FY 2014 REPORT

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes (Legume Innovation Lab)

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East and Southern Africa

Malawi (SO2.2 and SO3.1), Mozambique (SO2.1), Tanzania (SO2.2), Uganda (SO1.A3 and SO2.1), Zambia (SO1.A3 and SO2.2)

Latin America and the Caribbean

Guatemala (SO1.A1, SO1.A4, BTD and MasFrijol), Haiti (SO1.A4 and BTD), Honduras (SO1.A4 and BTD), Nicaragua (BTD)

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Benin	International Institute of Tropical Agriculture (IITA–Benin)
Burkina Faso	Institut de l'Environnement et de Recherches Agrícolas (INERA)
Ghana	Crops Research Institute (CRI) and Savannah Agriculture Research Institute (SARI)
Guatemala	Instituto de Ciencia y Tecnología Agrícolas (ICTA)
	Fundación para la Innovación Tecnológica, Agropecuaria y Forestal (FUNDIT)
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	Inter-American Institute for Cooperation on Agriculture (IICA)
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Malawi	University of Malawi, Bunda
Mozambique	Instituto de Investigação Agrária de Moçambique (IIAM)
Nicaragua	Instituto Nicaragüense de Tecnologías Agrícolas (INTA)

Niger	Institut National de la Recherche Agronomique du Niger (INRAN)
Senegal	Institut Sénégalais de Recherches Agricoles (ISRA)
Tanzania	Sokoine University of Agriculture (SUA)
Uganda	Makerere University
	National Agricultural Research Laboratories (NARL)
	National Crops Resources Research Institute (NaCRRI)
Zambia	Zambian Agriculture Research Institute (ZARI)
	University of Zambia (UNZA)

Abbreviations and Acronyms

AOR	Agreement Officer's Representative, USAID
ARS	Agricultural Research Service (USDA)
BCMNV	Bean Common Mosaic Necrosis Virus
BCMV	Bean Common Mosaic Virus
BIC	Bean Improvement Cooperative
BGYMV	Bean Golden Yellow Mosaic Virus
BHEARD	Borlaug Higher Education Agricultural Research and Development Program
BNF	Biological Nitrogen Fixation
Bt	*Bacillus thuringiensis*
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture)
CRI	Crops Research Institute (Kumasi, Ghana)
CRSP	Collaborative Research Support Program
CSB	Community Seed Bank
CSIR	Council for Scientific and Industrial Research (Ghana)
EAP	Escuela Agrícola Panamericana–Zamorano (Honduras)
FTF	Feed the Future
HC	Host Country
IARC	International Agriculture Research Center (of the CGIAR)
ICM	Integrated Crop Management
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICTA	Instituto de Ciencia y Tecnologia Agrícolas (Guatemala)
IIAM	Instituto de Investigação Agrária de Moçambique (Mozambique)
IITA	International Institute of Tropical Agriculture
INERA	Institut de l'Environnement et de Recherches Agricoles (Burkina Faso)
INIAP	Instituto Nacional Autónomo de Investigaciones Agropecuarios (Ecuador)
INRAN	Institut National de la Recherche Agronomique du Niger (Niger)
INTA	Instituto Nacional de Tecnologías Agrícolas (Nicaragua)
IPM-omics	Integrated Pest Management-omics
ISRA	Institut Sénégalais de Recherches Agricoles (Senegal)
KSU	Kansas State University
MAS	Marker-Assisted Selection
ME	Management Entity for the Legume Innovation Lab (Michigan State University)
MO	Management Office of the Legume Innovation Lab
MSU	Michigan State University
NaCRRI	National Crops Resources Research Institute (Uganda)
NARS	National Agriculture Research System(s)
NGOs	Nongovernmental Organizations
NSS	National Seed Service (Haiti)

PCCMCA	Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos y Animales
PI	Principle Investigator
QTL	Quantitative trait loci
RFP	Request for Proposals
SABREN	Southern African Bean Research Network
SARI	Savannah Agriculture Research Institute (Tamale, Ghana)
SNF	Symbiotic Nitrogen Fixation
SNP	Single Nucleotide Polymorphism
SO	Strategic Objective
SUA	Sokoine University of Agriculture (Tanzania)
TMAC	Technical Management Advisory Committee
UCR	University of California, Riverside
UNZA	University of Zambia
UPR	University of Puerto Rico
USDA	United States Department of Agriculture
ZARI	Zambian Agriculture Research Institute (Zambia)

II. Table of Contents

I. Management Entity: Michigan State University i

II. Table of Contents v

I. Executive Summary 1

II. Program Activities and Highlights 1

III. Key Accomplishments 2

IV. LIL Research Program Overview and Structure 3

V. Research Project Reports 5

SO1.A1. Genetic Improvement of Middle-American Climbing Beans for Guatemala 5

SO1.A3. Improving Genetic Yield Potential of Andean Beans with Increased Resistances to Drought and Major Foliar Diseases and Enhanced Biological Nitrogen Fixation (BNF) 6

SO1.A4. Development and Implementation of Robust Molecular Markers and Genetic Improvement of Common and Tepary Beans to Increase Grain Legume Production in Central America and Haiti 7

SO1.A5. Genetic Improvement of Cowpea to Overcome Biotic Stress and Drought Constraints to Grain Productivity 8

SO1.B1. IPM-omics: Scalable and Sustainable Biological Solutions for Pest Management of Insect Pests of Cowpea in Africa 9

SO2.1. Farmer Decision Making Strategies for Improved Soil Fertility Management in Maize–Bean Production Systems 10

SO2.2. Enhancing Pulse Value-Chain Performance through Improved Understanding of Consumer Behavior and Decision-Making 11

S03.1. Legumes and Growth 12

SO4.1. Impact Assessment of Dry Grain Pulses CRSP Investments in Research, Institutional Capacity Building and Technology Dissemination for Improved Program Effectiveness 13

VI. Associate Award Research Project Reports 14

Strategic Investment in Rapid Technology Dissemination: Commercialization of Disease Resistant Bean Varieties in Guatemala, Nicaragua, Honduras and Haiti (Bean Technology Dissemination –BTD) Cooperative Agreement No. AID-OAA-LA-10-00007. 14

MASFRIJOL: Associate Award under the Feed the Future Innovation Lab for Grain Legumes AID-EDH-A-00-07-00005 15

VII. Human and Institutional Capacity Development 16

VIII. Technology Transfer and Scaling Partnerships 20

IX. Governance and Management Entity Activity 20

X. Issues 23

XI. Future Directions 23

XII. Appendices 25
Legume Innovation Lab Financial Awards to U.S. Universities 25
Bean Technology Dissemination Financial Report with Expended Funds by Subcontracted Institutions 26
MASFRIJOL Associate Award Financial Report with Expended Funds by Subcontracted Institutions 27
XIII. Three Distinct Success Stories 28
Understanding and Guiding Farmer Decision-Making Strategies 28
Tepary Beans Offer Hope for Hot, Drought Prone Areas Affected by Climate Change 30
MASFRIJOL—Unique Partnerships and Model for Scaling 32

I. Executive Summary

The Legume Innovation Lab (LIL), 2013–2017, supports research and institutional capacity strengthening projects to 1. enhance grain legume productivity through genetic improvement and integrated pest management, 2. improve smallholder farmer decision making regarding sustainable soil fertility management in legume–cereal cropping systems, 3. strengthen legume value-chain performance, and 4. improve dietary nutritional quality through increased consumption of grain legumes. Administered by Michigan State University, nine multi-institutional, multicountry and multidisciplinary projects are subcontracted to Lead U.S. universities that sub-subcontract collaborating research institutions (NARS, agriculture research centers) in 13 Feed the Future focus countries in West Africa, Eastern and Southern Africa, and Central America and Haiti. LIL research projects focus primarily on common bean and cowpea because of their strategic importance to the food and nutritional security of the rural poor in these regions. As an extension of the Dry Grain Pulses CRSP (2007–2013), LIL is a mature program with a relatively full research pipeline of technological (e.g., improved disease-resistant, climate-resilient varieties; sustainable IPM [integrated pest management] solutions for insect management in cowpea; communications tools for low education farmers) and knowledge (e.g., factors influencing farmer management decision making, factors critical for sustainability of seed systems, nutritional and health value of grain legumes for growth of young children, function of grain legume value chains) outputs that can benefit stakeholders of grain legume value chains in developing countries.

The Management Office of LIL also administers two associate awards: 1. *Strategic Investment in Rapid Technology Dissemination: Commercialization of Disease Resistant Bean Varieties in Guatemala, Nicaragua, Honduras and Haiti* (Bean Technology Dissemination –BTD) (2010–2014) and 2. *MASFRIJOL* (2014–2018), contracted by the USAID Mission to Guatemala.

A 10-member Technical Management Advisory Committee (TMAC) monitors the technical progress of LIL through the evaluation of annual project workplans, budgets and technical progress reports as well as advises both the Management Office and USAID on all technical and administrative matters regarding program implementation and performance.

Specific information on LIL program management, activities, and projects and achievements can be found on the program's webpage, legumelab.msu.edu.

II. Program Activities and Highlights

Following the issuance of an RFP in FY 2014, a new research project on improving the nutrition of young children and women through grain legume consumption was awarded to Washington University School of Medicine in St. Louis, Dr. Mark Manary, Lead PI, in collaboration with the University of Malawi College of Medicine. This three-year project will involve two clinical trials in Malawi to determine if the consumption of common bean and cowpea-based foods by young children improves growth, ameliorates Environmental Enteropathy, and alters the intestinal microbiome during two critical high risk periods, 6–11 months and 12–35 months of age.

A new research and capacity strengthening project (SO1.A1) entitled *Genetic Improvement of Middle-American Climbing Beans for Guatemala* was invited from and subcontracted to North Dakota State University, Dr. Juan Osorno, Lead PI, in 2014. The Instituto de Ciencia y Tecnologia Agrícolas (ICTA) in Guatemala is the collaborating host country institution. The project will genetically improve disease resistance in climbing bean lines with high yield potential and adaptation to highland growing conditions.

U.S. and HC PIs of the nine subcontracted Legume Innovation Lab projects met with their respective project teams to review research progress, plan and coordinate future research and training activities, and prepare FY 2015 project Workplans and Budgets.

LIL held its Global Grain Legume Researchers Meeting, *Improving Agriculture and Nutrition through Grain Legumes*, from May 12–16, 2014, in Athens, Greece. The meeting brought together approximately 75 U.S. and host country researchers to meet as project teams to coordinate and to plan FY 2015 research activities, to network with grain legume scientists in other disciplines, and to deepen the integration of key FTF priorities into their research efforts. Thematic sessions with invited speakers were convened on *Agriculture for Nutrition, Innovations in Sustainable Seed Systems for Grain Legumes,* and *Strategic Partnerships in Research and Capacity Building to Achieve Development Outcomes*.

The Associate Award *Strategic Investment in Rapid Technology Dissemination: Commercialization of Disease Resistant Bean Varieties in Guatemala, Nicaragua, Honduras and Haiti* (Bean Technology Dissemination or BTD) Cooperative Agreement No. AID-OAA-LA-10-00007 concluded on March 31, 2014. A regional BTD reporting meeting was held March 19–20, 2014, in Guatemala City. A final report (October 1, 2010–March 31, 2014) of the project's dissemination achievements was completed and submitted to USAID. An electronic copy of the report can be accessed at http://legumelab.msu.edu/masfrijol/tech_dissemination/technical_reports.

III. Key Accomplishments

The LIL Management Office was awarded a four-year (2014–2018), $3,848,729 Associate Award (AID-OAA-LA-14-00005), entitled "MASFRIJOL," from the USAID Guatemala Mission. The program seeks to increase both the productivity and consumption of common bean among indigenous Mayan communities in the Western highlands through parallel interventions: 1. enhancing smallholder farmer access to quality seed of improved, disease-resistant climbing and bush-type bean varieties and 2. increasing knowledge of the nutritional value of beans in diets, especially as related to children and women of childbearing age, among household decision makers who shape dietary choices. Within 2014, seed of improved bean varieties has been distributed to more than 7,000 households in the Guatemala Feed the Future area.

Following USAID's awarding of a 4.5-year extension to MSU for the Legume Innovation Lab (AID-EDH-A-00-07-00005) in 2013, the Management Office shepherded a rigorous review process and awarded eight projects by early FY 2014 to lead U.S. universities researchers and their collaborating host country research partners

All LIL projects prepared *Impact Pathway Plans* that describe a vision for success for research outputs and include plans for technology dissemination and scaling up to achieve widespread adoption and developmental impacts.

Key research achievements in FY 2014 include the following:

- **SO1.A1.** The improved climbing bean variety, "Bolonillo-Texel," underwent extensive field evaluation prior to a projected release for commercial production in Guatemala in 2016.
- **SO1.A3.** A machine vision system was developed to predict quality ratings of color and appearance in canned beans, thus improving the effectiveness and efficiency of evaluation of bean lines for breeding.
- **SO1.A3.** The multiple disease-resistant black bean line "XRAV-4-4" and the red mottled bean lines "PRO737-1" and "PRO633-10" were formally released by the University of Puerto Rico. The tepary bean line "Tep-22" that combines resistance to common blight, rust and bruchids was formally released by USDA–TARS.
- **SO1.A4.** Three large, white-seeded cowpea varieties were released by ISRA in Senegal. The linkage between pinkeye and aphid resistance QTL was broken allowing for the breeding of aphid-resistant blackeye lines.
- **SO1.B1.** IPM strategies to manage insect pests in cowpea using biologicals combined with the timely applications of neem and *Maruca*–specific viral spray have been refined and are being validated in diverse field locations.
- **SO2.1.** Significant variability in soil fertility characteristics and cropping systems as well as social capital and bean market patterns have been documented among communities in Uganda and Mozambique.

- **SO2.2.** A discrete choice survey instrument was designed for implementation in Zambia, Malawi and Tanzania.
- **SO4.1.** A study was completed assessing factors that contributed to the success and sustainability of bean seed systems in Guatemala, Haiti, Honduras and Nicaragua under different socioeconomic and agricultural contexts.

The Bean Technology Dissemination Associate Award Project that ended in March 2014 disseminated quality declared seed of 39 different varieties of bean along with 20,500 packages of *Rhizobium* inoculant to more than 102,000 households and established approximately 257 community seed banks in the target countries of Guatemala, Haiti, Honduras and Nicaragua.

IV. LIL Research Program Overview and Structure

The Legume Innovation Lab focuses its research and institutional capacity strengthening efforts on four Strategic Objectives (SOs) in the 4.5-year extension (2013–2017).

Strategic Objective 1. Advancing the Productivity Frontier: To substantively and sustainably increase grain legume productivity by improving adaptation to diverse agroecologies and reducing smallholder farmer vulnerability to climate change, with special consideration for the livelihoods of women

- **SO1.A:** To substantively enhance the genetic yield potential of grain legumes by exploiting new research tools afforded by genomics and molecular breeding approaches (e.g., MAS), with a focus on improving resistances to economically important abiotic and biotic constraints that limit yield in the agroecological regions where legumes are commonly grown in Africa and Latin America
- **lSO1.B:** To sustainably reduce the yield gap for selected grain legume crops produced by smallholder, resource-poor farmers in strategic cropping systems

Strategic Objective 2. Transforming Grain Legume Systems and Value Chains: To transform grain legume-based systems through improved smallholder production management decision making and more effectual governance management of grain legume value chains by stakeholders

Strategic Objective 3. Enhancing Nutrition: To improve the nutritional quality of diets and to enhance the nutritional and health status of the poor, especially women and young children, through the consumption of edible grain legume-based foods

Strategic Objective 4. Improving Outcomes of Research and Capacity Building: To improve outcomes of legume research and capacity building projects and to assess impacts to improve future investment decisions

In 2014, Michigan State University administered a portfolio of nine subcontracted multi-institutional collaborative research and capacity strengthening projects and two associate awards. A lead PI and U.S. university is contractually responsible for the development of annual workplans and budgets, coordination of implementation, monitoring of technical progress, and reporting for each project.

The Legume Innovation Lab's technical approach for FY 2013–2017 contributes to USAID's Feed the Future goals and research strategy for grain legumes by:

- Contributing directly to the FTF themes of:
    1. Advancing the Productivity Frontier
    2. Transforming Key Production Systems
    3. Enhancing Nutrition and Food Safety;

- Assuming a leadership role within the international grain legume research community through engagement of leading scientists at U.S. universities and institutional partners in selected FTF focus countries, and coordination with CGIAR legume scientists through the CG Research Program on Grain Legumes;
- Focusing on priority FTF focus countries and cropping systems (the West African Sudano–Sahelian systems, the Eastern and Southern African maize-based systems, and the maize–bean cropping system in Central America);
- Supporting USAID's whole-of-government approach through coordination with USDA/ARS FTF research;
- Enhancing the capacity of strategic national and international agriculture research institutions to address critical staffing needs so as to be able to respond to future challenges of the grain legume sectors;
- Advancing gender equity through research, technology dissemination, and capacity building activities that directly benefit women;
- Achieving broad, quantifiable, sustainable impacts from outputs of Legume Innovation Lab research as evidenced by widespread technology adoption and benefits to stakeholders of legume value chains—from smallholder farmers to consumers of grain legumes; and
- Supporting USAID country and regional mission FTF strategic value chains and agriculture sector development priorities.

V. Research Project Reports

SO1.A1. Genetic Improvement of Middle-American Climbing Beans for Guatemala

Lead U.S. Principal Investigator and University: Juan M. Osorno, North Dakota State University

Collaborating Host Country and U.S. PIs and Institutions: Julio C. Villatoro, Fernando Aldana, Karla Ponciano, Julio Martinez, and Edgardo Carrillo, ICTA, Guatemala; Phil McClean, North Dakota State University

Description and Objectives

ICTA has collected approximately 600 accessions of Middle-American climbing beans from all bean production regions of Guatemala. This collection has been characterized morphologically and agronomically, and several markers have been identified. These climbing bean accessions are considered to have high yield potential and are adapted to high altitude conditions but have not benefitted from a concerted breeding effort utilizing molecular genetic tools. The objectives of this project, therefore, are to:

- Develop improved Middle-American climbing bean lines with improved disease resistance and agronomic performance
- Characterize genetic diversity within the Middle-American germplasm
- Better understand the current socioeconomic situation and constraints to bean production within the context of intercropping systems in the Guatemalan highlands

Achievements

- Nine elite breeding lines of Middle-American climbing beans with potential to be released in the near future were on-farm field tested and validated across 14 locations.
- The line "Bolonillo-Texel," large black round-seeded climbing bean preferred by highland consumers underwent extensive on-farm testing and validation across 18 locations in order to accelerate release as an improved variety in Guatemala. If validation results are positive, plans are to multiply seed of Bolonillo-Texel for dissemination in the MasFrijol project in 2016.
- The initial molecular genetic characterization of 25 climbing bean accessions and 6 breeding lines has been successfully completed.

Capacity Building

Two female students from Guatemala have been successfully recruited for formal graduate degree training (M.S. in Plant Sciences) at NDSU, to begin in FY 2015.

Lessons Learned

- SO1.A1 is a new project initiated in FY 2014. The MO is pleased with the technical progress achieved during year one.
- The MO also commends the PIs for their willingness to interact with the MasFrijol Associate Award project team to plan and to ensure that new climbing bean varieties generated by the project can be multiplied and seed made available to highland farmers.

Presentations and Publications

Moghaddam, S.M., S. Mamidi, Q. Song, J.M. Osorno, R. Lee, P. Cregan, and P.E. McClean. 2013. Developing marker-class specific indel markers from next generation sequence data in *Phaseolus vulgaris*. Frontiers in *Plant Genetics and Genomics* 5:185.

SO1.A3. Improving Genetic Yield Potential of Andean Beans with Increased Resistances to Drought and Major Foliar Diseases and Enhanced Biological Nitrogen Fixation (BNF)

Lead U.S. Principal Investigator and University: James D. Kelly, Michigan State University

Collaborating Host Country and U.S. PIs and Institutions: Stanley Nkalubo, NaCRRI, Uganda; Kennedy Muimui, ZARI, Zambia; Wayne Loescher, MSU; James Steadman, University of Nebraska, Lincoln, and Carlos Urrea, University of Nebraska, Scottsbluff; Karen Cichy, USDA–ARS, East Lansing, Michigan

Description and Objectives

1. Integrate traditional and marker-assisted selection (MAS) approaches to combine resistances to economically important foliar diseases, drought and improved biological nitrogen fixation (BNF) and assess acceptability of fast cooking, high mineral content in a range of large-seeded, high-yielding red mottled, white and yellow Andean bean germplasm for the Eastern Africa highlands (Zambia and Uganda) and the U.S.
2. Characterize pathogenic and genetic variability of isolates of foliar pathogens collected in Uganda and Zambia and identify sources of resistance to angular leaf spot (ALS), anthracnose (ANT), common bacterial blight (CBB), bean common mosaic virus (BCMV) and bean rust present in Andean germplasm.
3. Use single nucleotide polymorphism (SNP)-based, genome-wide association mapping to uncover regions associated with drought tolerance, disease resistance, cooking time and BNF to identify QTLs for use in MAS to improve Andean germplasm.
4. Develop phenometric approaches to improving the efficiencies of breeding for abiotic stress tolerance, especially drought.

Achievements

- A total of 192 diseased bean samples were collected containing Rust (84), ALS (52), CBB (11), Anthracnose (26) and root rot (19) from two agroecologies and nine districts in Uganda. Isolates of ANT, ALS and Rust are being obtained and purified for race characterization and use in future bean germplasm screening for disease resistance.
- A machine vision system was successfully developed to automatically predict the quality ratings of color and appearance in canned black beans as a professional visual perception. Developed models allow for prediction accuracies of 93.7% for color and 87.1% for appearance, and sorting of canned beans in “acceptable” and “unacceptable” quality groups by color and appearance simultaneously, with accuracies higher than 89%. The implemented machine vision technique can successfully replace the subjective, tedious, and costly visual sensory analysis at research facilities and bean canning industries.

Capacity Building

Two short-term courses were offered: *Advanced Methods for Disease Screening* and *Breeding Techniques and Advances in Plant Breeding (Use of Marker Assisted Selection Breeding Techniques) for Zambian and Ugandan Bean Breeding Program PIs and Technicians.* Four PhD and one MS students’ graduate programs are supported under the SO1.A3 project.

Presentations and Publications

Cichy, K.A., A. Fernandez, A. Kilian, J.D. Kelly, C.H. Galeano, S. Shaw, M. Brick, D. Hodkinson, and E. Troxtell. 2014. QTL analysis of canning quality and color retention in black beans (*Phaseolus vulgaris* L.). *Molecular Breeding* 33:139–154. doi: 10.1007/s11032-013-9940-y.

Miklas, P.N., J. D. Kelly, J. R. Steadman and S. McCoy. 2014. Registration of partial white mold resistant pinto bean germplasm line USPT-WM-12. *J. Plant Registrations* 8:183–186.

Mukeshimana, G., L. Butare, P.B. Cregan, M. W. Blair and J.D. Kelly. 2014. Quantitative trait loci associated with drought tolerance in common bean. *Crop Sci.* 54:923–938. doi: 10.2135/cropsci2013.06.0427.

SO1.A4. Development and Implementation of Robust Molecular Markers and Genetic Improvement of Common and Tepary Beans to Increase Grain Legume Production in Central America and Haiti

Lead U.S. Principal Investigator and University: James Beaver, University of Puerto Rico, Mayaguez, PR

Collaborating Host Country and U.S. PIs and Institutions: Juan Carlos Rosas, EAP–Zamorano, Honduras; Julio Cesar Villatoro, ICTA, Guatemala; Emmanuel Prophete, NSS, Ministry of Agriculture, Haiti; Consuelo Estevez de Jensen, UPR; Timothy Porch, USDA/ARS/TARS, PR; Phil Miklas, USDA/ARS, Prosser, WA; Juan Osorno and Phil McClean, NDSU

Description and Objectives

The focus of the S01.A4 project is incorporating resistance/tolerance genes to biotic and abiotic constraints into bean market classes for the tropical lowlands of Central America and the Caribbean (Haiti). Specific project research objectives include:

1. To genetically improve Middle-American common and tepary beans for adaptation to low fertility soils, resistance to bruchids, and improved resistances to powdery mildew, ALS, and BGYMV, BCMV and BCMNV
2. To develop and implement robust molecular markers for disease-resistance genes

Achievements

- The multiple disease-resistant black bean cultivar "XRAV-40-4" and red mottled bean breeding lines PR0737-1 and PR0633-10 were formally released by the University of Puerto Rico.
- White and pinto bean lines that combine resistance to BGYMV, BCMNV and rust resistance and yellow beans that have resistance to BGYMV, BCMV and leafhoppers were developed.
- The BGYMV and BCMNV resistant black bean line MEN-2201-64ML from EAP–Zamorano exhibited superior performance under drought conditions in Nicaragua and El Salvador.
- Black bean breeding lines that combine resistance to BGYMV, BCMNV and bruchids are ready for field testing in Honduras.
- Angular leaf spot isolates from Honduras and Puerto Rico were found to have high levels of virulence. Populations are being developed to identify a molecular marker for the Bgp-1 gene that confers resistance to pod deformation in the presence of BGYMV.
- The tepary bean Tep-22 that combines resistance to common bacterial blight, rust and bruchids was formally released. A potential source of resistance to BCMNV in tepary bean was identified. Populations to increase seed size and improve agronomic traits of tepary beans were developed.

Capacity Building

Informal training in plant pathology and BNF research techniques was provided at EAP–Zamorano and the University of Puerto Rico. A candidate for M.S. degree training of students from Guatemala has been identified. The thesis research projects of three male and five female B.S. degree students at EAP–Zamorano were supported by the project.

Presentations and Publications

Beaver, J.S., E.H. Prophete, J.C. Rosas, G. Godoy Lutz, J.R. Steadman and T.G. Porch. 2014. Release of "XRAV-40-4" black bean (*Phaseolus vulgaris* L.) cultivar. *J. Agric. of the Univ. of Puerto Rico* 98:83–87.

Porch Clay, T.G., Beaver, J.S., Abawi, G.A., Estevez de Jensen et al. 2014. Registration of a small-red dry bean germplasm, TARS-LFR1, with multiple disease resistance and superior performance in low nitrogen soils. *J. Plant Reg.* 8:177–182.

Vargas, A. T.G. Porch and J.S. Beaver. 2014. Evaluation of the tepary bean (*Phaseolus acutifolius*) CIAT germplasm collection for response to common bacterial blight and bean common mosaic necrosis virus. *Ann. Rep. Bean Improv. Coop.* 57:181–182.

SO1.A5. Genetic Improvement of Cowpea to Overcome Biotic Stress and Drought Constraints to Grain Productivity

Lead U.S. Principal Investigator and University: Philip A. Roberts, University of California, Riverside

Collaborating Host Country and U.S. PIs and Institutions: Issa Drabo and Jean-Baptiste Tignegre, INERA, Burkina Faso; Ibrahim Atokple & Francis Kusi, SARI, Ghana; and Ndiaga Cisse, ISRA & CERAAS, Senegal; Timothy J. Close, University of California, Riverside

Description and Objectives

SO1.A5 project objectives are to 1. discover insect tolerance and resistance QTL for cowpea breeding; 2. increase African and U.S. cowpea productivity by improved varieties with resistance to insect stresses, drought tolerance and disease resistance; 3. expand farmer marketing opportunities with improved cowpea varieties; and 4. provide training and capacity building in modern cowpea breeding.

Achievements

- A uniform test protocol was designed for aphid biotype screening under field conditions at UCR and a seedling screenhouse protocol was developed at SARI, Ghana to enable direct comparisons of aphid populations.
- A panel of resistance sources was established and uniform test protocols designed for field and screen house aphid screening to characterize cowpea aphid biotypes.
- Linkage between pinkeye and aphid resistance QTL was broken to breed aphid-resistant blackeye cowpeas.
- Two F3 populations were developed in Burkina Faso to identify QTLs for pod bug resistance.
- Three large white-seeded CRSP cowpea varieties were released in Senegal after 10 final on-station and on-farm trials.
- In Burkina Faso, 18 prerelease CRSP cowpea lines were evaluated in on-farm and on-station trials in 2013; farmers' Participatory Variety Selection chose nine lines that were tested in 20 on-farm trials in 2014. The 2014 data will inform which candidate lines will be submitted for release.

Capacity Building

Five LIL Capacity Strengthening awards supported the development of screen houses (Ghana and Burkina Faso), cowpea seed storage (Senegal), off-season field irrigation (Burkina Faso), and short-term training for a Ghana scientist at UCR. A training/planning workshop utilizing molecular breeding modules was held at UCR for scientists from Ghana, Senegal, Burkina Faso, Nigeria, and Mozambique. Three advanced degree students (2- PhD, 1- TS) from Senegal and Burkina Faso are being supported by the SO1.A5 project.

Presentations and Publications

Huynh, B.L., Close, T.J., Roberts, P.A., Cisse, N., Drabo, I., Boukar, O., Lucas, M.R., Wanamaker, S., Pottorff, M., Ehlers, J.D. 2013. Gene pools and the genetic architecture of domesticated cowpea. *The Plant Genome* 6:1–8.

Lucas, M.R., Huynh, B.L., Vinholes, P., Cisse, N., Drabo, I., Ehlers, J.D., Roberts, P.A., Close, T.J. 2013. Association studies and legume synteny reveal haplotypes determining seed size in *Vigna unguiculata*. *Front. Plant Sci.* 4:95. Pages 1–9. doi: 10.3389/fpls.2013.00095

Pottorff, M., Li, G., Ehlers, J.D., Close, T.J., Roberts, P.A. 2014. Genetic mapping, synteny, and physical location of two loci for *Fusarium oxysporum* f. sp. *tracheiphilum* race 4 resistance in cowpea [*Vigna unguiculata* (L.) Walp]. *Molecular Breeding* 33:779–791.

SO1.B1. IPM-omics: Scalable and Sustainable Biological Solutions for Pest Management of Insect Pests of Cowpea in Africa

Lead U.S. Principal Investigator and University: Barry Pittendrigh, University of Illinois at Urbana–Champaign

Collaborating Host Country and U.S. PIs and Institutions: Manuele Tamò, IITA–Benin; Clémentine Dabiré-Binso, INERA–Burkina Faso: Laouali Amadou, INRAN, and Ibrahim Baoua, University of Maradi, Niger; Stephen Asante, SARI, and Haruna Braimah, CRI, Ghana; Julia Bello-Bravo, UIUC; Eustache Biaou, INRAB–Benin.

Description and Objectives

- To define the insect pest problems on cowpea: 1. scouting, field experiments, light traps; 2. genomic markers to define pest and biocontrol agent populations–movement patterns and sources of the outbreaks; 3. computational modeling; and 4. understanding the biology of pest populations.
- To develop IPM solutions: To develop environmentally and economically appropriate pest control solutions for smallholder cowpea production systems utilizing biocontrols in combination with other IPM strategies.
- To scale up solutions: To test approaches and systems to effectively deploy insect management solutions in a cost effective and sustainable manner for the benefit of smallholder cowpea farmers. Three strategies for scaled-up solutions to be tested include the following: 3.1. direct release into the environment and natural establishment; 3.2. educational solutions; and 3.3. private sector and NGO involvement.

Achievements

- Insect pest populations causing yield losses in cowpea throughout four West African countries have been characterized through field-level monitoring and the use of molecular genetic tools, coupled with GIS tools.
- Strategies to manage insect pests in cowpea using biologicals combined with timely applications of a neem and *Maruca*-specific viral spray have been refined and are being validated under field conditions.
- Experimental analysis has shown that animated educational materials to be as effective as extension agent presentations. This finding indicates that the educational tools, involving animations voice overlaid into local languages, can be scaled up for deployment of the outputs of the IPM research on cowpea.
- Networks of collaborating organizations are being established and given training on the use of ICT and the IPM educational materials. The Ethiopian Agricultural Transformation Agency has placed the SAWBO videos on tablet computers for extension agents in an effort to reach more than 160, 000 smallholder farmers in Ethiopia.

Capacity Building

Short term training: 1. Training of NGOs (150 participants) on the use of SAWBO materials in Ghana, and 2.Farmer training on IPM methods in Burkina Faso (120) and Niger (100).

Degree training: The graduate degree training of six PhD, five MSc, and four BSc students are being supported at universities in Burkina Faso, Benin and Niger with SO1.B1 PIs supervising the thesis research.

Lessons Learned

The PIs have discovered considerable opportunity for cross-collaboration between LIL projects. Educational content has been passed to other projects for use in other countries.

Presentations and Publications

Toffa Mehinto, J., Atachi, P. , Douro, K., Dannon, E., Tamò, M. 2014 Mortality of *Maruca vitrata* (Lepidoptera: Crambidae) larval stages induced by different doses of the entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria bassiana*. *International Journal of Advanced Research* 2: 273–285.

Traore, F., C.L. Dabire-Binso, N.M. Ba, A. Sanon and B.R. Pittendrigh. 2014. Annual cycles of the legume pod borer *Maruca vitrata* Fabricius (Lepidoptera: Crambidae) populations in southwestern Burkina Faso: Host-plants and natural enemies. *Arthropod–Plant Interactions* 8(2): 155–162.

Wetro, E., A. K. Tounou, C. Agboton, B. Datinon, R. Srinivasan, B.R. Pittendrigh and M. Tamo. 2014. Bionomics of the parasitoid *Apanteles taragamae* as influenced by diets fed to its host, *Maruca vitrata*. *BioControl* 59: 55–65.

SO2.1. Farmer Decision Making Strategies for Improved Soil Fertility Management in Maize–Bean Production Systems

Lead U.S. Principal Investigator and University: Robert Mazur, Iowa State University (ISU)

Collaborating Host Country and U.S. PIs and Institutions: Moses Tenywa and Haroon Sseguya, Makerere University, Uganda; Onesimus Semalulu, National Agricultural Research Laboratories, Uganda; Ricardo Maria, Cassamo Sumila and Venâncio Salégua, Institute of Agriculture Research of Mozambique; Eric Abbot, Andrew Lenssen and Ebby Luvaga, ISU; Russell Yost, University of Hawaii at Manoa; and Julia Bello-Bravo and Barry Pittendrigh, UICC

Description and Objectives

This project is developing appropriate aids (methods and procedures) that will enable smallholder farmers with varying levels of education to better diagnose soil-related production constraints, and to make improved site-specific crop system management decisions that contribute to higher productivity of beans and associated crops and, over time, to improved soil fertility. It will also assess the effectiveness of innovative communication approaches and technologies to engage farmers with diverse characteristics and other key stakeholders in widespread dissemination and adoption of diagnostic and decision support aids.

Achievements

- Physical and chemical properties of three predominant soil types for growing common beans in study communities in Uganda's Masaka and Rakai districts and in Mozambique's Gurué district were analyzed to better understand soil fertility constraints to bean productivity.
- Challenges and opportunities to bean production have been identified for all project districts in Uganda and Mozambique, which is an important step for developing specific research hypotheses.
- The lessons learned from the IIAM social scientist's work with the Uganda team have contributed to an improved baseline household survey design and implementation in Mozambique.
- Interdisciplinary researchers from U.S. universities helped young IIAM social and soil scientists to gain experience in data collection (PRA, baseline survey, soil samples) and analysis.
- Significant variations in soil types and cropping systems as well as in social capital and market patterns have been documented among communities. This variability underscores the need for and potential value to farmers of the different types of decision support aids being developed.

Capacity Building

- Short-term training was provided to host country collaborators on the following: 1. Soil identification, characterization and classification; 2. Soil testing; 3. Innovation platform formation; and 4. Household baseline survey design and implementation.
- Degree training: Two MS students from Uganda and Mozambique are enrolled at ISU and one PhD student from Mozambique at the University of Hawaii, Manoa.

Lessons Learned

In both countries, we are operating within complex systems that directly and indirectly influence key elements of farming systems. In Mozambique, the creation of large-scale agricultural enterprises that emphasize certain crops (e.g., soybeans) affects bean growing and soil fertility efforts. In Uganda, government initiatives favoring large commercial farmers over smallholder farmers have myriad impacts. Our project strategy and activities have to adapt to these dynamics to achieve our key goals.

Presentations and Publications

Goettsch, L. & A. Lenssen. 2014. U.S. Borlaug Fellows in Global Food Security graduate research grant. Practical methods to alleviate constraints to common bean (*Phaseolus vulgaris L.*) production in Masaka, Uganda. Goettsch, L. 2013–2015. Louis Thompson Endowment Graduate Fellowship. Agronomy Department, ISU.

SO2.2. Enhancing Pulse Value-Chain Performance through Improved Understanding of Consumer Behavior and Decision-Making

Lead U.S. Principal Investigator and University: Vincent Amanor-Boadu, Kansas State University

Collaborating Host Country and U.S. PIs and Institutions: Gelson Tembo, University of Zambia; Lawrence Mapemba, Lilongwe University of Agriculture and Natural Resources, Malawi; Fredy Kilima, Sokoine University of Agriculture, Tanzania; Allen Featherstone and Kara Ross, Kansas State University

Description and Objectives

- To identify and analyze the principal factors shaping bean/cowpea consumption and their relative positions in consumers' food rankings in the selected countries
- To conduct situation analyses for bean/cowpea production and marketing/distribution systems with a view to identifying the nature and extent of the gaps in their value chains
- To implement formal and informal capacity building initiatives to address identified gaps and support value chain management capacity across the legume industry in the focus countries

Achievements

During FY2014, the most important achievement was the design and development of the electronic discrete choice survey instrument for the three focus countries. The second achievement was the strengthening of the relationships with upstream supply chain partners. These partners were included in the development sessions for the discrete choice experiment survey. Their involvement was crucial to the development of the survey, since they had a wealth of knowledge and expertise in bean varieties and bean attributes. Partners played an important role in determining which bean varieties to study for each of the three focus countries and which attributes and attribute levels to include in the discrete choice experiment. The partners provided expert advice on improving the quality and validity of the survey by identifying and, thus eliminating, all infeasible choice sets and options from the survey. The results from the discrete choice experiment will provide empirical information for breeders to determine the characteristics and attribute sets of existing technologies that can be brought to market or what needs to be developed for specific markets and consumer profiles.

Capacity Building

Short-term training: Enumerator Training on Discrete Choice Experiments: This training program was designed for the enumerators to introduce them to and familiarize them with the discreet choice approach.

Long-term degree training: A Zambian student is enrolled in a PhD program at KSU, two MSc students at Sokoine University in Tanzania, and two MSc students at Lilongwe University (LUANR) in Malawi. These students are assisting with the conduct of the SO2.2 project's field research as part of their thesis research.

Lessons Learned

KSU's subcontract with the University of Zambia was delayed by the UNZA administration, which presented challenges since Zambia had been selected as the initial country for the discrete choice experiment. The PIs in Zambia were familiar with the methodology from the previous Pulse CRSP project (PVCI). A new survey timeline has been established that will allow the research to get back to the work plan schedule. The plan is to still conduct the survey in Zambia first, followed by Malawi and Tanzania. Schedules may need to be adjusted, however, if the UNZA subcontract is not signed by early 2015.

Presentations and Publications

Ross, K.L., A. Shanoyan, V. Amanor-Boadu, Y. A. Zereyesus, and G. Tembo. From Subsistence to Commercial Production: Factors Affecting Smallholder Bean and Cowpea Producers Market Participation in Zambia. Selected paper prepared for presentation at the Annual World Symposium of the International Food and Agribusiness Association, Cape Town, South Africa, June 16–17, 2014.

Chishimba, E., G. Tembo, V. Amanor-Boadu and M. Mwiinga. Factors Affecting Bean Profitability among Bean Traders in Zambia. Department of Agricultural Economics and Extension Education, UNZA, Lusaka, Zambia. 2014.

S03.1. Legumes and Growth

Lead U.S. Principal Investigator and University: Mark Manary, Washington University School of Medicine in St Louis, Missouri

Collaborating Host Country and U.S. PIs and Institutions: Ken Maleta and Chrissie Thakwalakwa, University of Malawi College of Medicine, Malawi; Indi Trehan, Washington University School of Medicine in St. Louis, U.S.

Description and Objectives

Interventions that decrease the burden of childhood malnutrition are urgently needed, as millions of children die annually due to undernutrition and hundreds millions more are stunted. Environmental enteropathy (EE), a pervasive chronic subclinical inflammatory condition among children when complementary foods are introduced, places them at high risk for stunting, malabsorption, and poor oral vaccine efficacy. Here we propose two randomized, controlled clinical trials to determine if common beans or cowpeas improve growth, ameliorate EE, and alter the intestinal microbiome during this high-risk period. The first study involves 6–11 month old children who will receive common beans, cowpeas, or standard local complementary foods for 6 months. Anthropometry will be compared among the three groups. EE will be assessed using a urine dual-sugar absorption test and by quantifying human intestinal mRNA for inflammatory messages, and the intestinal microbiota characterized by deep sequencing of fecal DNA to enumerate the host microbial populations and their metabolic capacity. The second randomized, controlled trial will enroll 12–35 month old children and follow them for 12 months; each subject will receive dietary interventions, either legume-based or control. The research team has begun to develop recipes in conjunction with MSc students in the Department of Food Science and Technology–LUANAR. They are currently looking at fiber content and have been in touch with other universities regarding the processing of cowpeas and common beans.

Anthropometric, host inflammatory and gut microbiota analyses will be conducted similar to the first study. By amalgamating the power of the clinical trial and advanced biological analyses, we will elucidate the potential of legumes to have a major impact of child health in sub-Saharan Africa.

Achievements

The contract with WUSL was finalized as of September 29, 2014. IRB process has been started.

Capacity Building

The SO3.1 project will facilitate the training of 2 doctoral-candidate nutrition students from the University of Malawi and 2 food science master's students from the Lilongwe University of Agriculture and Natural Resources (LUANAR)

Lessons Learned

The project was being initiated in late FY 2014, thus no lessons have been learned at this time.

Presentations and Publications

No presentations or publications to report.

SO4.1. Impact Assessment of Dry Grain Pulses CRSP Investments in Research, Institutional Capacity Building and Technology Dissemination for Improved Program Effectiveness

Lead U.S. Principal Investigator and University: Mywish Maredia, AFRE, Michigan State University

Collaborating Host Country and U.S. PIs and Institutions: Eric Crawford (Co-PI) and Byron Reyes (Collaborator), Agricultural, Food and Resource Economics, Michigan State University

Description and Objectives

1. Provide technical leadership in the design, collection and analysis of data for strategic input and impact evaluation
2. Conduct ex ante and ex post impact assessments: (2a) the economics of supply and demand for the sustainable development of legume grain seed system; (2b) Systematic analysis of existing datasets to assess the role of grain legumes in smallholder farming systems, and (2c) Field Experiment on the Dissemination of Postharvest Technologies in Burkina Faso
3. Build research capacity in the area of impact assessment

Achievements

An assessment study conducted in Central America examined factors contributing to the success and sustainability of seed systems for grain legumes in different socioeconomic and agricultural systems contexts. Findings include: (a) organized smallholder farmers can produce high quality bean seed with appropriate training; (b) community based seed systems may not have adequate capacity to meet the seed needs of the community in terms of diversity of varieties demanded; (c) smallholder farmers are willing to pay a premium for bean seed over grain prices; and (d) flexibility in payment method and proximity/presence of seed production/distribution closer to the community were identified as strengths of the community seed production model.

A field study was completed in Burkina Faso to assess the effectiveness of animated videos shown on a cell phone to train farmers on two postharvest cowpea storage technologies. Mixed results were obtained when traditional extension education was compared to the video method. The high level of understanding and comprehension reported by the farmers who saw the videos, and the low cost of using this method indicate that integrating this method of transferring scientific information to farmers through cell phones with the traditional extension method can be a cost-effective method of scaling out new technologies based on farmers' own knowledge sharing networks.

Capacity Building

Two short-term training courses on the theory and methodology of doing impact evaluation were conducted in collaboration with CIAT and other national partners in the LAC region. The SO4.1 project is supporting one U.S. student in an MS degree program at MSU.

Lessons Learned

The support and collaboration received from other LIL projects for impact pathway development and baseline analyses is a strength of the program.

Presentations and Publications

Maredia, Mywish, Shankar, B., Kelley, T., Stevenson, JJ. 2014. Impact Assessment of Agricultural Research, Institutional Innovation, and Technology Adoption: Introduction to the Special Section. *Food Policy* 44 214–217

Magen, Benjamin, Crawford, E., Maredia, M. 2013. "Economic Impact of Research Investment in the Development and Dissemination of Improved Cowpea Varietal Technology." Poster presented at the Agricultural and Applied Economics Association Annual Meeting, Washington, D.C., August.

Maredia, M., Reyes, B. A., DeYoung, D. 2014. "An assessment of the Bean Seed Distribution Models Implemented under the Bean Technology Dissemination Project: Results of key informant interviews and surveys conducted in Guatemala, Honduras and Nicaragua." Final Meeting of the BTD Project, Guatemala City, March 20, 2013.

VI. Associate Award Research Project Reports

Strategic Investment in Rapid Technology Dissemination: Commercialization of Disease Resistant Bean Varieties in Guatemala, Nicaragua, Honduras and Haiti (Bean Technology Dissemination –BTD) Cooperative Agreement No. AID-OAA-LA-10-00007.

Project Description

The Bean Technology Dissemination (BTD) Project was funded by the Feed the Future, Bureau for Food Security, USAID, and executed in collaboration with national institutions and other development partners. The project was executed from October 2010 through March 2014. With a focus on increasing bean productivity, the BTD Project was implemented by the Legume Innovation Lab to address the shortage of high quality bean seed available to resource-poor farmers in Guatemala, Nicaragua, Honduras, and Haiti. The project also provided farmers with access to other productivity-enhancement technologies and training in collaboration with NARS and support from several NGOs working in each country.

Collaborators

NARS in Guatemala (ICTA) , Honduras (DICTA), Nicaragua (INTA) and Haiti (NSS), University of Puerto Rico, Escuela Agrícola Panamericana–Zamorano in Honduras, FUNDIT (Guatemala) and IICA (Haiti).

Achievements

The BTD Project led to the dissemination of 39 different improved varieties to more than 102,000 households in the target countries, with approximately 257 Community Seed Banks (CSBs) established in Nicaragua, Honduras, Guatemala, and Haiti; 75 of these CSBs are willing to continue supplying seed of improved varieties in their respective communities. Additionally, more than 20,500 packages of *Rhizobium* inoculant were produced for project collaborators. Hands-on community training was provided to thousands of farmers on seed production, conditioning, and storage; *Rhizobium* inoculation; and organic fertilizer (bokashi, compost) production.

Capacity Building

The BTD project strengthened the NARSs's ability to take high quality seed of improved bean varieties to rural areas, a capacity that the NARSs lacked and which negatively affected their ability to respond to farmer demands for certified or apta seed. Additionally, the Bean Program at EAP–Zamorano was able to increase production of foundation seed of more than 15 improved bean varieties required by project collaborators in all four countries, which renewed the NARSs's reputation as a good source of this basic seed for their other extension projects.

Lessons Learned

As the BTD Project came to a close, it was determined that the most significant contributions to sustainable seed systems were accomplished in Nicaragua, thanks to the community-based seed multiplication model Community Seed Banks. An early partnership with INTA helped establish CSBs for the multiplication of quality seed to meet the needs of farmers. BTD's supportive technology provided the emerging base to extend the model to Guatemala and Honduras during years 2 and 3, where important lessons were learned in establishing similar seed multiplication and dissemination models. In Haiti, where project execution conditions were the most difficult, it was not until the final 2012 season of seed multiplication that the community-based seed multiplication and dissemination model was tried in two locations with successful results. The BTD project experience provides evidence for the transferability of the CSB model to other countries. The CSB model has been shown to be a viable and sustainable alternative seed system model in areas where production and handling costs, logistical storage, transportation and distribution factors, and seed certification present formidable constraints and disincentives for private sector investment and participation.

MASFRIJOL: Associate Award under the Feed the Future Innovation Lab for Grain Legumes AID-EDH-A-00-07-00005

Project Description

This Associate Award Cooperative Agreement is focused on beans and is designed to mobilize the expertise and experience of the Legume Innovation Lab and its network of partners to strengthen the USAID Mission to Guatemala's efforts to achieve its Feed the Future strategic development goals for the country. The project started in April 2014 and is scheduled to end in March 2018. Interventions that enhance the productivity of the bean–maize system and increase understanding of the nutritional importance of beans are expected to sustainably promote greater household bean consumption, enhance the nutritional value of diets, and improve the food and nutritional security of highland Mayan communities. MASFRIJOL is therefore an innovative approach that combines agricultural and nutritional interventions, utilizing 4-wheel drive vehicles and community-based public sector technicians to reach households at their doorsteps to address the unique needs of the Guatemalan highlands.

Collaborators

- Fundación para la Innovación Tecnológica, Agropecuaria y Forestal (FUNDIT)
- Instituto de Ciencia y Tecnología Agrícola (ICTA)
- Ministerio de Salud Pública y Asistencia Social (MSPAS)
- Centro de Comunicación para el Desarrollo (CECODE)
- Implementing partners in the USAID/Guatemala Mission's Western Highlands Initiative Program (WHIP)

Achievements

Since MASFRIJOL was initiated in April 2014, the project has been able to disseminate quality declared seed of improved bean varieties to more than 7,000 households in the Guatemala Feed the Future area. During this time, the project has also succeeded in establishing a field office and is actively engaging in extension activities in highland communities in collaboration with USAID/Guatemala WHIP partners.

Lessons Learned

Over the last six months, MASFRIJOL has mobilized project resources and partners in an expeditious and effective way to inventory groups of beneficiaries, carry out training activities, and reach thousands of families during the bean planting season. Because the project is in the early stages and began without direct previously established contacts with rural communities, MASFRIJOL benefited greatly from the facilitated community access and assistance received from the USAID WHIP implementing partners. Continuing to build stronger, mutually beneficial relationships among AGEXPORT, ANACAFE, Save the Children, CRS, and MSPAS and MAGA professionals will, therefore, remain a priority for the MASFRIJOL team.

VII. Human and Institutional Capacity Development

Training

The Legume Innovation Lab invests in the development of human resources through short-term training and graduate degree training in strategic areas. These investments strengthen the capacity of national agriculture research institutions in areas related to grain legumes, from breeding and productivity research to consumption and market demand.

Short-Term

Twenty short-term training programs were conducted through Legume Innovation Lab projects, as can be seen in table 1 (p. 18). These training programs were designed to meet local needs identified by Legume Innovation Lab researchers. In some cases, advanced scientific research methods were addressed, including genetic screening methods. In other cases, farmers and farmer organizations were engaged in the research process and training developed from the research, as with the seed production and biological control trainings.

Long-Term

Long-term training is a hallmark of Legume Innovation Lab research projects, in which degree candidates learn the practice and application of science, which is then applied to his or her own country's needs. Each student is mentored by an internationally recognized legume researcher, establishing a long-term professional relationship their advisor and a community of legume researchers.

Number (by gender)

In FY14, Legume Innovation Lab projects funded, fully or partially, 45 students. Table 2 shows the breakdown of students according to degree program and by gender.

Long term training Students, by Degree Program				
	PhD	MS	BS	Total
Men	9	11	7	23
Women	5	7	7	20
Total	14	15	14	43

Table 2. LIL Funded Students, by Degree and Gender

Purpose

As shown in Table 2, above, the majority of students were in either doctoral or master's programs. Some regional training is provided in local universities for bachelor's degrees, helping to ensure a pool of candidates for advanced degree studies in the future. Encouraging students in the agricultural sciences at all levels proves to be important for host country institutions.

Field/Discipline

The degree training programs span the agricultural disciplines, including agronomy and soil science, entomology, plant breeding and genetics, crop production, agricultural economics and agribusiness, and the life sciences.

Home Institution

A range of home institutions are also represent among Legume Innovation Lab-affiliated students, from the national agricultural research institutes (e.g., ZARI, IIAM, ICTA and INERA) to educational institutions (Sokoine and Makerere). A few trainees come from NGOs or the private sector, where there is a clear need for greater human capacity for

legume sector development. Table 3 indicates the countries of origin for the Legume Innovation Lab long-term trainees for Fy2014, with a total of 17 trainees from Feed the Future countries and 25 from elsewhere..

Long term training students, by country		
	Men	Women
Feed the Future Countries		
Ghana	1	1
Honduras	2	0
Malawi	1	1
Mozambique	1	0
Senegal	0	1
Tanzania	1	1
Uganda	4	1
Zambia	1	1
subtotal	11	6
Other		
Benin	6	4
Bolivia	0	1
Burkina Faso	1	3
Ecuador	0	2
El Salvador	1	2
Nigeria	0	2
USA	4	0
subtotal	12	14
Total	23	20

Table 3. LIL long-term trainees by country and gender

Training Institution

Degree training takes place in both the United States and in developing countries. Degree training will be initiated at regional institutions that have high quality training and a recognized mentor. Such institutions include Sokoine University, Makerere University, University of Benin, University of Ougadougou, LUANAR (Malawi), University of Maradi, and the Zamarano Institute. In the United States, there are students at the University of Hawaii, Manoa; ISU, MSU, UPR and KSU. The majority of students are training in African institutions (18 students) or international centers (10). Seven of the students are training at US institutions with the remainder in Latin America (8 students).

Title	Country	Home Institution	Training Institution	Men trainees	Women trainees
Drought and Disease Screening methods	Uganda	NaCCRI	NACRRI/Namulonge	11	4
Drought and Disease Screening methods	Uganda, Zambia	ZARI/NaCCRI	MSU	2	0
Seed production methods for farmers	Zambia	ZARI, Farmer Orgs	ZARI	19	10
Seed production methods for farmers	Zambia	ZARI, Farmer Orgs	ZARI	16	14
Seed production methods for farmers	Zambia	ZARI, Farmer Orgs	ZARI	20	8
Plant pathology techniques	Honduras, Tanzania	Zamorano, Sokoine Univ.	UPR	1	2
Angular leaf spot	Guatemala	ICTA, Guatemala	Zamorano Institute	0	1
Molecular breeding (12 participants)	Burkina Faso, Ghana, Senegal, Moz.,Nigeria	INERA, SARI, ISRA, IIAM, Ahmadu Bello Univ.	UCR	11	1
Cowpea seed production/storage	Burkina Faso	INERA	INERA	70	45
ICT training on SAWBO (NGOs) (in person and then inline training)	Burkina Faso	INERA, NGOS	INERA, INRAN	75	75
IPM with ICT and biocontrol (various trainings)	Niger	INRAN, NGOS	INERA, INRAN	70	50
IPM with ICT and biocontrol (various trainings)	Burkina Faso	INERA, NGOs	INERA	70	30
Soil identification, characterization and classification	Uganda	Makerere, NARL	Makerere, NARL, Univ. Hawaii	2	2
Soil testing	Mozambique	IIAM	IIAM	3	2
Innovation platform formation	Uganda	Makerere University and Masaka District Agriculture Office	Makerere	3	0
Survey design and implementation	Mozambique	IIAM	Makerere	1	0
Discrete Choice experiments	Zambia	ZARI, Students	KSU	14	18
Impacts pathway training at Project planning meetings	All LIL countries	All LIL collaborating institutions	MSU	45	15
Impact assessment training: Colombia	Colombia, Peru, Ecuador	CIAT, national partners in South America	MSU and	15	7
Impact assessment training: Honduras	Honduras, Guatemala, Nicaragua	Zamorano and other Central American institutions	MSU	13	3
			Total numbers	461	287

Table 1: The 20 short-term training programs conducted through Legume Innovation Lab projects

Institutional Development

Description

The Legume Innovation Lab invited proposals from Principal Investigators (PIs) for activities that will contribute to enhancing the capacity of Host Country institutions. A total of $300,000 had been budgeted in the Cost Application for Institutional Strengthening awards during FY 2013 and 2014. The Legume Innovation Lab recognized that National Agriculture Research Systems (NARS) and agricultural universities in developing countries need to build and maintain capacities in strategic areas of research, training and outreach in order to effectively and sustainably address the challenges facing the grain legume (bean, cowpea and related edible legume crops) sectors and to contribute to economic growth and food and nutritional security within their respective countries. This requires investments in human resource development, scientific equipment, laboratory and field facilities, computer technology, and infrastructure. The intent of these Institutional Capacity Strengthening awards was therefore to address critical needs of Host Country (HC) collaborators which exceed the budgetary limits of the current Legume Innovation Lab projects, and to respond to identified grain legume program needs of agricultural research institutions in USAID priority countries.

In response to the solicitation in FY 2014, the Management Office received a total of 17 proposals from partner host country institutions. Based on the TMAC's evaluations and recommendations, MSU obligated a total of $239,686 to 14 partner institutions in 10 host countries in support of institutional strengthening activities associated with seven subcontracted projects. The list of institutions and host countries benefitting is presented in the spread sheet presented below. The institutional capacity strengthening funds were added to FY 2014 and 15 modifications to subcontracts to the lead U.S. universities for the respective projects. See Appendix 1 which presents obligated amounts through FY 2015 to U.S. universities for the nine subcontracted projects under the Legume Innovation Lab.

Host Country Partners

Project No.	PROJECT	HC	Institution	Award letter amount
1	SO1.A1	Guatemala	ICTA	$11,000
2	SO1.A3	Zambia	ZARI	$18,000
3	SO.1A4	Haiti	Nat. Seed Service	$5,000
4	SO.1A4	Guatemala	ICTA	$11,520
	SO.1A4	Honduras & CA region	EAP–Zamorano	$13,640
6	SO1.A5	Burkina Faso	INERA	$6,000
7	SO.1A5	Burkina Faso	INERA	$8,125
8	SO1.A5	Ghana	Sav. Ag. R. Int.	$7,500
9	SO1.A5	Ghana	Sav. Ag. R. Int.	$15,000
10	SO1.A5	Senegal	ISRA	$29,500
11	SO1.B1	Niger	INRAN	$22,550
12	SO1.B1	Ghana	CSIR	$25,700
13	SO2.1	Uganda	NARO & Makerere	$26,000
14	SO2.1	Mozambique	IIAM	$26,015
15	SO4.1	Honduras & CA region	EAP– Zamorano	$14,136
				$239,686

Table 4: Host Country Partners—Benefitting from LIL FY 2014 Institutional Strengthening Awards Partners

VIII. Technology Transfer and Scaling Partnerships

Apart from the two Associate Awards, BTD and MASFRIJOL, Legume Innovation Lab projects did not directly support technology transfer and scaling up activities in FY 2014. Host Country partners, however, are being encouraged to cultivate relationships in their respective countries with USAID sponsored programs and with NGOs so that outputs of Legume Innovation Lab research might be adapted, disseminated and scaled-up both within the respective country or region. In subsequent annual reports of the Legume Innovation Lab, as technologies and new knowledge have been generated by the new research LIL projects, it is reasonable to anticipate more extensive reporting of the transfer, adoption and scaling up of technologies.

IX. Governance and Management Entity Activity

FY 2014 was the first full year in the 4.5 year extension phase of the Legume Innovation Lab (LIL), April 1, 2013 through September 30, 2017. Major administrative functions and activities carried out by the Management Office of LIL in FY 2014 included:

Subcontracts were established with lead U.S. universities for the nine projects in LIL extending the projects through September 30, 2014, obligating funds for FY 2013 and 2014 in accord with approved FY 2013–14 workplans and budgets. In the case of the University of Puerto Rico, lead university for SO1.A4, Michigan State University determined that UPR did not have adequate capacity to manage sub-subcontracts and financial matters with partner U.S. and Host Country institutions in the project. As a consequence, MSU and the LIL MO assumed responsibility for administering the sub-subcontracts with EAP–Zamorano/Honduras, ICTA/Guatemala, NSS/Haiti, North Dakota State University and USDA–ARS/Prosser, Washington.

In January 2014, the MO issued a Request for Proposals from Principal Investigators (PIs) for activities that will contribute to enhancing the capacity of Host Country institutions. Following review and advisement by the TMAC, the MO approved and awarded a total of $239,686 to 15 proposed institutional strengthening activities. These funds were added to the obligations to Lead Universities for pass-through to the respective sub-subcontracted host country institutions.

LIL held its Global Grain Legume Researchers Meeting, Improving Agriculture and Nutrition through Grain Legumes, on May 12-16, 2014 in Athens, Greece. The meeting brought together approximately 75 U.S. and host country researchers to meet as project teams to coordinate and plan FY 2015 research activities, to network with grain legume scientists in other disciplines, and to deepen the integration of key FTF priorities into their research efforts. Thematic sessions with invited speakers were convened on Agriculture for Nutrition, Innovations in Sustainable Seed Systems for Grain Legumes, and Strategic Partnerships in Research and Capacity Building to Achieve Development Outcomes. The LIL MO was responsible for meeting program planning, travel and hotel arrangements, program materials and reports, and all activities associated with implementation of the meeting. Michigan State University directly supported the meeting with financial assistance for the purchase of supplies and special events.

The MO issued in August 2013 a Request for Preproposals entitled “Improving the Nutritional Quality of Diets through Grain Legume Consumption for Enhanced Nutritional Status of the Poor, Especially Women and Young Children.” A total of 13 preproposals were received by September 30, 2014. The MO arranged for each of the 13 proposals to be externally peer reviewed by four respected international nutritionists. Based on the qualitative and quantitative evaluations by the peer reviewers and the TMAC’s advisement, two preproposals were selected which most closely aligned with the objectives and the criteria of the RFP and presented the highest evaluated research approach. From the two selected universities, full proposals with workplans and budgets were obtained in 2014 and again peer evaluated by different group of external reviewers. Washington University School of Medicine in St. Louis (Dr. M. Manary, PI) was awarded the project and a subcontract established with MSU in FY 2014 (signed September 2014).

The MO requested project teams to prepare and submit FY 2015 Workplans, Budgets, Milestones for Technical Progress, and Performance Indicator Targets by July 3, 2014. The project teams (U.S. and HC PIs) met in Athens during the Global Meeting to review research and training progress and plan future collaborative activities. The TMAC members met with each of the project teams to advise and suggest ways to strengthen the respective projects. Upon receipt of the FY 15 project Workplans and accompanying documents, the MO requested an evaluation of these workplans by the TMAC. The TMAC completed its evaluations, held a conference call to discuss their assessments of each of the projects and approve consensus recommendations which were written up. The Director of LIL, I. Widders, sent individualized memos to the lead PIs in October 2014 with MO comments on the workplans and budgets, the TMAC’s recommendations, and expectations for response during implementation of the workplans in FY 2015.

In response to negative determinations in the Internal Environmental Examination (IEE) of the Legume Innovation Lab’s research portfolio, USAID required the program to develop an Environmental Mitigation and Monitoring Plan (EMMP) for the safe procurement, handling and use of pesticides, fertilizers, microbial inoculants and biologicals in research activities both in host countries and U.S. To ascertain what pesticides, fertilizers, microbial inoculants and

biologicals would likely be purchased and used with USAID LIL funding, the MO requested on July 2, 2014 that all subcontracted U.S. and Host Country institutions complete a survey form. The survey requested detailed information on projected pesticide, fertilizer and microbial inoculant procurement and use over the life of the research project (through September 30, 2017) and institutional measures in place to ensure safe storage, handling, application and disposal so as not to pose risks to human and environmental health. Based on the completed surveys received from all subcontracted institutions in LIL, the MO developed and presented an EMMP that was presented to USAID and subsequently approved. In addition, the MO presented to USAID a compiled list of all pesticides, fertilizers, microbial inoculants and biologicals for projected use in all the projects and projected expenditure of USAID funds for their procurement. Modifications to subcontracts to obligate FY 2015 funds also included a requirement for compliance with the approved EMMP for the Legume Innovation Lab.

At the request of USAID's Bureau Environmental Officer, an external review was commissioned by the MO of the SO1.B1 project and the potential environmental risks associated with the introduction/release of biologicals (parasitoids, virus for the control of Maruca larvae) for research on the management of insect pests in cowpea systems in West Africa. The External Review report completed by Srinivasan Ramasamy, Head of Entomology Group, AVRDC, on 10/20/2014 was approved by USAID.

The Management Office of LIL has sought to reach out and to strengthen ties with the CGIAR's Grain Legume Research Program administered by ICRISAT. LIL Director Widders attended two Research Management Committee meetings of the CG Grain Legume Program in FY 2014 in Hyderabad, India, and Saskatoon, Canada, and participated in countless email communications regarding technical and administrative issues. Noel Ellis, director of the CG Grain Legume Program, also served as an active member of the TMAC and contributed to the review of LIL project workplans and technical progress reports. He unfortunately was not able to attend the 2014 Global Grain Legume Researchers Meeting. In addition, Widders has visited CIAT–Columbia and IITA–Benin to discuss collaborations with the Legume Innovation Lab on research, training and outreach initiatives related to common bean and cowpea.

The Legume Scholars Program is another example of partnerships with the CGIAR. In FY 2014, ICRISAT contracted MSU and the Management Office of the Legume Innovation Lab to administer the Legume Scholars Program; a total of $750,000 was obligated to support scholarships for developing country students committed to careers in grain legume research to pursue PhD or MS degrees at U.S. universities under the supervision of Innovation Lab scientists. A contract is also being established with the University of Georgia and the Peanut and Mycotoxin Management Innovation Lab to support Legume Scholars Program scholarships.

LIL project teams prepared and submitted FY 2013–14 Performance Indicator Reports (by October 1, 2014) and detailed Technical Progress Reports (by November 7, 2014) for their respective LIL projects to the Management Office. A LIL Performance Narrative, Performance Indicator data, and success stories for FY 2014 were submitted into USAID's FTMS electronic reporting system in October 2014. The *FY 2013–14 Technical Progress Reports* for the subcontracted research and institutional strengthening projects have been compiled by the Management Office and will be presented to the TMAC for review. A full FY 2014 *Technical Progress Report* for the Legume Innovation Lab will be submitted to the USAID–AOR. A *2014 Highlights Report* will also be prepared for public distribution in early 2015.

The LIL MO has identified its website (legumelab.msu.edu/) as a key component of its communication and promotions strategy. In FY 2014, the LIL website was updated to include information relative to the Legume Innovation Lab in recognition of the fact that substantial changes occurred between the previous Dry Grain Pulses CRSP (2007–2013) and the current program (2013–2017), including a shift in technical focus to ensure alignment with FTF, the research and capacity strengthening objectives of subcontracted projects, the specific partner U.S. and host country institutions in the program, the target FTF countries, and the like. In addition to an update, the MO is seeking to post success stories, spotlight articles, project workplans and technical progress reports, research briefs, and key announcements that may

be of interest to program participants (PIs), USAID, stakeholders and the general public. A redesign to facilitate access by more diverse electronic devices is also under way.

The Legume Innovation Lab and IITA met in 2014 and IITA invited LIL to cohost the 2016 World Cowpea Conference, tentatively scheduled in Livingston, Zambia, during the week of March 1–7, 2016; the Legume Innovation Lab agreed. IITA has also agreed to combine the upcoming World Cowpea Conference with the Pan-African Grain Legume Conference planned by the Legume Innovation Lab. The CG Grain Legumes Program, Tropical Legume Program, the Pan-African Bean Research Alliance and the subregional programs (CCARDESA, ASARECA and CORAF) have all been approached about cohosting these two joint conferences. These concurrent conferences will provide opportunities for Legume Innovation Lab host country scientists to present their research findings to a larger international community of grain legume scientists, to network for strengthened collaboration, to give visibility to the research investments by USAID in grain legumes, and to communicate the importance of grain legumes to food and nutritional security, to sustainability of cropping systems, to generating valued income for farmers and other stakeholders of value chains, and to improving the livelihoods of the rural poor in Africa.

In response to a proposal by the International Pulse Trade and Industry Confederation (CICLS), the United Nations and the FAO has declared FY 2016 as the International Year of Pulses (IYOP). CICLS has established a Steering Committee and five thematic committees to plan and coordinate activities to celebrate the 2016 International Year of Pulses. Irvin Widders has been appointed as a member of the Productivity and Sustainability thematic committee. The IYOP Steering Committee has recommended to the UN/FAO that the 2016 Pan-African Grain Legume Conference being planned by the Legume Innovation Lab be declared as an "FAO Signature IYOP International Event." CICLS is also considering promoting other Legume Innovation Lab and CG Grain Legume Research program research activities and events, including the Legume Scholars Program, as part of 2016 IYOP activities.

X. Issues

An unexpected challenge in FY 2014 resulted from the approximately $2 million reduction in USAID's obligation of funds to the Legume Innovation Lab from the level originally set forth in USAID's contract to Michigan State University. This reduction in funding necessitated changes in the research project portfolio, including a reallocation of funds among projects and reductions in funding support for new projects presented in the Technical Application to enhance photosynthesis for increased productivity of grain legumes and to investigate the role of grain legumes in child nutrition. This FY 2014 reduction in obligation to the Legume Innovation Lab significantly weakens the program's ability to invest in critical research areas with high potential for impact and that would contribute to achieving USAID FTF research goals of advancing the productivity frontier and improving the nutritional quality of diets.

XI. Future Directions

- In celebration of the UN/FAO's 2016 International Year of Pulses, the Legume Innovation Lab will provide leadership to the organization of a Pan-African Grain Legume Research Conference and a World Cowpea Conference, to be held in Zambia in March 2016, in partnership with the CG Grain Legume Program, IITA, CIAT, subregional programs, and NARS. Planning meetings and other arrangements will be carried out to prepare for these conferences.
- The TMAC will conduct a midphase evaluation of the technical progress of all LIL projects, by reviewing FY 2013–14 Technical Progress Reports and by conducting selected site visits to partner institutions in FTF countries and the U.S. in 2015.
- The MO will obtain data on the dissemination and adoption of Pulse CRSP and Legume Innovation Lab technologies to capture, at least partially, the significant development outcomes and impacts of investments in research through the program.

- The Legume Scholars Program, a joint program with ICRISAT and the Peanut and Mycotoxin Management Innovation Lab, will be implemented, with students placed in graduate programs at U.S. universities in 2015.
- A new three-year (FY 2015–2017) project on *Enhancing Photosynthesis in Grain Legumes* will be developed and subcontracted to Michigan State University (David Kramer, Lead PI) with a total obligation of approximately $500,000.
- LIL will continue to coordinate grain legume research and contribute to research planning by the CG's Grain Legume Program through Director Widders's service on the Research Management Committee.
- MASFRIJOL project activities in Guatemala will be scaled up in FY 2015 now that subcontracts with partner institutions and the program office, and staffing are fully in place.
- A case study will be carried out by Dr. Maredia and INERA PIs of a large farmer organization (greater than 6,700 members) in Burkina Faso, which has been producing quality-declared cowpea seed for its members for more than 25 years. The goal is to better understand the function of this organization and the factors that have contributed to its success as a community-based system, including its sustainability and growth.

XII. Appendices

Legume Innovation Lab Financial Awards to U.S. Universities

LEGUME INNOVATION LAB PROJECTS SUBCONTRACTED TO U.S. UNIVERSITIES:								
	Project Name	**Lead U.S. Institution**	**Start/End dates**	**Total Project Estimated Funding**	**FY 2013 Obligation**	**FY 2014 Obligation**	**FY 2015 Obligation**	**Total Obligated to date**
1	SO1.A1- Genetic Improvement of Guatemalan Climbing Beans	North Dakota State University	Oct. 22,2013 thru Sept. 30,2017	$ 718,212	$ -	$ 197,716	$ 172,881	$ 370,597
2	SO1.A3 - Improving Genetic Yield Potential of Andean Beans	Michigan State University	April 1, 2013 thru Sept. 30, 2017	$ 2,017,928	$ 166,347	$ 544,992	$ 430,069	$ 1,141,408
3	SO1.A4 - Mesoamerican Bean Breeding	University of Puerto Rico	April 1, 2013 thru Sept. 30, 2017	$ 2,030,160	$ 103,923	$ 354,047	$ 395,410	$ 853,380
4	SO1.A5 - Genetic Improvement of cowpea	University of California Riverside	April 1, 2013 thru Sept. 30, 2017	$ 2,066,125	$ 44,360	$ 532,867	$ 485,352	$ 1,062,579
5	SO1.B1 - IPM-omics	University of Illinois at Urbana-Champaign	April 1, 2013 thru Sept. 30, 2017	$ 2,048,250	$ 59,074	$ 534,176	$ 485,000	$ 1,078,250
6	SO2.1 - Farmer Decision Making	Iowa State University	April 1, 2013 thru Sept. 30, 2017	$ 1,752,015	$ 45,375	$ 393,700	$ 52,015	$ 491,090
7	SO2.2 - Enhancing Pulse Value-Chain	Kansas State University	April 1, 2013 thru Sept. 30, 2017	$ 1,090,421	$ 48,926	$ 304,264	$ 388,425	$ 741,615
8	SO3.1 - Nutrition	Washington University	April 1, 2014 thru Sept. 30, 2017	$ 3,000,000	$ -	$ 536,015	$ 1,025,265	$ 1,561,280
9	SO4.1 - Impact Assessment	Michigan State University	April 1, 2013 thru Sept. 30, 2017	$ 914,136	$ 62,778	$ 258,824	$ 207,206	$ 528,808
	Total			**$ 15,637,247**	**$ 530,783**	**$ 3,656,601**	**$ 3,641,623**	**$ 7,829,007**

Bean Technology Dissemination Financial Report with Expended Funds by Subcontracted Institutions

Project Name	Project Dates	Obligated Amount	
BTD	10/1/2010–03/31/2014	$3,386,907.00	
Budget/Subaward	Awarded Amount	Expended Amounts	Difference
Management Office	$719,079.30	708103.52	$ 10,975.78
Impact Study, Maredia	$141,908.21	141908.21	$ -
NITLAPAN	$ 81,506.00	81506	$ -
DICTA	$261,897.00	261897	$ -
FUNDIT	$589,871.70	589870.40	$ 1.30
IICA	$386,700.00	327923	$ 58,777.00
INTA	$391,880.00	$296,096.00	$ 95,784.00
NSS	$ 10,652.00	0	$10,652.00
UPR	$88,474.79	$86,138.58	$ 2,336.21
EAP–Zamorano	$714,938.00	714938	$-
Total	$3,386,907.00	3,208,380.71	$178,526.29

MASFRIJOL Associate Award Financial Report with Expended Funds by Subcontracted Institutions

Project Name	Project Dates	Total Award
MasFrijol	3/26/2014– 3/25/2018	$ 3,549,994.00
	Total Obligated by 12/2014	Total Expended by 12/2014
MSU Management Office	$543,524.00	$275,416.56
FUNDIT	$301,572.00	$38,536.00
ICTA	$316,349.00	$82,685.00
MSPAS	$135,216.00	$51,288.00
CECODE	$116,392.00	$16,298.00
	$1,413,053.00	$464,223.56

XIII. Three Distinct Success Stories

Understanding and Guiding Farmer Decision-Making Strategies

Poor soil fertility and crop management practices have left thousands of smallholder bean farmers in Uganda and Mozambique struggling to achieve even 25 percent of their potential crop yield. A Legume Innovation Lab project on *Farmer Decision Making Strategies for Improved Soil Fertility Management in Maize–Bean Production Systems* at Iowa State University, in collaboration with Makerere University and the National Agricultural Research Laboratories in Uganda and the Institute of Agriculture Research of Mozambique, however, is combining soil and social science to bring hope to these farmers. A key goal of the project is to develop science-based methods to address soil problems in fields along with social science-based methods to help low literate farmers understand and implement crop management practices that improve—and then maintain and even improve—their soil.

Farmers and researchers in Mozambique take soil samples to measure soil fertility

To identify limiting soil nutrients, the project team analyzed the physical and chemical properties of the predominant soil types for growing beans in communities in Uganda and Mozambique. Their findings led to nutrient-controlled greenhouse studies that revealed the effects of specific macro- and micronutrients on bean plant growth and development. Field trials using these macro- and micronutrients to understand the soil-specific nutrient and crop management practices necessary to increase bean crop productivity in farmer fields are currently under way. Positive results are expected to provide practical information on how to improve soil fertility through crop management that even low-literacy farmers can readily adopt.

Researchers in Uganda conduct a Nutrient Omission Study

The team is analyzing data from interviews conducted with hundreds of small-holder farmers to learn the details of their farming practices and management decisions but also the social, economic, and cultural factors that impact how they learn and what helps them be open to learning new farming concepts.

These interviews and discussions have revealed that creating a continuous community-learning environment enables farmers to make informed actions that they can believe in The project team is forming farmer-led learning groups that will be supported in field experiments to test and demonstrate the impact of variations in farmer- and scientist-recommended management practices and technologies for bean production. These groups will help develop

community cohesion among isolated farmers and provide them with opportunities to learn, share their thoughts and assessments, trust one another, collectively transform their beliefs and knowledge, and encourage one another to make changes. The team will then identify creative ways to engage those farmers not yet making changes or embracing innovations.

Two field researchers in Uganda evaluate bean plants during a field trial

The project's success lies in the team's understanding how to increase soil fertility through scientifically-informed crop management practices that can be integrated into existing cropping systems and their commitment to engaging core groups of farmers, women and men, in developing and testing innovative communications approaches and technologies for learning and sharing information about new options for sustainable improvement. While the team's work is still in its early stages, their accomplishments in the field and their connection to farmers' groups is already showing signs that improved crop yields will be part of the near and long-term future for smallholder farmers in Uganda and Mozambique.

Tepary Beans Offer Hope for Hot, Drought Prone Areas Affected by Climate Change

Smallholder bean farmers living in hot, dry agroecological zones in Central America and Haiti have difficulty growing common bean, a staple crop critical for household food security and livelihoods. The *tepary* bean *(Phaseolus acutifolius)*, a sister species of common bean grown by Native Americans for more than 5,000 years in semi-arid production systems in Mexico and the Southwest United States, has naturally evolved with resistances to drought and high temperature conditions. This underutilized bean species, which produces seeds similar in shape, color, and taste to common bean, is an alternative crop that can be grown in semi-arid areas and agricultural systems with increased prevalence of drought and high temperatures resulting from climate change.

Seed of improved tepary versus unimproved tepary (top left)

Dr. Timothy Porch, a USDA-ARS Research Geneticist and Co-PI in a Legume Innovation Lab project led by the University of Puerto Rico (Dr. James Beaver, Lead PI) and the Escuela Agroicola Panamericana–Zamorano in Honduras, is seeking to increase bean productivity in lowland (< 1000 m) bean production regions of Central America and Haiti. The strategy for addressing climate change adopted by this project is to genetically improve tepary bean for agronomic traits and yield potential rather than to breed common bean for increased tolerances to drought and high temperatures. Common bean is a species best adapted to agroecological zones with moderate rainfall and temperatures. By exploiting the tepary bean's natural heat and drought tolerance characteristics, Legume Innovation Lab scientists believe that this new crop will provide countless smallholder farmers in regions adversely affected by climate change with a viable means to produce bean grain.

A major constraint to bean production in Central America is viruses. *Bean common mosaic virus* (BCMV) and *bean common mosaic necrosis virus* (BCMNV) can cause up to 90% yield loss in susceptible varieties. Dr. Porch has identified BCMV- and BCMNV-resistant tepary bean lines in the USDA-GRIN and CIAT tepary germplasm collections. New high yielding varieties of tepary bean with acceptable seed quality traits, along with virus, common bacterial blight, and weevil resistances are currently being bred.

In 2013, the first improved tepary bean line was released by the Legume Innovation Lab project in collaboration with Feed the Future's USDA-ARS project, the University of Puerto Rico, and Colorado State University. This variety has larger seeds, improved disease resistances, and upright plant architecture for easier harvest, characteristics that are important to bean farmers.

“We breed beans—common and tepary—by selecting for specific traits to achieve two very different but equally important objectives,” said Porch. “The first is to breed lines with increased vigor and disease- and pest-resistances, traits that contribute to high grain yield. The second is to breed for seed traits—color, size, taste, cooking time—that are important to consumers. If we don’t pay attention to the seed traits, advances made in improving agronomic traits may be irrelevant. Consumers purchase and eat beans that look, cook up, and taste good. Market demand for a new bean variety is essential for a new variety to be adopted. Plant breeders have to focus on both objectives—and we do.”

A field planted with common bean (l) and tepary bean (rt.)

As a result of USAID investments under Feed the Future, systematic breeding of tepary bean is being conducted for the first time. Advanced lines of tepary beans are currently being evaluated under field conditions in Honduras, Burkina Faso, and Puerto Rico. Future breeding efforts will utilize marker-assisted selection to accelerate the combining of genes for expanded disease resistance and desired agronomic traits.

Tepary bean provides hope to smallholder bean farmers affected by climate change both in the Americas and in Africa. Within the savanna regions of West Africa, tepary is already grown on a limited scale but sought by consumers for its flavor as a compliment to cowpea. Unfortunately, smallholder farmers in both continents don’t have access yet to improved, high yielding varieties of tepary bean. With projections of expanding and more frequent drought in many regions, the tepary bean has the potential of being a game-changing technology, providing farmers with an alternative but similar and equally nutritious bean crop that will enhance their resilience to pending climate change.

MASFRIJOL—Unique Partnerships and Model for Scaling

Achieving nutritional outcomes from outputs of agriculture research by Innovation Labs is a formidable challenge facing USAID's Feed the Future (FTF) programs.

Within the western highlands of Guatemala, a FTF focus region, indigenous Mayan populations present one of the world's highest incidences of undernutrition, as measured by child stunting (UNICEF 2013). The sad aspect of this situation is that Food and Nutrition Technical Assistance III Project (2013) dietary recommendations identify the nutrient-dense common bean, a traditional staple food in the region, as an important component of a diverse, nutritious diet to address this chronic malnutrition.

MASFRIJOL, a four-year associate award to the Legume Innovation Lab (managed at Michigan State University) and contracted by the USAID Mission to Guatemala, is implementing a novel approach to improve the nutrition of the rural poor in the Guatemalan highlands. The program seeks to increase both the productivity and consumption of common bean through parallel interventions: 1. enhancing smallholder farmer access to quality seed of improved disease-resistant climbing and bush-type bean varieties and 2. increasing knowledge of the nutritional value of beans in diets, especially as related to children and women of childbearing age, among household decision makers who shape dietary choices.

The innovation in MASFRIJOL's scaling-up strategy comes from the selection of the national institutional partners in Guatemala: the Instituto de Ciencia y Tecnología Agrícola (ICTA) under the Ministerio de Agricultura (MAGA) and the Ministerio de Salud Pública y Asistencia Social (MSPAS). Both ICTA and MSPAS are committed to improving the livelihoods of the rural poor.

Within highland FTF communities, agriculture extension agents (MAGA) and rural nutrition technicians (MSPAS), with training through MASFRIJOL, are working jointly to promote community-based seed production of improved bean varieties (from ICTA) and to implement culturally appropriate nutrition education programs (developed by Centro de Comunicacion para el Desarrollo-CECODE). Both the groups of technicians and institutions appreciate the importance of food-based agricultural solutions to address the undernutrition of highland children, stating that this is the first time that they have worked together on a common program toward a common goal within rural communities. For them, beans, which are a traditional staple food in local diets, a staple crop in the milpa system followed by the indigenous people, a women's crop, and a cash crop that can increase household income, are the perfect solution.

The combined efforts of these national institutions with USAID partners working in this FTF region is an effective scaling program which was able to reach more than 8,000 households with improved bean varieties during the first six months of operation in 2014.

MASFRIJOL's vision is that joint public institutional ownership of this fused agriculture–nutrition program will be embraced by government officials and, thus, sustainable when the nutritional benefits are realized among rural children in indigenous highland communities.