladesh.

Appendix 1. IPM Innovation Lab Review Meeting December 10 and 11, 2018 Presenters/Contact/Presentation Sheet

1. Amer Fayad, Associate Director, IPM IL, afayad@vt.edu
Presentation: Monitoring and Evaluation and Gender Analysis
2. Van Crowder, Executive Director, Center for International Research, Education, and Development (CIRED), Virginia Tech
Presentation: IPM IL relationship with CIRED
3. Muni Muniappan, Director, IPM IL, rmuni@vt.edu
Presentation: IPM IL Introduction and Summary
4. Sara Hendery, Communications Coordinator, IPM IL, saraeh91@vt.edu
Presentation: Communications
5. Hanh Tran, Visiting Entomologist at Virginia Tech from Vietnam, Southern Horticultural Research Institute (SOFRI), hanhvcaq7@gmail.com
Presentation: IPM for Exportable Fruit Crops in Vietnam
6. Dely Gapasin, TAC Member, dely@delygapasin.com
Presentation: TAC Experience with IPM IL
7. Lawrence Datnoff, TAC Chair, LDatnoff@agcenter.lsu.edu
Presentation: TAC Experience with IPM IL
8. Zara Shortt, Financial Coordinator, IPM IL, shorttz@vt.edu
Presentation: Accounting for IPM IL
9. Wondi Mersie, Associate Dean and Director of Research, Agricultural Research, Virginia State University, WMersie@vsu.edu
Presentation: Biological Control of the invasive weed *Parthenium hysterophorus* in East Africa
10. George Norton, Professor of Agricultural Economics, Virginia Tech University, gnorton@vt.edu
Presentation: Vegetable Crops and Mango IPM in Asia
11. Megan O'Rourke, Assistant Professor, Department of Horticulture, Virginia Tech, megorust@vt.edu
Presentation: Invasive Species Modeling for South American Tomato Presentation: Vegetable Crops and Mango IPM in Asia
12. Paige Selvey, Senior Associate Director of Post-Award, OSP, Virginia Tech, pselvey@vt.edu
Presentation: Office of Sponsored Programs
13. Abhijin Adiga, Research Assistant Professor, Biocomplexity Institute, Virginia Tech, abhijin@virginia.edu

Leafminer and Groundnut Leafminer

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