# FY 2015 TECHNICAL PROGRESS REPORTS

**October 1, 2014–September 30, 2015**

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

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

Legume Innovation Lab

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**Host Countries and Legume Innovation Lab Projects**

***West Africa***

- Benin (SO1.B1),
- Burkina Faso (SO1.A5 and SO1.B1),
- Ghana, (SO1.A5 and SO1.B1),
- Niger (SO1.B1), Senegal (SO1.A5)

***East and Southern Africa***

- Malawi (SO2.2 and SO3.1),
- Mozambique (SO2.1),
- Tanzania (SO2.2 and SO4.1),
- Uganda (SO1.A3 and SO2.1),
- Zambia (SO1.A2, SO1.A3 and SO2.2)

***Latin America and the Caribbean***

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

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- USDA/ARS, Michigan State University USDA/ARS, Prosser, Washington
- USDA/ARS, Tropical Agriculture Research Station, Mayaquez, Puerto Rico

**Subcontracted International Institutions**

- **Benin** International Institute of Tropical Agriculture (IITA–Benin)

- **Burkina Faso** Institut de l'Environnement et de Recherches Agrícolas (INERA)
- **Ghana** Crops Research Institute (CRI)
  Savannah Agriculture Research Institute (SARI)
- **Guatemala** Instituto de Ciencia y Tecnología Agrícolas (ICTA)
  Fundación para la Innovación Tecnológica, Agropecuaria y Forestal (FUNDIT) Ministerio de Salud Pública de Guatemala (MSPAS)
  Consejos Comunitarios de Desarrollo (CECODE)
- **Haiti** National Seed Service (NSS), Ministry of Agriculture
- **Honduras** Escuela Agrícola Panamericana–Zamorano (EAP–Zamorano) and Dirección de Investigación y Tecnologías Agrícolas (DICTA)
- **Malawi** Lilongwe Univesity of Agriculture and Natural Resources (LUANAR)
- **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 Research Institute (NaCRRI)
- **Zambia** Zambia 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 |
| LUANAR | Lilongwe University of Agriculture and Natural Resources |
| **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 |
| **MSPAS** | Ministerio de Salud Publica y Asistencia Social, Guatemala |
| **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** | Principal 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) |

# 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 human nutrition and health through increased consumption of grain legumes. Administered by Michigan State University, ten multidisciplinary multi-institutional, multicountry and projects are subcontracted to Lead U.S. universities that sub-subcontract collaborating research institutions (NARS, agriculture research centers) in 11 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 administered one associate award in FY 2015s: *MASFRIJOL* (2014–2018), contracted by the USAID Mission to Guatemala.

A 10-member Technical Management Advisory Committee (TMAC) monitored the technical progress of subcontracted LIL projects through the evaluation of annual workplans, budgets and technical progress reports as well as advised both the Management Office and USAID on all technical and administrative matters regarding program implementation and performance. The TMAC also conducted periodic visits to project sites.

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

## Program Activities and Highlights

FY 2015 was the third year and the midpoint of the current four-and-a-half year extension phase (April 1, 2013 – September 29, 2017) of the Feed the Future Collaborative Research Program on Grain Legumes (Legume Innovation Lab) administered by Michigan State University (AID-EDH-A-00-07-00005). The Management Office is pleased to report that FY 2015 was a highly productive and successful year. All ten subcontracted research and institutional strengthening/training projects were highly productive and presented evidence of making technical gains toward project objectives.

The Management Office obligated $280,991.78 to host country institutions in FY 2015 for institutional strengthening activities (see section VII for details). This supplemental funding was awarded competitively to LIL partner host country institutions which submitted proposals. The TMAC reviewed the proposals and recommended projects for funding to the MO. These Institutional Capacity Strengthening awards are in addition to funds budgeted for institutional capacity strengthening and short term and degree training in each of the subcontracted projects.

To be in compliance with USAID standard provisions, the Management Office submitted an Environmental Mitigation and Monitoring Plan (EMMP for the Legume Innovation Lab with specific mitigation and monitoring requirements for individual subcontracted projects. USAID approved the EMMP and provided guidance on authorized fertilizers, pesticides and microbial inoculants that can be purchased with USAID-LIL funds and used in project research activities. The EMMP was included in all modifications to subcontracts under LIL.

The Legume Innovation Lab in partnership with the Feed the Future Innovation Lab for Collaborative Research on Peanuts and Mycotoxin Management and the CGIAR's Research Program on Grain Legumes contributed a total of $1,250,00 to support the *Legume Scholars Program (LSP)*. The objectives of the LSP are to (1) To build human research capacity of national agriculture research institutions in developing countries in applying cutting-edge science to address future challenges and opportunities of the legume sector in developing countries, (2), To facilitate greater collaboration in research between the CGIAR and the USAID Innovation Lab legume scientists through joint supervision of graduate student research projects, and (3) to attract a new generation of scientists prepared to address complex global challenges in sustainable ways to achieve agriculture development goals in legume producing countries around the world. In response to a request for nominations, a total of 248 nominations packages were received. After several iterations of review, the partners and USAID decided to award the LSP scholarships to five promising young scientists for PhD programs at U.S. universities under the supervision of Innovation Lab PIs.

In May 2015, ICTA–Guatemala served as the host of the 60th meeting of the Society of the Central American Cooperative Program for the Improvement of Crops and Animals (PCCMCA). Since ICTA has been a long term collaborator with the Bean/Cowpea CRSP and the current Legume Innovation Lab through the SO1.A1 and SO1.A3 research projects and the MASFRIJOL associate award, the MO was invited to organize and lead a thematic plenary session on current topics in bean research. Speakers in this session from LIL included Dr. Juan Osorno (NDSU), Drs. Barry Pittendrigh and Julia Bello Bravo (UIUC) and Dr. Irvin Widders. This session gave great visibility to USAID investments in collaborative research on common bean in the Central

American and Caribbean region and the technological outputs, especially improved varieties that have been released and are being grown commercially in over 10 countries.

Upon United Nations and FAO approval of 2016 as the International Year of Pulses (IYP), the Management Office worked with the Global Pulse Confederation (previously CICILS) and Emergingag.inc to obtain authorization of the joint Pan-African Grain Legume and World Cowpea Conference as one of ten signature international events to celebrate IYP. The Legume Innovation Lab, as the lead organizing institution in partnership IITA–Zambia and the PanAfrican Bean Research Alliance (PABRA/CIAT), took the initiative to convene a Conference Planning Committee to schedule and organize this first Pan-African, multigrain legume species and multidisciplinary conference to be held in Livingstone, Zambia, during the week of 28 February to 4 March 2016. Throughout FY 2015, monthly planning meetings were held, a scientific program committee was established, additional host and sponsoring institutions were recruited, a conference webpage was established (gl2016confa.iita.org/) and a call for abstracts was issued announced.

## Key Accomplishments

Key research achievements by subcontracted Legume Innovation Lab projects in FY 2015 include the following:

- **SO1.A1.** DNA was extracted from 600 accessions of climbing beans from Guatemala and processed for SNP genotyping to assess genetic diversity. A survey was conducted of approximately 500 small holder bean farmers and data analyzed to understand the scope and importance of climbing beans to households in the Guatemala highlands.
- **SO1.A2.** The Dynamic Environmental Imager (DEPI), the PhotosynQ platforms, the field deployable network of handheld sensors (MultiSpecQ), and the associated online communication and data analysis tools developed in the Kramer lab at MSU were validated for use in phenotyping of grain legumes (bean and cowpea) in controlled and field environments. Initial results suggest that PhotosynQ in conjunction with MultiSpecQ measurements will be useful in providing early estimates of yield and the onset of diseases.
- **SO1.A3.** Lines of common beans have been pyramided with three pyramided anthracnose and one root rot (Pythium) resistance genes, and are being advanced and evaluated for performance under field conditions in Uganda.
- **SO1.A4.** The small light red cultivar *Paraisito Mejorado 2–Don Rey,* which carries BGYMV and BCMV disease resistance and possesses excellent adaptation to low soil fertility, was released for commercial production in Honduras.
- **SO1.A5.** A differential cowpea panel of aphid resistance sources and control lines was seed-multiplied and used in multilocation field screening and screen house seedling screening. Several aphid resistance sources effective against both U.S. and West African aphid populations were identified.
- **SO1.B1.** Analyses of field data have shown that the animated educational approach via cell phones are as effective in reaching low education farmers, especially women farmers, as the

use of extension agent presentations. Educational animations on cowpea IPM can therefore be scaled up through cell phones for widespread impact.

- **SO2.1.** The effects of N, P, K, Mg, Ca, S, micronutrient and lime fertilization on common bean growth and development were elucidated from nutrient emission studies guided by analyses of chemical and physical properties of black, red and stony soil samples from key production districts in Uganda and Mozambique. Ongoing analyses of weekly common bean market prices and marketing patterns are being incorporated into the decision support aids and will be used for the training for farmers.
- **SO2.2.** Two workshops on entrepreneurial activities and strategic alliances in the food and agribusiness industries were conducted in each of the three target countries, Zambia, Malawi and Tanzania in FY 2015.
- **SO3.1.** Two large clinical trial sites were selected in Malawi (in Nsanje and Machinga Districts), and local village health workers and community leaders educated on the objectives of the dietary intervention study to determine the effects of eating grain legume based foods on infant growth and gut health. Excellent progress has been made in enrolling young children in the clinical studies: > 50% enrollment of 6–12 month old infants in Study 1 and 100% enrollment of 12 to 24 month old young children in Study 2. Clinical studies were initiated in late FY 2015.
- **SO4.1.** A case study was completed of a farmer association in Burkina Faso involved in cowpea seed production by training member farmers and providing technical oversight to produce quality declared seed for sale to other farmers in their communities.

By the end of FY2015, MASFRIJOL, an associated award from the USAID Guatemala Mission (AID-OAA-LA-14-00005) had reached 25,100 families in 285 communities in the target Feed the Future municipalities in the Western highlands of Guatemala with quality seed of improved varieties of common bean adapted to the agroecologies of the region. On-farm yields have increased by 200–400% by planting these improved varieties. In addition, 1,158 women and 4,506 men participated in nutrition education sessions that promote greater consumption of beans to enhance dietary nutritional quality and improve child growth. Implementing institutions in Guatemala, ICTA and MSPAS are partnering with eight other Feed the Future funded programs to extend the bean technologies and nutrition educational to more beneficiaries and communities.

## 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 2015, Michigan State University administered a portfolio of ten subcontracted multi-institutional collaborative research and capacity strengthening projects and one associate award. 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, and (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.

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


### Lead U.S. Principal Investigator and University

Juan M. Osorno, Dept. of Plant Sciences, North Dakota State University. Fargo, ND 58108.

### Collaborating Host Country and U.S. PIs and Institutions

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Angela Miranda, ICTA–Guatemala
Jessica Moscoso, ICTA–Guatemala – New team member
Gustavo Mejia, ICTA–Guatemala – New team member
Karla Ponciano, ICTA–Guatemala – Resigned February 2015
Julio Martinez, ICTA–Guatemala – Retired January 2015


## I. Abstract of Research and Capacity Strengthening Achievements


The project continues to make progress towards the testing and release of improved climbing beans for the highlands if Guatemala. A total of 10 lines have been tested across more than 15 locations at farmer's fields in order to obtain information about their agronomic performance as well as grower's feedback. An additional year of testing will be needed before making final decisions regarding release of varieties. Three lines are showing the best combination of seed yield and reduced aggressiveness that would allow high productivity in the maize under the Milpa system. On-farm testing of Bolonillo Texel continues in order to ensure adaptation and acceptability by growers. Phenotypic variation within this line has been noticed and we are making efforts to ensure genetic purity of the line, even though this is not a big issue for growers since they are used to grow heterogeneous material in their fields. In addition, seed cannot be separated once harvested. The 600 accessions of the climbing bean collection were finally received at NDSU and are under DNA extraction at the time of this report. The baseline study with the growers was successfully completed (~500 growers) and tabulated and is currently under statistical analysis. In addition, seed samples from most growers surveyed was obtained and is currently being increased at the ICTA greenhouses. This is a great opportunity to assess the current genetic diversity being used by growers as well as to compare with the original climbing bean germplasm collection collected 30 years ago. Last but not least, 2 female students started their M.S. training in plant breeding and genomics at NDSU. This will ensure the next generation of bean scientists for Guatemala. In addition, new collaborations have been established with project SO4-1 and MASFRIJOL to augment the success of the breeding efforts of this project.


## II. Project Problem Statement and Justification

With approximately 11 million habitants, Guatemala is mostly a rural country, with 60% of the population living in farms and 50% of the population being indigenous. Maize and beans are the main staple food in most households with a per capita bean consumption of 9.4 kg per year. Since few other sources of protein are available, this amount is not enough to ensure an acceptable nutritional quality, especially within poor households. As expected, the lack of protein intake has reduced the nutritional quality in many households, significantly affecting children. Chronic malnutrition is frequent among children under 5 years old in the western highlands, with 67% of children affected, making Guatemala the country with the highest malnutrition level in the western hemisphere. One out of every three children from ages six to 59 months in the western highlands shows some degree of anemia. Approximately 18% of reproductive-age women exhibit anemia, with 29% prevalence among pregnant women and 23% prevalence among breastfeeding women.

Beans are grown on 31% of the agricultural land and mostly in the low to midaltitude regions (0–1500 masl) in a monoculture system. Contrastingly, intercropping (locally known as Milpa) is the main production system in the highlands, where maize–bean is the most common crop association. Unfortunately, on-farm productivity of these climbing beans is approximately one third of their genetic yield potential mostly due to the lack of improved cultivars that are able to withstand biotic and abiotic stresses. Fungal and bacterial diseases as well as pests are the main cause for yield reductions. In addition, production is made with almost no inputs of fertilizers and/or other chemicals. Historically, climbing beans worldwide have received less attention and breeding efforts in comparison with the bush-type beans commonly grown in the lowlands, as shown by the significant yield gap between regions. In addition, there are genetic and environmental interactions among species (maize, bean, squash, etc.) not well understood within the intercropping system that may affect crop performance and hence, seed yield. The legume Innovation Lab has been involved in collaborative bean breeding research targeting lowland agroecologies in Central America, but research for the highland bean production systems is still lacking.

There is an existing collection of approximately 600 accessions of climbing beans collected across all bean production regions in Guatemala. This collection is kept by ICTA and has been characterized morphologically, agronomically, and with few molecular markers (6 SSR primers). Initial results suggest that ½ of the collection consist of duplicates. In addition, some initial crosses among climbing beans and selections have been made by the ICTA group. These lines will be used intensively in this project.

# III. Technical Research Progress

**Objective 1. Development of germplasm with improved disease resistance and agronomic performance.**

**Collaborators**

NDSU: Juan M. Osorno and Phil McClean.

ICTA: Julio Cesar Villatoro, Fernando Aldana, Jessica Moscoso.

### *1.1. Field testing of 10 selected lines (ICTA)*

A total of 10 climbing bean breeding lines that are at advanced breeding stages were selected to be part of field trials:

1. Bolonillo Altense
2. Bolonillo Hunapu
3. Bolonillo Texel
4. Bolonillo Anita
5. Bolonillo Labor Ovalle

6. Bolonillo San Martin
7. Bolonillo ICTA Santa Lucia
8. Voluble GUATE 1120
9. Voluble GUATE 1026
10. Local check from the grower (different among farms).

Most of these breeding lines are the product of initial crosses made 5–6 years ago and subsequent composite mass-selection and testing made by Dr. Fernando Aldana at the ICTA–Quetzaltenango station. Any superior line or lines could be released as varieties in the near future while a breeding pipeline is established. The trials were planted around May and grown both at the ICTA–Quetzaltenango station and at farmer's fields in 17 locations (Table 1).

**Table 1.** List of climbing bean trials (location and department) made during the 2015 growing season in the Guatemalan highlands.

| | LOCALIDAD | DEPARTAMENTO |
|---|---|---|
| 1. | PAXTOCA | TOTONICAPÁN |
| 2. | CHUISUC | TOTONICAPÁN |
| 3. | SAN ANTONIO SIJA | TOTONICAPÁN |
| 4. | XESENA | TOTONICAPÁN |
| 5. | PATACHAJ | TOTONICAPÁN |
| 6. | CHOQUI ALTO | QUETZALTENANGO |
| 7. | OLINTEPEQUE | QUETZALTENANGO |
| 8. | SJ OSTUNCALCO | QUETZALTENANGO |
| 9. | SP SACATEPEQUEZ | SN MARCOS |
| 10. | CHIANTLA | HUEHUETENANGO |
| 11. | SN SEBASTIAN | HUEHUETENANGO |
| 12. | SANTA POLONIA | CHIMALTENANGO |
| 13. | COMALAPA | CHIMALTENANGO |
| 14. | TECPAN | CHIMALTENANGO |
| 15. | EL TEJAR | CHIMALTENANGO |
| 16. | ZARAGOZA | CHIMALTENANGO |
| 17. | LABOR OVALLE | QUETZALTENANGO |


Most locations were tested under the common intercropping system (Milpa). Depending on space and resources at each location, the 10-entry trials were planted using a Randomized Complete Block Design (RCBD) with 2 or 3 replications. Farmer's trials included also the local varieties/landraces used by the farmer as the local check in order to be able to make side-by-side comparisons for these growers. Harvest of these field trials is still underway at some locations at the time this report is being written and should be finished by early December 2015. All this extensive testing is coordinated by the field validation unit at ICTA (Julio Franco is the coordinator), which is the final step before official variety release under ICTA standards. Results from the previous year (FY2014) are available as Appendix 1.

Across locations, Bolonillo San Martin had the highest seed yield, followed by Bolonillo Hunapu and Bolonillo Altense. Unfortunately, the general trend is that these genotypes are extremely aggressive in their growth in order to obtain the high yields reported and therefore, there is significant damage to the maize (mostly due to lodging). This is the main reason why growers have stopped growing beans in association with maize because culturally, the latter is the most important crop for them. This is more accentuated above 1500 masl because direct planting (instead of relay) cause more competition between maize and bean. Consequently, the best combination of high seed yield and minimum damage to maize is offered by Bolonillo Santa Lucia, Bolonillo Texel, GUATE 1026, and Bolonillo Labor Ovalle (Appendix 1). In addition, Bolonillo Anita was the most stable genotype across locations. ICTA validation unit needs a minimum of 3 years of multilocation testing before making decisions about which genotypes to be released, but we will keep directly involved in this process. Main production problem during the last 2 years are the Mexican weevil (Apion spp.) as well as rust, anthracnose, ascochyta, and angular leaf spot.

### *1.2. Breeding pipeline and genetic purification of selected material (ICTA/NDSU)*

As explained in the Technical Project Description, phenotypic variation has been detected not only within accessions but also within the improved lines selected by Dr. Fernando Aldana at ICTA–Quetzaltenango. The main reason for this is that Dr. Aldana kept these lines as bulked lines during multiple generations and therefore, no individual plant selections have been done during the breeding process. Therefore, individual plant selections were made within the breeding lines during the 2013 growing season and planted again as plant rows at ICTA–Quetzaltenango.

A total of 43 individual plant selections within each one of the 10 lines mentioned in objective 1A were made based on potential yield and quality, absence of disease symptoms, pod distribution and color, and other agronomic traits. These individual selections were sent to the ICTA–San Jeronimo station for winter increase and each selection was planted as individual rows for further evaluation/selection. This allowed for detection of additional genetic heterogeneity within lines while increasing seed. Since phenotypic heterogeneity was still detected, more individual plants and some bulked rows were selected and sent to ICTA–Quetzaltenango for evaluations during the 2015 growing season. A total of 130 individual plant selections were planted as rows and harvest of this material is almost complete at the time of this report. A final round of phenotypic evaluation will be made during FY2016 in order to ensure a homogeneous source of breeder seed to start the seed increase process.

Additional studies were focused in evaluating population dynamics and densities of Mexican bean weevil (*Apion godmani*) in the 4 most promising breeding lines mentioned in Objective 1.1. This study is actually part of the thesis project for a local Agronomy B.S. student in Quetzaltenango (Karen Agreda), and also an agroeconomic study of alternative intercropping systems besides the common Milpa to see if maize-bean productivity could be increased by having different arrangements. Finally, several rust mobile nurseries were deployed in different growing areas in order to assess the race structure of the pathogen across the region. At least 9 rust races could be identified based on the disease reaction observed in the differentials. Please refer to Appendix 2 to find specific details and results about these complementary studies.

### *1.3. Field evaluation of Bolonillo-TEXEL (ICTA)*

One of the improved lines selected by Dr. Fernando Aldana at advanced breeding stages (known as Bolonillo-Texel) was also tested at grower's fields. Side-by-side Milpa on-farm strip trials of the local's farmer variety/landrace and Bolonillo-Texel were grown (using the same maize material and agronomic practices) in 5–6 of the locations mentioned in Table 1 as on-farm strip trials. Bolonillo-Texel is one of the most promising breeding lines based on preliminary data previously collected by Dr. Fernando Aldana, ICTA–Quetzaltenango. Since these trials are mostly managed by growers, data collection is mostly focused on seed yield, agronomic performance, and personal feedback from each grower. Technical assistance from ICTA agronomists (special tanks to Elmer Estrada) and crop extension personnel from the Ministry of Agriculture have been crucial for finding these growers and locations.

Differences in pod color have been noticed in these trials, which confirm the genetic heterogeneity still present in Bolonillo Texel, even though this is not a big issue for local growers since they already grow heterogeneous material in their farms. However, it is a concern for this breeding project and we are doing all necessary activities (see objective 1.2) that will allow obtaining a uniform variety at the end of this project. The MASFRIJOL project is highly interested in obtaining a new climbing bean variety for his disseminations program, so efforts are in coordination with them in order to speed up this process as much as possible.

***1.4. First crossing block***

With the results obtained from the field testing and the evaluation of the germplasm collection during the 2014 growing season (objective 2.3), a first set of 23 potential parents were selected by Osorno, Villatoro, McClean, and Aldana, and planted in the greenhouse at the ICTA station in Chimaltenango during the 2015 growing season. Parental accessions were selected mainly based on uniform pod distribution, potential yield, and disease resistance.

Unfortunately, the first generation of single crosses during FY15 has encountered some difficulties in regards to flowering synchronicity in spite of planting the material at staggered planting dates. Anecdotal results suggest that this germplasm is highly sensitive to daylenght (photoperiod), so the long days during the summer would not trigger flowering in these materials. Therefore, some crosses planned initially won't be accomplished and will have to be attempted again during FY16. Since the collection was planted again in the trellis system available at ICTA–Chimaltenango, we took advantage of this opportunity and attempted to do crosses in the field rather than in the greenhouse. Results were relatively successful so far and F1 seed is being harvested at the time of this report. Therefore, complementary crosses will be attempted again during the 2016 growing season in order to have a continuous breeding pipeline for the future (see objective 1.2).

**Objective 2. Characterization of the genetic diversity of this unique set of germplasm**

**Collaborators**

NDSU: Juan M. Osorno and Phil McClean.
ICTA: Julio Cesar Villatoro, Fernando Aldana, Jessica Moscoso, Angela Miranda.

***2.1. Evaluation of core collection with the 6k SNP chip (NDSU)***

As explained in the milestones, this activity had to be postponed because the seed available from the germplasm collection stored at ICTA–Chimaltenango was in bad condition and would not pass phytosanitary inspection in order to be shipped to NDSU. Seed was severely affected by bruchids (mostly *Acanthoscelides* spp.). ICTA doesn't have adequate long-term seed storage infrastructure and it is something that needs to be addressed in the future. Another option would be to have a backup set of this collection with USDA-GRIN. It also appears that CIAT has most of the accessions from this climbing bean collection but this is something that needs to be revised.

In order to solve this issue with seed quality, it was decided to do a new field increase of all the germplasm collection at the ICTA–Chimaltenango station during FY14 in order to produce fresh seed to be shipped to NDSU for DNA analysis. Delays in getting a phytosanitary certificate from the Ministry of Agriculture in Guatemala caused that seed was not shipped to NDSU until August 2015. However, the timing was actually perfect since it did coincide with the arrival of the three new students (trainees) that will work with these accessions (Objective 4.1). One of the students (Gabriela Tobar) will have the molecular characterization of the collection as her main research topic for her M.S. degree.

Seed from each accession of the climbing bean collection is currently being processed for DNA extraction and SNP genotyping. First objective is to confirm the previous reports about half of the collection being duplicates. For this, a set of ~70 InDel markers will be used and then decisions will be made about what will be genotyped with SNP markers. We expect to present the first results of this molecular characterization at the Pan-African Grain Legume and World Cowpea Conference at Zambia in March 2016.

***2.2. Assessment of the intra-accession variability (NDSU)***

Because of the reasons exposed in the previous section, this activity had to be postponed as well. A genetic assessment of variation within the 10 selected lines used in objective 1.1 will be made in order to account for the heterogeneity not only among but within accessions and possibly, extrapolate that information to the rest of accessions. Preliminary phenotypic observations in the field suggest that there is a high amount of genetic heterogeneity (heterozygocity) within accessions. Therefore, 20 plants from each of the 10 selected accessions will be planted in the greenhouse at NDSU and DNA will be extracted, for a total of 200 DNA samples/individuals. These genotypes will be also screened with a subset of InDel markers developed in the NDSU bean molecular genetics lab (Moghaddam et al., 2014). The InDel markers were developed from polymorphic SNPs, but their advantage is that they can be easily reproduced by PCR and visualized in an agarose gel. Since the main goal is to assess intra-accession variability, this will be easily detected by looking at the band polymorphisms in the gels. Polymorphic Information Content (PIC) and other genetic parameters will be estimated. This information will allow a better understanding of the organization of the genetic diversity within this core collection for future use and research.

Because this collection will form the basis of future breeding efforts by ICTA, it is necessary to understand the diversity among the lines in the collection. At the same time, the project is interested in ensuring that a line is pure. All lines were visually screened at ICTA, and any line that contained multiple seed coat color or patterns were discarded. Those lines were delivered to NDSU in September 2015. In addition, at NDSU, any line with a single seed coat color and pattern, but which the seeds varied for seed size, was also discarded. This left ~400 lines. Two seeds for each line were planted in the NDSU greenhouse and leaf tissue was from each plant were collected and pooled. DNA was isolated from the leaf sample for each line.

### *2.3 Field evaluation of the ICTA collection of climbing beans (ICTA–NDSU)*

The entire collection of climbing beans from ICTA has been planted in FY2014 at the ICTA station in Chimaltenango to allow a re-evaluation of the material and also the production of a newer batch of seed. Each accession has been planted in short rows (~2 m) mostly for phenotypic observation. A first set of 23 potential parents were selected by Osorno, Villatoro, McClean, and Aldana, and planted in the greenhouse at the ICTA station in Chimaltenango during the 2014 growing season for initial crosses (Objective 1.4). A list of selected accessions can be found in Appendix 2. Parental accessions were selected mainly based on uniform pod distribution, potential yield, and disease resistance. Since the entire collection was planted again during FY2015, it gave us an opportunity to re-evaluate the 23 accessions selected the year before. The research group felt very confident that the 23 selected accessions represent the best of the collection in terms of agronomic performance. Some of these activities will overlap with FY2016. These selected accessions were used for the first set of crosses described in objective 1.4.

## **Objective 3. A better understanding of the current socioeconomic status and needs of bean production within the context of intercropping systems in the region**

**Collaborators**

NDSU: Juan M. Osorno.
ICTA: Gustavo Mejia, Julio Cesar Villatoro, Fernando Aldana.
MSU: Mywish Maredia, David DeYoung, and Byron Reyes from project SO4-1.

As described in the technical project description and FY15 work plan, a grower survey was deployed during March 2015 in the main regions where climbing beans are produced. The survey activity was very successful thanks to a great collaboration established with the project lead by Mywish Maredia (SO4.1). They have far more experience with surveys than any person in our team, so we appreciate their willingness to help. Originally, Julio Martinez from ICTA was the social economist in charge of this. However, he decided to retire in January 2015 and ICTA quickly assigned Gustavo Mejia, another social economist at ICTA–Quetzaltenango to be in charge of this activity. His involvement and passion in this activity was crucial for the success of the survey. Considerable time was devoted to designing the survey instrument, with skype calls every week until completed. Survey instrument (Word or PDF format) is available as Appendix 3.

We focused on the following departments based on some stratified analysis: Quiche, Huehuetenango, San Marcos, Totonicapán, and Quetzaltenango which represent most of the climbing bean production areas. Once approval for the survey was obtained from the Institutional Research Board (IRB) at NDSU, a group of ~15 surveyors was selected and trained by David DeYoung and Byron Reyes. Approximately 500 growers across 5 departments were surveyed during the 3–4 week period during March 2015.

Collected data has been entered into a digital format (Excel) by ICTA personnel and is currently under revision and filtering of errors at MSU. Therefore, during FY16, data will be analyzed using the proper statistical tools and results will be summarized. Results of this survey will be shared not only within the project but with other projects currently working in Guatemala (e.g. Masfrijol) and government agencies interested. First results will be shared at the Pan-African Grain Legume and World Cowpea Conference at Zambia in March 2016.

An interesting activity performed during the survey was the collection of a seed sample (~10 seeds) that was requested to each grower surveyed. Seed samples were donated voluntarily and ~85% of the growers surveyed accepted to give us a sample of the seed they use in their farms. Therefore, now we have a newer set of 540 climbing bean germplasm accessions that virtually represents what growers are using in their farms currently. Since seed amounts were limited, 4 seeds per sample were planted in the greenhouse for increase and future evaluation during FY2016. Future activities with this set of germplasm include a comparison of the original germplasm collection from ICTA with this new collection and see what changes in genetic diversity could be detected. This will provide an opportunity to do a phenotypic evaluation of the germplasm collected during the survey and possibly to identify genetic material of interest for the breeding pipeline (Objective 1.2). In addition, the specific location from where each seed sample was obtained is available and therefore, some geographical diversity analyses are possible in the near future. Even more, the new germplasm collected during the survey could be compared with the original germplasm collection via SNP analysis (Objective 2.1) and try to establish some genetic similarities and hence, some possible geographical origin for the original germplasm collection since all the passport data was lost several years ago. We foresee this study as a good research topic for one of the students coming to do their M.S. training at NDSU (Objective 4).

**Objective 4. Capacity building: training the next generation of plant breeders for Guatemala and establishing a long-term breeding plan to increase the productivity of climbing bean in the region**

Recruiting efforts during FY2014 and FY2015 at ICTA have allowed the identification of three candidates for M.S. at NDSU. Gabriela Tobar Piñon and Carlos Maldonado are ICTA employees initially identified through the CAPA project, which is an early career program at ICTA to identify outstanding individuals for future employment and ICTA. The third candidate is Luz de Maria Montejo who is a graduate from the Escuela Agricola Panamericana Zamorano and was working with the Guatemalan Ministry of Agriculture. Luz was highly recommended by Juan Carlos Rosas and Jim Steadman and therefore, she was transferred to ICTA. The 3 students started their M.S. programs at NDSU in the fall of 2015. Given our inexperience with TraiNet and the process, we experienced multiple difficulties during the process, which caused the delay in having our first M.S. student (Gabriela) starting in January 2015. The process was reinitiated for this student plus the two new candidates so they all successfully started their M.S. degrees in fall 2015. The three students are currently living in Fargo, ND taking classes and doing research at NDSU.

Research topics will be directly related to the research objectives described above. We foresee research projects focused on the analyses of genetic diversity, genetic resistance to diseases, and production systems, among others. The graduate students will be provided a broad range of training in conventional and molecular plant breeding techniques so that they can assume leadership roles in bean research programs in the target countries.

# IV. Major Achievements

1. On farm field testing and validation across 17 locations of 9 breeding lines with potential to be released in the near future.
2. On-farm testing and validation of Bolonillo-Texel across 6 locations.
3. Establishment of a breeding pipeline and first set of crosses.
4. Initial molecular characterization (DNA extraction) of climbing bean collection.
5. Completion of grower survey and data tabulation of ~500 questionnaires.

6. Collection of seed samples from surveyed growers and seed increases in the greenhouses.
7. Recruitment of 2 female students for formal training (M.S. in Plant Sciences) at NDSU.
8. New collaborations established with project SO4-1 and MASFRIJOL will augment the success of the breeding efforts of this project.

## V. Research Capacity Strengthening

During FY2015, our project successfully obtained one of the capacity strengthening awards for host countries. We used the funds to support activities related to the PCCMCA annual meetings (Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos y Animales). This is the most important scientific meeting in Central America and the Caribbean about crop and animal production research. It is an annual regional forum hosted since 1954 on a rotating basis by the National Institutes of Agricultural Research (INIA) in Central America and the Caribbean. Scientists from universities, private companies, NGOs, international organizations involved in agricultural research in the region and other countries meet to discuss and analyze current issues and perspectives of research, technology, and innovation in agriculture and to exchange experiences and promote cooperative activities. The meeting was hosted by ICTA in Guatemala City May 4–7, 2015. The meeting attracted approximately 300 participants from the region. There was a 2.5 hour plenary session that showcased all the activities that we are currently doing in the region, so it was a great opportunity to show the model of the Legume Innovation Lab and its regional impact.

## VI. Human Resource and Institution Capacity Development

**Short-Term Training**

***Training to surveyors for grower baseline study survey***
**Purpose of Training:** To train a group of 17 surveyors for the baseline study deployed in March 2015.
**Type of Training:** 3-day workshop.
**Country Benefitting:** Guatemala.
**Location and Dates of Training:** ICTA Quetzaltenango, March 5–7 2015.
**Number receiving training (by gender):**
**Home institution(s): ICTA–Guatemala**
**Institution providing training or mechanism:** Training was provided by David DeYoung from Michigan State Univ (SO4.1) and Byron Reyes (CIAT).

**Degree Training**

**First and Other Given Names:** Maria Gabriela
**Last Name:** Tobar Piñon
**Citizenship:** Guatemalan
**Gender:** Female
**Training institution:** NDSU
**Supervising CRSP PI:** Phil McClean
**Degree Program for training:** M.S. in Plant Sciences
**Program Areas or Discipline:** Plant breeding/genomics

**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** Yes
**Host Country Institution to Benefit from Training:** ICTA
**Thesis Title/Research Area:** Molecular characterization of germplasm collection of Guatemalan climbing beans.
**Start Date:** August 2015
**Projected Completion Date:** December 2017
**Training status (Active, completed, pending, discontinued or delayed):** Active
**Type of Support (full, partial or indirect) g for training activity:** Full

**First and Other Given Names:** Luz de Maria
**Last Name:** Montejo
**Citizenship:** Guatemalan
**Gender:** Female
**Training institution:** NDSU
**Supervising CRSP PI:** Juan M. Osorno
**Degree Program for training:** M.S. in Plant Sciences
**Program Areas or Discipline:** Plant breeding
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** Yes
**Host Country Institution to Benefit from Training:** ICTA
**Thesis Title/Research Area:** Disease resistance in Guatemalan climbing bean germplasm collection.
**Start Date:** August 2015
**Projected Completion Date:** December 2017
**Training status (Active, completed, pending, discontinued or delayed):** Active
**Type of Support (full, partial or indirect) for training activity:** Full

## VII. Achievement of Gender Equity Goals

The ICTA bean breeding program includes two women in their team (Angela Miranda and Jessica Moscoso) and they are in charge of the activities at San Jeronimo and Quetzaltenango. In addition, 2 women who are ICTA employees (Gabriela Tobar and Luz Montejo) have been recruited for formal training (M.S. in Plant Sciences) at NDSU.

## VIII. Explanation for Changes

**Objective 2 .** Delays in seed production and acquisition of phytosanitary certificates caused the molecular characterization to be delayed. This will be completed in early FY2016 and activities should be back in track.

## IX. Self-Evaluation and Lessons Learned

After 2 years working in this partnership between NDSU and ICTA–Guatemala, the project has been able to make a lot of progress. The genetic material previously developed by Dr. Aldana at ICTA–Quetzaltenango allowed having breeding material ready to be tested in farmer's fields. This will ensure this program has significant impact in the short to medium term while a new breeding pipeline is established (long term). So far we are impressed with the capabilities and passion that ICTA personnel put into this project. ICTA has proven success with the long term program supported by the Legume Innovation lab for bush type beans for the lowlands along with the University of Puerto Rico. Since we are halfway in the project's timeline, we have been devoting a lot of time discussing what needs to be done in the next 2 years in order to ensure successful accomplishment of all objectives. The pod color segregation observed in the advanced material is a new concern for the breeding program, but not so much for the growers since they already deal with phenotypic variation in their fields. Seeds cannot be visually separated once harvested. Nonetheless, we are working towards the genetic purification of these lines in order to ensure the genetic stability of any variety that ICTA decides to release.

After many difficulties, we were able to recruit 2 M.S. students to work in this project at NDSU. The climbing bean collection is used as part of their research requirements for completion of their degree. The training of this human resource will ensure the next generation of plant breeders for Guatemala.

# X. Scholarly Accomplishments (Project member in bold)

Song Q., Jia G., Hyten D.L., Jenkins J. , Hwang E.Y., Schroeder S.G., **Osorno J.M.**, Schmutz J., Jackson S.A., **McClean P.E.**, and Cregan P.B. 2015. SNP Assay Development for Linkage Map Construction, Anchoring Whole Genome Sequence and Other Genetic and Genomic Applications in Common Bean. G3: Genes | Genomes| Genetics g3–115.

**Osorno J.M.** 2015. Avances en las secuencias genomicas de cultivos. Annual Meetings PCCMCA. Guatemala City, Guatemala. May 1–5. Oral presentation.

**Tobar-Piñon M.G.**, Illescas O.V., and **Villatoro J.C.** 2015 Evaluación sensorial y de aceptación de productos alimenticios a partir de variedades de frijol (*Phaseolus vulgaris*) biofortificado. Annual Meetings PCCMCA. Guatemala City, Guatemala. May 1–5. Oral presentation.

**Montejo, L.M.**, **Villatoro, J.C.**, and Dardon, D. 2015. Identification of physiological races of common bean rust (*Uromyces appendiculatus*). Annual Meetings PCCMCA. Guatemala City, Guatemala. May 1–5. Poster presentation.

**Maldonado-Mota C., Villatoro J.C., Miranda A., Moscoso-Alfaro J., Aldana L.F.** 2015. Fitomejoramiento de frijoles (*Phaseolus vulgaris*) biofortificados para Guatemala. Annual Meetings PCCMCA. Guatemala City, Guatemala. May 1–5. Poster presentation.

Khankhum S., Valverde R., Pastor-Corrales M., **Osorno J.M.,** and Sabanadzovic S. 2014. Two endornaviruses show differential infection patterns between gene pools of *Phaseolus vulgaris*. Arch. Virol. 160:1131–1137.

# XI. Progress in Implementing Impact Pathway Action Plan

After two years of this new project, we are confident that our activities have been in accordance with our impact pathway plan, with the exception of the molecular characterization of the germplasm collection. Specific plans are in place for FY2016 to ensure we meet the established pathways by the end of next funding cycle. Please refer to the Impact Pathway Plan document for more details.

## ANNEXES

**Appendix 1.** Study of stability and yield of 10 genotypes of climbing beans across 17 locations from the western highlands in Guatemala. (Estudio de estabilidad y rendimiento de diez genotipos de frijol voluble en 17 localidades del altiplano occidental de Guatemala).

**Appendix 2.** ICTA bean program annual report of activities for climbing beans (Informe de Proyecto de frijol voluble).

**Appendix 3.** Grower survey instrument (Guatemala encuesta de frijol voluble).

# Milestones

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**

**Report on the Achievement of "Milestones of Progress"**
**(For the Period: April 1, 2015 -- September 30, 2015)**

**This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2015**

***Project Title:*** **SO1.A1 Genetic Improvement of Middle-American Climbing Beans for Guatemala**

| | ***Abbreviated name of institutions*** | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NDSU | | | ICTA | | | Institution 3 | | | Institution 4 | | | Institution 5 | | | Institution 6 | | |
| | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | |
| ***Milestones by Objectives*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** |
| | ***(Tick mark the Yes or No column for identified milestones by institution)*** | | | | | | | | | | | | | | | | | |
| **Objective 1** | **Development of germplasm with improved disease resistance and agronomic performance** | | | | | | | | | | | | | | | | | |
| 1.1 Evaluation of selected accessions and other early- | **0** | | | **X** | **X** | | **0** | | | **0** | | | **0** | | | **0** | | |
| 1.2 Genetic purification of selected material | **0** | | | **X** | **X** | | **0** | | | **0** | | | **0** | | | **0** | | |
| 1.3 Field evaluation of Bolonillo-TEXEL | **0** | | | **X** | **X** | | **0** | | | **0** | | | **0** | | | **0** | | |
| 1.4 First crossing block | **0** | | | **X** | **X** | | **0** | | | **0** | | | **0** | | | **0** | | |
| **Objective 2:** | **Characterization of the genetic diversity of this unique set of germplasm** | | | | | | | | | | | | | | | | | |
| 2.1 Analysis of genetic diversity of core 300 with 6k S | **X** | | **X** | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 2.2 Analysis of within-accesion variation of selected a | **X** | | **X** | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 2.3 Field evaluation of the ICTA collection of climbing | **0** | | | **X** | **X** | | **0** | | | **0** | | | **0** | | | **0** | | |
| **Objective 3:** | **A better understanding of the current socio-economic status and needs of bean production within the context of intercropping syste** | | | | | | | | | | | | | | | | | |
| 3.1 First grower survey | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 3.2 Data tabulation and analysis | **X** | | X | **X** | X | | **0** | | | **0** | | | **0** | | | **0** | | |
| **Objective 4:** | **Capacity building: training the next generation of plant breeders for Guatemala and establishing a long-term breeding plan to increa** | | | | | | | | | | | | | | | | | |
| 4.1 Recruitment of potential graduate students | **X** | X | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 4.2 Second student admitted at NDSU | **X** | X | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| **Name of the PI reporting on milestones by institution** | Juan M. Osorno | | | Julio C. Villatoro | | | PI name | | | PI name | | | PI name | | | PI name | | |
| **Name of the U.S. Lead PI submitting this report to the MO** | Juan M. Osorno | | | | | | | | | | | | | | | | | |
| | **Signature** | | | | | | | | | | | | | | | | **Date** | |

* *Please provide an explanation for not achieving the milestones on a separate sheet.*

# Performance Indicators

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**
**REVISED PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 14, FY 15, FY16, and FY 17**

**Project Name: SO1.A1- Genetic Improvement of Middle-American Climbing Beans for Guatemala**

**Summary of all institutions**

| Indic. numbe | Output Indicators | FY 14 Target | FY 14 Revised | FY 14 Actual | FY 15 Target | FY 15 Revised | FY 15 Actual | FY 16 Target | FY 16 Revised | FY 16 Actual | FY 17 Target | FY 17 Revised | FY 17 Actual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (October 1, 2013 - September 30, 2014) | | | (October 1, 2014 - September 30, 2015) | | | (October 1, 2015 - September 30, 2016) | | | (October 1, 2016 - September 30, 2017) | | |
| 1 | 4.5.2(6) Number of individuals who have received USG supported long-term agricultural sector productivity or food security training | 0 | 0 | 0 | 2 | 3 | 2 | 2 | 2 | 0 | 2 | 2 | 0 |
| | Total number by sex | 0 | 0 | 0 | 2 | 3 | 2 | 2 | 2 | 0 | 2 | 2 | 0 |
| | Number of women | 0 | 0 | 0 | 2 | 2 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| | Number of men | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| | Total number by New/continuing | 0 | 0 | 0 | 2 | 3 | 2 | 2 | 2 | 0 | 2 | 2 | 0 |
| | Number of New | 0 | 0 | 0 | 2 | 3 | 2 | 0 | 2 | 0 | 2 | 2 | 0 |
| | Number of Continuing | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 2 | 4.5.2(7) Number of individuals who have received USG supported short-term agricultural sector productivity or food security training | 20 | 14 | 75 | 65 | 140 | 135 | 78 | 78 | 0 | 85 | 85 | 0 |
| | Total number | 20 | 14 | 75 | 65 | 140 | 135 | 78 | 78 | 0 | 85 | 85 | 0 |
| | Number of women | 5 | 4 | 55 | 20 | 95 | 110 | 27 | 27 | 0 | 35 | 35 | 0 |
| | Number of men | 15 | 10 | 20 | 45 | 45 | 25 | 51 | 51 | 0 | 50 | 50 | 0 |
| | Numbers by Type of individual | 20 | 14 | 75 | 65 | 140 | 135 | 78 | 78 | 0 | 85 | 85 | 0 |
| | Producers | 15 | 10 | 9 | 40 | 130 | 125 | 50 | 50 | 0 | 60 | 60 | 0 |
| | People in government | 5 | 4 | 7 | 20 | 10 | 10 | 28 | 28 | 0 | 25 | 25 | 0 |
| | People in private sector firms | 0 | 0 | 50 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | People in civil society | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III) | 0 | 0 | 0 | 20 | 20 | 20 | 20 | 20 | 0 | 23 | 23 | 0 |
| | Phase 1: Number of new technologies or management practices under research as a result of USG assistance | 0 | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 0 | 10 | 10 | 0 |
| | Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance | 0 | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 0 | 10 | 10 | 0 |
| | Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 |

**Notes:**

These indicators are developed under the Feed the Future Monitoring System. Please provide 'total' numbers and also disaggregate where applicable. Just providing 'totals' will not be approved.

This table corresponds to the Feed the Future Performance Indicators data collection sheet under the FTFMS system. Where an indicator does not apply to the type of work done under the project, leave it blank.

Please follow the indications in the Legume Innovation Lab Indicators Handbook that will be provided to you by the Management Office. Contact Mywish Maredia (maredia@anr.msu.edu) for further information.

There is additional guidance on the USAID/Microlinks website: http://agrilinks.org/sites/default/files/resource/files/FY14%20FTFMS%20Guidance_2.pdf

# Improving Photosynthesis in Grain Legumes with New Plant Phenotyping Technologies


### Lead U.S. Principal Investigator (PI) and affiliated Lead U.S. University

David M. Kramer, Biochemistry and Molecular Biology and Plant Research Lab, Michigan State University

### Host Country and U.S. Co-PIs and Institutions

Kelvin Kamfwa, University of Zambia
Kennedy Muimui, ZARI, Zambia
Wayne Loescher, MSU
James Kelly, MSU
Tim Close, U.C. Riverside
Phil Roberts, U.C. Riverside
Maren Friesen, MSU, Plant Biology

### Other Direct Participants and Collaborators

Greg Austic (MSU)
Dan TerAvest (MSU)
Robert Zegarac (MSU)
Donghee Hoh (MSU)
Wayne Loescher (MSU)
Isaac Osei-Bonsu (MSU)
Isaac Dramadri (MSU)
Stanley Nkalubo (NaCRRI, Uganda)


## I. Abstract of Research Achievements and Impacts


To avert food shortages and feed its growing population, there is critical need for increasing the productivity of grain legumes in Zambia, which ranks 164 out of 184 countries in the Human Poverty Index. Grain legumes are important crops in Zambia constituting both critical sources of protein and income. Bean production is constrained by its low inherent photosynthetic efficiency which is highly sensitive to abiotic and biotic stresses, including diseases, pests, low soil fertility, heat and drought.

To achieve major gains in yield, we need to improve both the robustness and the efficiency of photosynthesis. This is a complex problem requiring the combined application of advanced genomics and high throughput phenotyping approaches. We will take a critical step in this direction by establishing a base of phenotyping technologies and advanced genetics and genomics approaches to identify quantitative trait loci (QTLs) that condition more efficient and robust photosynthesis and productivity in cowpea and common beans. We will also test the ability of a newly developed research platform, PhotosynQ, to enable researchers and farmers to conduct plant phenotyping experiments, analyze data and share results, and thus allow improvements in breeding and management on local to global scales.

Our approach is to harness two new phenotyping technologies, the Dynamic Environmental Phenotyping Imager (DEPI) and the PhotosynQ platform, a field-deployable network of handheld sensors (MultiSpeQ) and associated online communication and analysis tools.

## II. Project Problem Statement and Justification

The goals of the proposed research are to assess the possibilities of 1) accelerating breeding efforts to improve grain legumes using two innovative technologies for high resolution, high throughput phenotyping and 2) integrating these tools into a region-led, multinational effort to improve grain legumes for agricultural production in Africa. The proposed project addresses several challenges that currently limit the application of these techniques for phenotype-driven plant screening, selection and engineering for agriculture in Africa, including the cost of the instrumentation, the availability of networks to share and analyze results and computational tools to usefully interpret phenotypic measurements in terms of genetic variations in yield and robustness. Advances in Internet communications, rapid prototyping and manufacturing, basic and applied science (including genetics, genomics, biological spectroscopy and data mining) are providing opportunities for professional and citizen scientists everywhere to "leapfrog" old technological impediments and take leading roles in improving local crops. Furthermore, a dramatic drop in price and increase in accuracy of sensors means that tools to measure soil, seed, and plant health do not have to be prohibitively expensive for anyone, anywhere.

## III. Technical Research Progress

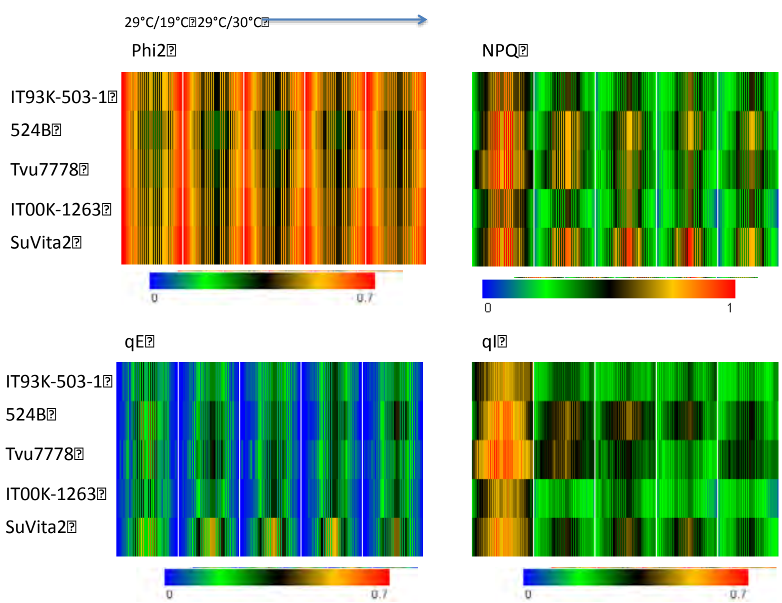


**Figure 1. Differential effects of nighttime temperatures on photosynthetic parameters in five cowpea accessions.** Shown are a series of heat maps taken over a five-day period depicting the responses of four photosynthetic parameters, the quantum efficiency of photosystem II (Phi2), nonphotochemical exciton quenching (NPQ), 'energy dependent' NPQ (qE) and long-term or photoinhibitory NPQ (qI). On the first day, plants were exposed to 29°C during the day and 19 °C the night. On the second day, this regime was changed so that the nighttime temperature was increased to 31°C.

**Objective 1. Probing photosynthetic responses in RIL and GWAS lines.**

This objective aimed to determine if DEPI could reveal phenotypic differences in cowpeas and common bean RIL and GWAS lines that could potentially be mapped. In the 2015 work period we tested identified conditions that result in substantial photosynthetic phenotypic differences between selected cowpea and common bean parent lines. Because of changes in the start date, we focused mostly on cowpeas. We found clear differences in responses of photosynthesis to fluctuating light, daytime temperature and nighttime temperature (Figure 1). All three effects are potentially important for plant productivity. It is becoming increasingly clear that responses to rapid fluctuations in environmental conditions, especially light, are critical for efficiency and robustness of photosynthesis. Interestingly, we saw large phenotypic variations with lower rather than higher daytime temperatures; this phenoptype may be important for breeding plants that perform well in cooler climates. Finally, effects of nighttime temperatures are very interesting, and perhaps most immediately applicable, given the known effects of high nighttime temperatures on flower viability and yield.

These results set us up for more detailed experiments, specifically to determine if we can identify QTLs that condition these response. Thus, in the 2015–2016 work year, we will focus on building rapid, high throughput methodology for mapping QTLs associated with these properties using the DEPI platform. The key question we will ask is, how can we reliably (with high statistical power) probe photosynthetic responses in RIL and GWAS lines?

**Objective 2. Increase the capacity, effectiveness and sustainability of agriculture research institutions which serve the bean and cowpea sectors in the target FTF countries by establishing an African–USA community of networked scientists, extension agents, students and growers to address field-level research and production questions.**

A major goal of this aim is to test the feasibility of using PhotosynQ to enhance local efforts to improve grain legume productivity. To achieve this, the project will integrate our HC collaborators at each stage, enable them to train and lead collaborators in both US and HC sites, and test the utility of the platform in the HC.

In 2015, two graduate students—Isaac Dramadri (from Uganda, currently in the Kelly lab at MSU), and Kelvin Kamfwa (from Zambia, Uganda currently in the Kelly lab at MSU), were trained in the operation, theory and use of the PhotosynQ platform for local field application. They then used these devices to perform field experiments, the results of which are now being processed. We have also improved the reliability, calibration and appropriate methodologies for the field experiments in greenhouses and fields at MSU.

A second advance in this objective was the validation and testing of the PhotosynQ platform. Graduate student Isaac Osei-Bonsu performed key experiments that established that the PhotosynQ MultispeQ device was able to rapidly measure photosynthetic responses that are relevant to field conditions (Figure 12). He also showed that the two platforms (DEPI and PhotosynQ) produce comparable results and thus that we can probe photosynthesis under both controlled laboratory and true field conditions. These results are part of a manuscript on PhotosynQ that will be submitted soon.

Most exciting, we have initiated an analysis of data from both LIL-funded and other projects using PhotosynQ in an effort to determine which parameters and approaches may be useful indicators of the productivity and robustness of photosynthesis. By comparing the results from multiple MultispeQ field trials in both Africa and U.S., we were able to develop methods that give early estimates of crop yield and the onset of diseases, which we think can be applied in Africa to crop management, determining the genetic bases of performance phenotypes, and directing breeding efforts. It is important to note that the commonly used phenotyping measurements (SPAD, photosystem II photochemical efficiency) by themselves were poor predictors of yield or disease. However, MultispeQ provides rapid measurements of multiple (both traditional and novel) phenotypic parameters, and multivariant analysis algorithms, including contributions from environmental and plant multiple phenotyping parameters, showed strong correlations with eventual yield. An example data set is shown in Figure 3, depicting the correlation models for seed yield for a trial using four sunflower varieties. MultispeQ data were taken during flowering. The "standard" photosynthetic parameter Phi2 (R2=0.15, top panel) showed only weak correlations, whereas an algorithm using five parameters showed good correlation (R2=0.66, middle panel). When variety was included in the model, the correlation was further improved (R2=0.88, bottom panel). This result is important because it indicates the possibility of distinguishing between variety and field conditions impacts on yield. Qualitatively similar results were obtained for pigeon pea (Malawi) and wheat (MSU).

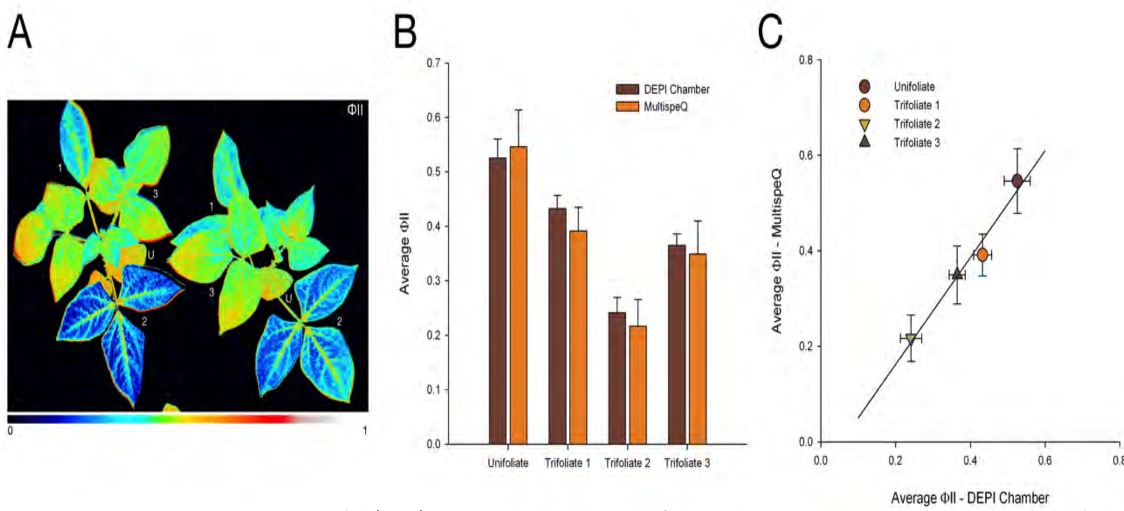


**Figure 2:** Comparing PSII yield (ΦII) measurements performed on cowpeas in a DEPI Chamber and using the MultispeQ, measuring the light intensity in the chamber and replicating it inside the MultispeQ using the red actinic LED. The measurements using the MultispeQ were taken on the same leaf used to determine ΦII from the image collected in the DEPI Chamber. (A) Example false color image of cowpea recorded in a DEPI chamber. The coloration represents the measured ΦII values as indicated in the color gradient below. U – Unifoliate, 1-3 – Trifoliate. (B) Averaged ΦII values from three biological replicates for the Unifoliate and the first three Trifoliates, comparing the DEPI Chamber and the MultispeQ. (C) Individual ΦII measurements recorded with both instruments. The line represents the linear fit ($R^{2=}$ 0.9614).

In addition, trials on Soybean sudden death syndrome (Michigan) suggest that PhotosynQ parameters may be used as early indicators of disease.

Based on these results, we will accelerate and expand our proposed work.

In 2016, our major focus will be on moving the platform to the fields in both the US and HC. Specifically, Kelvin Kamfwa will initiate his part of the project at University of Zambia, involving four masters or Ph.D. students.

Training and initiation of field research at UC Riverside and NDSU. We are expecting a new student, Isaac Osei-Bonsu, a Legume Scholars Program, from Ghana to join the project. Isaac will initially work on the with the UC Riverside or NDSU groups to help train and interpret data from common bean and cowpea field trials set up with our collaborators in NDSU and UC Riverside. The student team will be immediately supervised by Greg Austic, Dan TerAvest and Jeffrey Cruz (USA, Kramer lab).

**The Goals for 2015–2016**

1. Transferring 15 PhotosynQ MultispeQ units to Zambia and initiating first field trials (Sept 2015–Jan. 2016).
2. Training of four students in Zambia in the use of PhotosynQ platform (Target Date: Jan. 2016).
3. Testing of field measurement protocols in Zambia (Target Date: Jan., 2016)
4. Development of rapid cowpea and common bean phenotyping protocols in DEPI chambers (Target Date: Feb., 2016)
5. Initial feasibility study of cowpea lines for QTL mapping in DEPI (Target Date: March, 2016)
6. Initial feasibility study of cowpea lines for QTL mapping in UC Riverside (Target Date: Sept. 2016)
7. Initial feasibility study of common bean lines for QTL mapping at NDSU (Target Date: Sept. 2016)
8. Detailed study of selected cowpea or bean lines for phenotypes under simulated environmental conditions (Target date: Oct, 2016)
9. Use DEPI results from outcome 12 to determine which sets of lines are most promising for QTL mapping (Target date: March–April, 2016)
10. Assessment of field performance of PhotosynQ platform in Zambia (Target date: Oct, 2016).

# IV. Major Achievements

1. First proofs of concept for QTL mapping of photosynthetic properties in cowpea and common bean in controlled simulated environments;
2. Validation of DEPI and PhotosynQ platforms;
3. Initial results that suggest PhotosynQ measurements can produce actionable results from field trials;
4. Training several graduate students

# V. Research Capacity Strengthening

We have made progress in several areas of research capacity building.

First, as described above, LIL support was used to test and validate the beta prototypes of the PhotosynQ MultispeQ devices. Important lessons about the manufacturing and calibration process, which were incorporated in the improved “locked beta” units that were distributed in Africa. This knowledge was contributed to the new version of the instrument, will be used to produce the next version of the MultispeQ due out in April 2016.

A total of 10 beta devices, together with computer and other support, have been produced for delivery to Zambia for the 2016 growing season. These will be received by Dr. Kelvin Kamfwa when he returns to Zambia in early 2016.

Several LIL participants have been trained in the use of the PhotosynQ platform, including co-P.I. Kelvin Kamfwa, graduate students DongHee Hoh, Isaac Osei-Bonsu and Jesse Traub, as well as collaborators Tom Close (U.C. Riverside), Phillip Roberts (U.C. Riverside) and Phil McLean (NDSU).

**PhotosynQ Lending Library.** Based on results from this and other project, we established a PhotosynQ Lending Library program, allowing partners to have access to a library of instruments and training. This allowed us to use relatively few devices to collect a large amount of data. This library has resulted in a large number of new users, both in Africa and in the US, and has services our collaborators in California and North Dakota.

**PhotosynQ Mobile Phenotyping groups.** Based on our experiences in several countries, we developed and implemented a new platform wherein crews of qualified, trained data collectors can travel to experimental stations and farms and collect large amounts of high quality data in short periods. This effort has been very successful, increasing the number of projects, the number of data points taken and the quality of the results. It also help collaborators analyze, and interpret their results. As a result of this success, we have 'cloned' this program at several locations, including the US. In addition, our Mobil Phenotyping Group leader in Malawi is working to establish his own independent company to phenotype plants across Malawi.

**Expanded Network of Researchers and Projects in Malawi.** Because of the success of our initial trials, the establishment of the Mobile Phenotyping Groups and very high interest in the technology, we were also able to expand our network of scientists to include 4 researchers from Malawi's Department of Agricultural Research Services (DARS). These four scientists are situated at 3 different research stations across Malawi: Chitedze Research Station, Kasinthula Research Station, and Bvumbwe Research Station. In conjunction with these scientists we were able to successfully conduct data collection on 12 projects both on research stations and on smallholder farms (See table below). These projects were very diverse in their goals and potential impacts to researchers and, ultimately, smallholder farmers in Malawi. These projects range from plant breeding/variety selection of various crops (maize, common beans, pigeonpea, sunflower, sweet potato, and quinoa) to cropping systems studies that focus on the effects of tillage, crop rotation, residue, fertilizer rates, and irrigation schemes on crop production of maize, cowpea, and sweet potato.

# VI. Human Resource and Institution Capacity Development

***Short-Term Training***

1. **Purpose of Training:** Instruct users and collaborator in the use of the PhotosynQ platform and MultispeQ device.
2. **Type of Training:** both on- and off-site training as well as internet-based instruction, one-on-one with PhotosynQ developers and users.
3. **Countries** Benefitting**:** Uganda, U.S.A., Zambia
4. Location and dates of training

5. **Number receiving training (by gender):** 1 F, 3 M
6. **Home institution(s):** Several LIL participants have been trained in the use of the PhotosynQ platform, including
    a. Graduate student, now co-P.I. Kelvin Kamfwa (MSU, U. Zambia),
    b. Graduate student DongHee Hoh (MSU)
    c. Graduate student Isaac Osei-Bonsu (MSU, Ghana)
    d. Graduate student Isaac Dramadri (MSU, Uganda)
    e. Graduate student Jesse Traub
    f. Lab members from collaborators in labs of
        i. Tom Close (U.C. Riverside)
        ii. Phillip Roberts (U.C. Riverside)
        iii. Phil McLean (NDSU).
        iv. James Kelley (MSU)
        v. Wayne Loescher (MSU)
7. **Institution providing training or mechanism:** MSU, U. Zambia

***Degree Training***

1. **Name of trainee:** Isaac Osei-Bonsu
2. **Country of Citizenship:** Ghana
3. **Gender:** M
4. **Host Country Institution Benefitting from Training:** U. Zambia
5. **Institution Providing Training:** MSU
6. **Supervising CRSP PI:** Kramer
7. **Degree Program:** Ph.D.
8. **Field or Discipline:** Plant Biology
9. **Research Project Title (if applicable):** QTL Mapping of photosynthetic properties in grain legumes
10. **Start Date:** 9/1/2015
11. **Projected Completion Date:** 2019
12. **Is trainee a USAID Participant Trainee and registered on TraiNet?** (?)
13. **Training status (Active, completed, pending, discontinued or delayed):** Active

# VII. Achievement of Gender Equity Goals

# VIII. Achievement and Progress Along the Impact Pathway

**Outputs**

We proposed to “Provide advanced scientific instrumentation for developing countries. The project will produce 20 MultispeQ instruments, 16 of which will be delivered to labs in Zambia and Uganda. Qualitatively, these instruments will immediately allow researchers in Africa to perform cutting edge research, enabling them to perform the work described in the proposal. In addition, we expect the capabilities of the instruments to enable researchers in HCs to initiate new research projects. “

In our first partial year of funding, we have exceeded our goals. The beta devices have been produced, tested and refined; a suit of experimental protocols have been developed; the field trials on grain legumes have been performed both in the USA and in Africa; sufficient units are available for the next year's work in Zambia, and key members of the teams have been trained in the us of the platform; and early results from these trials shows promise for direct applications for stress detection, crop management, and breeding.

We are thus well set up to approach the next year's goals, which address the remaining metrics.

## IX. Explanation for Changes

We have made more progress than anticipated, and thus our next year goals are accelerated. As detailed in the 2016 Work Plan, we will expand the deployment of the PhotosynQ platform to more users and field trials, and to assess the utility of DEPI to map photosynthetic responses to at least two environmental challenges.

## X. Self-Evaluation and Lessons Learned

We are particularly excited by the early results from our field trials, which appear to show direct utility for the PhotosynQ measurements in crop management and plant breeding. We are also gratified by the interest in the community in using the platform.

One major goal that we hope to tackle in 2016 is the engagement of women students, researchers, extension agents and farmers. The platforms we are deploying offer the possibility of bringing in more diversity, especially with the expected expansion of our goals. We do have specific goals to support women students in Zambia. However, reaching the broader impact we hope for will take some effort and require expertise beyond that of our group. Thus, and we need and hope to directly engage experts and other gender-equality efforts in this area.

## XI. Scholarly Accomplishments

Two manuscripts citing support from LIL are in preparation.

## XII. Data Management

N/A

## ANNEXES

**Annex 1. Tables, Figures and Photos Cited in the Report**

**Annex 2. Literature Cited** (List of all literature cited in the body of the technical progress report.)

## Milestones

# Performance Indicators

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**
**REVISED PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 14, FY 15, FY16, and FY 17**

**Project N SO1.A2 Improving Photosynthesis in Grain Legumes with New Plant Phenotyping Technologies**

**Summary of all institutions**

| Indic. numbe | Output Indicators | FY 14 Target | FY 14 Revised | FY 14 Actual | FY 15 Target | FY 15 Revised | FY 15 Actual | FY 16 Target | FY 16 Revised | FY 16 Actual | FY 17 Target | FY 17 Revised | FY 17 Actual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (October 1, 2013 - September 30, 2014) | | | (October 1, 2014 - September 30, 2015) | | | (October 1, 2015 - September 30, 2016) | | | (October 1, 2016 - September 30, 2017) | | |
| **1** | 4.5.2(6) Number of individuals who have received USG supported long-term agricultural sector productivity or food security training | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 0 |
| | Total number by sex | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 0 |
| | Number of women | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 2 | 2 | 0 |
| | Number of men | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total number by New/continuing | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 0 |
| | Number of women | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 |
| | Number of men | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 |
| **2** | 4.5.2(7) Number of individuals who have received USG supported short-term agricultural sector productivity or food security training | 0 | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 0 | 10 | 10 | 0 |
| | Total number | 0 | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 0 | 10 | 10 | 0 |
| | Number of women | 0 | 0 | 0 | 6 | 6 | 6 | 6 | 6 | 0 | 6 | 6 | 0 |
| | Number of men | 0 | 0 | 0 | 4 | 4 | 4 | 4 | 4 | 0 | 4 | 4 | 0 |
| | Numbers by Type of individual | | | 0 | 10 | 10 | 10 | 10 | 10 | 0 | 10 | 10 | 0 |
| | Producers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | People in government | 0 | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 0 | 10 | 10 | 0 |
| | People in private sector firms | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | People in civil society | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **3** | 4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III) | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Phase 1: Number of new technologies or management practices under research as a result of USG assistance | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Notes:**

These indicators are developed under the Feed the Future Monitoring System. Please provide 'total' numbers and also disaggregate where applicable. Just providing 'totals' will not be approved.

This table corresponds to the Feed the Future Performance Indicators data collection sheet under the FTFMS system. Where an indicator does not apply to the type of work done under the project, leave it blank.

Please follow the indications in the Legume Innovation Lab Indicators Handbook that will be provided to you by the Management Office. Contact Mywish Maredia (maredia@anr.msu.edu) for further information.

There is additional guidance on the USAID/Microlinks website: http://agrilinks.org/sites/default/files/resource/files/FY14%20FTFMS%20Guidance_2.pdf

# Improving Genetic Yield Potential of Andean Beans with Increased Resistances to Drought and Major Foliar Diseases and Enhanced Biological Nitrogen Fixation (BNF) (S01.A3)


### Lead U.S. Principal Investigator and University

James D. Kelly, MSU, East Lansing, MI

### Collaborating Host Country and U.S. PIs and Institutions

Wayne Loescher, Dept. Horticulture, MSU
James Steadman, University of Nebraska, Lincoln
Carlos Urrea, University of Nebraska, Scottsbluff
Karen Cichy, USDA-ARS, East Lansing, MI
Stanley Nkalubo, NaCRRI, Uganda
Kennedy Muimui, ZARI, Zambia


## I. Abstract of Research and Capacity Strengthening Achievements


Common bean (*Phaseolus vulgaris* L.) is the most important grain legume consumed in Uganda and Zambia. The development of improved bean varieties and germplasm with high yield potential, healthy root systems, improved symbiotic nitrogen fixation (SNF) with resistance to multiple diseases, and sustained or improved water use efficiency under limited soil water conditions are needed to increase profit margins, and lower production costs. An improved understanding of plant traits and genotypes with resistance to multiple stresses from abiotic (drought) and biotic (root and foliar pathogens) sources will provide unique genetic materials for enhanced plant breeding methods and sources to study plant tolerance mechanisms in common bean. Improvements in current understanding of the physiology of drought and evapotranspiration and the genetics of drought tolerance in common bean and the development of effective molecular and quantitative methods for the selection of drought tolerance are needed. The project will use QTL analysis and SNP-based genome-wide association mapping to uncover regions associated with drought tolerance, anthracnose resistance, enhanced SNF and shorter cooking time. Results of this project would contribute to improved yield, farm profitability and human resources in the host countries and indirect benefit to participating U.S. institutions and bean producers.


## II. Project Problem Statement and Justification

Beans are the second most important food legume crop after ground nuts in Zambia and are a major source of income and cheap protein for many Zambians. Most of the bean crop (62%) is produced on 60,000 ha in the higher altitudes, cooler and high rainfall zones of the northern part of Zambia. Andean beans are predominant and land races are the most widely grown although a few improved cultivars are also grown as sole crops or in association mainly with maize. Bean production is constrained by several abiotic and biotic stresses that include diseases, pests, low soil fertility and drought. All the popular local landraces in Zambia are highly susceptible to pests and diseases that severely limit their productivity. This is reflected in the very low national yields ranging from 300 to 500 kg/ha that result in annual deficit of 5,000MT. To avert future food shortages and feed the growing population of 13M, there is critical need for increasing the productivity of most food crops including beans as Zambia ranks 164 out of 184 countries in the Human Poverty Index. Beans are an important crop in Uganda and are grown on over 660,000 ha of land and consumed throughout the country. Beans are a major source of food and income for the rural smallholder farmers especially the women and children. The majority of bean production in Uganda is dependent mainly on the use of inferior landrace varieties which are generally low yielding due to susceptibility to the major biotic and abiotic (drought, low soil fertility) stresses. These stresses gravely undermine the potential of the bean as a food security crop, a source of income, and as a main source of dietary protein for the majority of Ugandans. Drought affects 60% of global bean production and the severity of yield reduction depends on the timing, extent, and duration of the drought stress. The development of improved varieties and germplasm with high yield potential, healthy root systems, improved SNF with resistance to multiple diseases, and sustained or improved water use efficiency under limited soil water conditions are needed to increase profit margins, lower production costs. The project will use QTL analysis and SNP-based genome-wide association mapping to uncover regions associated with drought tolerance, disease resistance, enhanced SNF and faster cooking time.

# III. Technical Research Progress

**Objective 1. Integrate traditional and marker-assisted selection (MAS) approaches to combine resistances to economically important foliar diseases, drought and improved symbiotic nitrogen fixation (SNF) 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.**

***1.1 Evaluation of integrated nursery in Uganda***

During this year, several nurseries have been evaluated and from these nurseries a number of lines have been selected as sources of resistance or for conducting yield trails and /or genetic studies. Some of the nurseries evaluated and their sources of origin are indicated below. A series of segregating populations and nurseries bred for drought tolerance have been received and together with lines generated within the country have been evaluated in the Ugandan environment. These include;

35 PIC drought tolerant large seeded breeding populations obtained South Africa (ARC-Grain Crops Institute-Potchefstroom) from which 421 individual plants have been selected. Initial selections made from these materials was based on adaptation, plant architecture, number of pods, seed size, seed color and yield, the attributes suitable for the Uganda market and consumers. This particular germplasm was unique in that we initially did not have any large seed drought genotypes in our breeding program. These plants have been planted to establish families which will further be screened for drought and other biotic stresses.

Adaptation and preliminary yield trials were conducted on-station at NaCRRI, Namulonge for a total of 169 newly acquired drought bean lines obtained from CIAT. In the preliminary yield trials conducted. From these 98 lines that showed promise (yielded $\geq$ 1500 kg/ha) were selected for further evaluation and utilization in Uganda drought breeding program.

Evaluation of ADP lines is being undertaken on two fronts, in the first evaluation, a panel consisted of 250 genotypes, of which 233 were from the global ADP panel and 17 local genotypes were evaluated for drought at end of the first season (May–August 2014) on-station at NaCRRI–Namulonge, targeting off-season planting. The field experiment consisted of two treatments (irrigated and nonirrigated), in two replications planted in the field. Also plans were underway to optimize the use of photosynq for measuring photosynthetic traits in common bean under field conditions. Unfortunately, during the off season planting, the station received unusual high rainfall and no drought stress was observed. These moist conditions however led to multiple disease condition and data was collected on all agronomic traits and on major common bean disease such as ALS, rust disease, CBB and BMCV were observed that more than 80% of the ADP lines were seriously affected by the above named foliar diseases. Angular leaf spot and rust were noted as the major diseases challenging these lines. There were also some technical challenges and lack of trained field staff that did not allow for the use of the photosynq technology.

In the other experiment 23 ADP lines with faster cooking time with one local check, are being evaluated on-farm in participatory variety section using the mother-baby trial evaluation method. In total 9 mother gardens have established in four Ugandan districts (Hoima, Kamuli, Masaka and Rakai) with a total of close to 90 baby trails where farmers have been availed with 3 genotypes for own testing. The trials are directly engaging 326 farmers (women=230) within nine famer groups. This experiment is currently at R7 and we hope by at the end we will be able to identify at least one fast cooking line that has characteristic that are preferred by Ugandan famers.

Anthracnose and Pythium root rot. Use is being made of 43 breeding populations from earlier work where a series of crosses and selection assisted with the use of molecular markers were made and the result was lines that had been pyramided with 3 anthracnose and one root rot (Pythium) genes and are being advanced and evaluated in field condition on-station. A total of 144 individual plants were selected from the 43 population as indicated in Table 1 below. The selected lines have been established in yield trials to evaluation performance and advance promising families

### *1.2 Evaluation of Integrated Nursery in Zambia*

A regional nursery Southern Africa Bean Evaluation Nursery (SARBEN) consisting of 100 genotypes of various market class and traits was evaluated at Misamfu Research Station in Zambia. The nursery was evaluated in single row plots of 4m long spaced at 60 cm between rows and 10cm intra row spacing. The lines were evaluated for major diseases and yield. The trial mean yield of 1602 kg/ha was obtained with the highest yielding genotype giving 3046 kg/ha and poorest yielded 633 kg/ha. The major diseases were ALS, CBB, ANT, Rust and BCMV. Among these diseases, CBB had high incidence compared to the other diseases. Most lines were found to be resistant/tolerant to ANT, BCMV and Rust. Genotype SDDT SS-C2 and CIM-SUG07-ALS-S1-3 had scores of 5 and 4 respectively for ALS. Genotype HIGH MIN P No 105 GR was found to be more susceptible to Common Bacterial blight with a score of 7 (on the CIAT scale 1-9). A number of lines were found to have combined resistance to most diseases that prevailed in the season.

### *1.3 Identification of resistance sources in Uganda*

A series of efforts have been initiated in trying to identify resistance source for the different foliar diseases. Most notable is the screening of the acquired germplasm both in the field and some cases in the screenhouse to establish the reaction of the reaction of the different germplasm to the different pathogens. Below are some of the activities that have been undertaken in trying to find resistant sources for the respective diseases.

***Rust resistance***. To identify rust resistant lines, a germplasm collection of 143 lines made up of 30 landraces, 20 released and 93 introduced lines including the 12 rust differentials was screened using field. The reason for the selection of the introduced lines for inclusion in this germplasm set, was their linkage to having drought tolerance, anthracnose and possible rust resistance genes. Identification of rust resistant sources was done using both phenotypic and genetic characterization (conducted at MSU by PhD student) (Appendix 1) and identified lines including Mexico 309, CNC, P1181996, Mexico 235, Redland Pioneer, Oura Negro and Aurora. These have been utilized to introgress rust resistance into Ugandan germplasm.

***Anthracnose and Angular leaf spot***. For resistance to these two pathogens we will still rely on the differential genotypes like AB 136, G2333 for anthracnose and Mexico 54, for ALS, until we are able to obtain clean isolates and screen the available germplasm for nay new resistant sources.

***Common Bacterial blight (CBB) resistance*****.** To identify resistance sources of resistance to CBB, 132 genotypes comprising of 80 local collection and 32 imported germplasm (from Nebraska) have been screened using the most prevalent *Xanthomonas campestris* pv. *phaseoli (Xcp)* isolate "Kawempe 1" in Uganda. We have so far identified six genotypes CBB22, CBB34, CBB37, CBB2, CBB24 and CBB45 as the most resistant, all from the Nebraska CBB nursery. Resistance sources were identified in a number of nurseries that were under evaluation. These lines were identified on the basis of good seed size and color, upright architecture. These lines will be included on the list of lines that have been identified and used in the region for control of a number of diseases.

***Nebraska.*** The ADP was also screened to common bacterial blight at the West Central Research and Extension Center, North Platte, NE, in an augmented replicated trial. The plot size will consisted of 1 row 3 m long spaced 0.56 m. The resistant XAN 159 line; the moderately resistant Neb 1 Sel. #27, and ABC-Weihing; and the susceptible Orion lines were used as a reference checks. At flowering, plants were sprayed with a bacterial solution of $3 \times 10^7$ cfu $ml^{-1}$ using a backpack sprayer with the CBB Nebraskan strains SC-4A and LB-2. The lines were evaluated at the pod filling stage using a 1-9 scale, where 1= immune and 9= very susceptible. H9659-21-1 had the lowest CBB score of 2.9 followed by Badillo with a score of 3.4. Njano-Dulea and OPS-RS4 had a score of 3.6. Masusu, Uyole 96, OPS-RS1, Red Rider, and AC Elk had a score of 4.1. Micran, H9659-27-10, Montcalm, and USCR-CBB-20 had a score of 4.4. Kijivu, Mrondo, Mkokola, and Kablanketi had a score of 4.6. The checks XAN 159, Neb 1 Sel. #27, ABC-Weihing, and Orion had a score of 2.4, 3.3, 3.9, and 8.3, respectively. On July 2015, a CBB Nursery was assembled and dispatched to Uganda and Zambia for being tested at both locations. Fifty entries were selected based on CBB screening at North Platte, NE during 2013 and 2014.

***Bean common Mosaic Virus resistance***. In Uganda a germplasm collection of 84 lines has been assembled and we are yet to screen for resistance and as such we have not yet identified resistance sources for BCMV.

***Drought tolerance***. We obtained over 150 lines tolerant drought, these have been screened for adaptation in Uganda and some have been even utilized in crosses. We intend to screen these in the field although so far we have failed due to the unpredictable weather conditions (rains off season). No new drought tolerant lines have been identified as yet but a five old CIAT lines (SEN 98, SEN 99, SCR 48, SCN 6 and SCN 9) have been utilized in making crosses and the progenies are already being evaluated for consumer preferred agronomic traits and yield.

A drought evaluation nursery was planted during the off-season (July-November) under irrigation for evaluation for drought in Zambia. The nursery consisting of 60 lines was planted in single rows in two blocks. One block was stressed (irrigation discontinued just before flowering - about 30 DAP) while the other block was not stressed. A number of lines were observed to show some tolerance while some were not tolerant to drought. The nursery is expected to be harvested within November 2015.

The ADP lines were also evaluated to terminal drought (irrigation was stopped at flowering stage) in western Nebraska. Yield and 100-seed weight was reduced by 41.2 and 9.6% when beans were stressed, respectively. VA-19 had the highest geometric mean, followed by Bilfa 4, Bukoba, A 800, and Krimson with values of 3035, 2418, 2349, 2100, and 1973 kg $ha^{-1}$, respectively. Bilfa 4 had the lowest yield reduction comparing normal and drought stress with a value of 6.5%. On July 2015, a drought trial was assembled and dispatched to Uganda and Zambia for being tested at both locations under normal and drought conditions. Sixty entries were selected based on experiments conducted at Scottsbluff, and Mitchell, NE 2013 and 2014.

A 25-entry uniform drought nursery was grown in Michigan in 2015. Weather conditions did not favor the development of drought and the local check varieties outyielded the drought tolerant lines. The nursery was coordinated by Drs. Urrea and Porch.

**Field Evaluation of the Nutritionally Superior Common Bean Genotypes with Farmers in Three Agroecological Zones in Uganda**

Iron and zinc deficiency are the most prevalent micronutrient deficiencies in the world Biofortification has a potential to address micronutrient malnutrition especially in developing countries where plant based staples are widely grown and consumed. Common bean is an important source of micronutrients. The efficacy of biofortified crops to address human malnutrition can further be improved if genotypes with highly bioavailable minerals are developed. Andean bean genotypes with high iron and zinc concentration, and high iron bioavailability were identified from a set of diverse Andean bean germplasm using an *in vitro* caco-2 cell line assay. A subset of 23 of the best lines for mineral nutrition and also fast cooking are being evaluated in farmers' fields along with local check genotypes in a participatory variety selection in Hoima, Kamuli, and Masaka. Nine farmer groups each comprised of about 40 farmers are participating in the research. There are three farmer groups per district and each group has a large garden planted with 23 experimental entries (genotypes) + 1 local check so the mother trial has 24 entries as two field reps under RCBD. Each genotype was planted (in August 2015) as a 5-row plot, the rows are 3.5 meters long, and between row spacing is 50 cm. The entire 5-row plot is planted with about 220 dry bean seeds. For each mother trial there are 8 farmers (or 8 baby trials), therefore there are 8*9 or 72 baby trials. Each baby trial has a subset of 3 genotypes, the farmers have been encouraged to include a local check in their baby trial plots. Baby trial genotypes are planted as single replicates. The farmers are from three districts representing three agroecological zones in Uganda that are important in both bean production and consumption. The study will help us identify which of the nutritionally superior genotypes might be well adapted for the Ugandan conditions and are preferable to the Ugandan farmers and consumers and what are the breeding needs for nutritionally superior fast cooking cultivars to be accepted by farmers.

***1.1 Crossing and backcrossing resistance sources in Uganda***

The project has embarked on the process of introgression the different resistance genes into the backgrounds of some of the most preferred Andean bean varieties in Uganda. Work on the introgression is in most cases at the initial stages. Below are some of the different crosses that have been initiated.

***Rust***. Using the seven identified rust resistant source, (Mexico 309, CNC, P1181996, Mexico 235, Redland pioneer, Ouro Negro and Aurora), crosses have already been initiated with Uganda market class bean lines including NABE 15, NABE 16, NABE 19 and NABE 21 to try and introgress rust resistance into their background.

***Drought***. To introgress drought tolerance into farmer and market bean cultivars, use was made of already known drought tolerant sources. Evaluations and selections are being made from the advancing of the progenies arising from 15 crosses that were have been made between Ugandan market class varieties K132, NABE 4 and NABE 15 with introduced drought tolerant germplasm that included SEN 98, SEN 99, SCR 48, SCN 6 and SCN 9. To date, nine (9) promising lines from nine different crosses have been selected and are currently undergoing preliminary yield trials (PYT) on-station at NaCRRI. Additional crosses are planned using selection that will be made from drought germplasm obtained from Nebraska.

***Common bacterial blight* (CBB)**. Cross have also been initiated between CBB resistant materials CBB22, CBB34, CBB37, CBB2, CBB24 and CBB45 with four Ugandan Andean susceptible market class varieties, NABE 15, NABE 16, NABE 17 and NABE 19 to try and introgress CBB resistance.

**Crossing and backcrossing resistant sources in Zambia.** Under the crossing program a number of lines an early generation trail of 60 selected lines from the F4s were constituted into a trial and was evaluated at Misamfu – Zambia. The lines performed very well with the highest line, Kalungu x Lyambai/3 yielding highest with 2342 kg/ha followed by CIM-ALS-FeZn08-16-6 (2088kg/ha), Chambeshi x NUA 45/1 (1900kg/ha) Chambaeshi x NUA 59/3 (1771kg/ha) and Chamabeshi x NUA 45/2 (1679 kg/ha). These lines combined high yield with resistance to major diseases (ALS, CBB, ANT, Rust). These lines were also large seeded meeting the preference of the Zambian small scale farmers and end users. Forty-eight percent (48%) of the lines yielded above 1 t/ ha. One line (Lusaka x NUA 45/4) did not germinate so no yield was recorded for this line. The lines are currently being advanced to $F_5$ under irrigation. Part of the seed of the selected lines will be tested for levels of Iron and Zinc.

### *1.2 Evaluation of lines for SNF*

Adaptation and evaluation trials for 68 low soil fertility and drought tolerant genotypes obtained from CIAT–Colombia were conducted on-station at NaCRRI. The low soil fertility and drought tolerant materials were evaluated and multiplied to generate enough seed to test in other sites. The indication is that most of these lines perform well under Ugandan conditions and it envisaged that good genotypes will be obtained from these materials. These genotypes are currently being evaluated again for yield and other stresses.

### *1.3 Population development for genetic studies*

We have started generating population especially for the new crosses these include, populations for rust, CBB resistance, BCMV and stem maggot resistance and hope that will lead into formulate some genetic studies for resistance to the different stresses in relation to the Andean Ugandan market class genotypes. Based on 2013 and 2014 data collected in Nebraska (common bacterial blight, experiments on drought, and cooking time), 14 F1 combinations were initiated in 2015. A new set of hybrids is planned on December 2015.

***1.4 Cooking time prediction in intact dry bean seeds using visible/near-infrared spectroscopy***

Dry beans require long cooking times to become palatable and there is significant genetic variability for this trait. The objective of this study was to evaluate the utility of visible and near-infrared reflectance spectroscopy (Vis/NIRS, 400-2,498 nm) for predicting cooking time from intact dry seeds. A total of 475 bean samples of the ADP grown at the Montcalm Research Farm, Michigan with wide variations in cooking time (15 to 90 min) were used in this study. Spectral preprocessing methods coupled with a feature selection method were tested for improving the prediction of cooking time using partial least squares regression (PLSR) models. Overall, the two-wavelength ratio preprocessing approach produced more precise results ($R_{pred}$ = 83.2%) than smooth ($R_{pred}$ = 68.1%), 1$^{st}$ ($R_{pred}$ = 73.0%) and 2$^{nd}$ ($R_{pred}$ = 69.3%) derivatives, or continuous wavelength transform ($R_{pred}$ = 74.8%). The Vis/NIRS technique appeared promising for predicting cooking time from intact dry seeds. Nonetheless, further tests using samples from different years and locations along with the application of additional spectral imaging techniques (e.g., multi- and hyper-spectral) and image processing methods should be considered for improving the prediction of cooking time. The ADP panel was also grown under normal and drought stress in western Nebraska and the panel were cooked in a Mattson cooker. Seeds were soaked overnight (16 hours) then, placed in the Mattson Bean Cooker, and beans were cooked when 80% of the weighted plungers dropped. On average, the beans under normal conditions cooked at 59 minutes and bean under drought stress at 68 minutes. Under normal conditions, Montcalm, Soya, Kablanketi, Soya, and USCR-CBB-20 had the lowest cooking time of 29, 37, 38, 39, and 40 minutes, respectively. Under drought stress, Moro, Njano Dolea, Kablanketi, Bukoba, Wallace 773-V98, RH No.12, and Soya had the fastest cooking time of 39, 46, 47, 47, 48, 49, 51, 52, and 52 minutes, respectively.

***1.5 Seed multiplication***

A number of promising lines including those from MSU were increased so as to prepare for inclusion of promising one into trails for the 2015/16 crop season in Zambia

**<u>Objective 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.</u>**

***2.1 Anthracnose and Angular Leaf Spot (ALS) characterization and screening in Uganda***.

Although plant diseases samples were collected for ANT and ALS, race characterization has not been completed due challenges of contaminations encountered during isolation. In the due course, samples were used up and as such we have embarked on further collections of the same within this season but we have continued to screen materials especially those that had been initially pyramided with anthracnose and root rot resistance genes in the field. Pathotype characterization for these two diseases will commence as soon as we are able to get our isolation protocol right. Considering that most of the disease samples have degenerated, we have embarked on collecting new diseased samples for these two pathogens.

***2.2 Rust characterization and screening.*** Having failed to utilize the mobile nursery technique for the identification of rust pathotypes in the field, we collected and sent 136 rust diseased samples to Nebraska for isolation and identification. Unfortunately these samples were lost due to fluctuation in the moisture levels, only one spore was recoverable. We are currently collecting new samples which we hope to characterize genotypically. Samples received in UNL from Zambia were leaves that were collected from the rust differential lines (mobile nursery) set out to monitor for rust near Kasama. No rust was collected from differential lines Mexico 309 (Ur-5) or PI 181996 (Ur-11). Based on the reactions of the differential cultivars in UNL greenhouses to the Zambian rust, the Ur genes -4, -6, -7, -12, -13, and -9 do not provide protection. However, cultivars with Ur-3, -3+, -5, and -11 would provide resistance. The set of leaf samples from Uganda and collected on an air strip road near Kireka north of Kampala were not allowed to air dry before shipping. They also were packed very tightly into a plastic container and had a white mold growth on the leaves. From one sample Ur-3, -4, -6, -7, -9, -12, and -13 were susceptible and Ur-3+, -5, and -11 were resistant. We plan to determine race structure of new leaf samples. Having received two sets of leaves in conditions less than favorable for rust pathogen viability, we developed two protocols: one, to help with rust infected bean leaf collections and another for expedited shipment to UNL. We have shared them with our collaborators in Uganda and Zambia.

***2.3 Common bacterial Blight (CBB) screening.*** In Uganda they obtained and utilized already available pathotypes “Kawempe 1” to screen the available CBB nursery for resistant sources and will use it to screen for resistance in the resulting progenies. During screening, they inoculated the second trifoliate leaf of an 18 day old plant using the razor blade method and two pods are inoculated per plant during pod filling stage using the multiple needle scratch method. Both leaf and pod inoculated should be on the same plant as recommended by Singh and Miklas, (2015). Disease severity was measured at 14, 21 and 35 days after inoculation, using the CIAT 1–9 rating scale. Data so far collected for the available germplasm is indicated in Table 2.

***2.4 Compile data base of past pathogen collectionsin Uganda.***

Although still raw and rough, we have initiated a computer based data base for all collection so far made indicate areas of collection and numbers collected. We also intend to show the pathotypes found in the respective area as soon as the characterizations are completed. Long term storage of pathotypes is still a challenge though but we are leasing with CIAT–Uganda to find a solution.

***2.5 Anthracnose race characterization, screening in Zambia***

Low pressure of ANT was observed during the season and from the nurseries that were evaluated at Misamfu, screening for ANT was done using field infection. Due to dry spells that occurred during the season the screening for ANT was not up to date, though a number of lines were found to be resistant**.**

***2.6 Angular Leaf Spot characterization, screening in Zambia***

An ALS nursery consisting of 46 lines was evaluated at Misamfu. The lines were planted in an ALS hot spot so as to get a natural field infestation. The lines were planted in single row plots 4m long spaced at 60cm between rows and 10cm intra row. Data collected included Days to flowering, Stand at harvest, ALS, BCMV, ANT, CBB, Rust, 100 seed weight and Yield. The yield range was from 346 – 2342 kg/ha. The line G9282 was the highest yielder and was found to be resistant to ALS, BCMV and Rust but was intermediate or tolerant to CBB (Score 4). Line BM 12732-57 VEF 2000 121 was resistant to all the diseases that were prevalent during the season, but was small seeded, which might not be preferred by the Zambian small scale famers. This line could be used as source for resistance in the breeding program. High incidences of CBB were noticed during the season. ALS sources used in the region CAL 143 and AND 277 were found still resistant and were among the top yielders in this nursery with yield of 1792 and 1717 kg/ha respectively.

### *2.7 Rust characterization, screening*

Rust characterization using the Rust differential (received from UNL) was done in collaboration with Dr. Jim Steadman of UNL. The results have since been shared with UNL for characterization**.**

### *2.8 Common Bacterial Blight Screening in Zambia*

A regional Common bacterial blight nursery consisting of 49 lines were plated at Misamfu in single row plots. Most of the lines in the nursery had traceable parentage of VAX lines which are used in the region as CBB resistance sources. Data collected included Days to flowering, Stand at harvest, ALS, BCMV, Anthracnose, CBB, Rust, 100 seed weight and Yield. The mean yield for the nursery was 1519 kg/ha from a range of 683 – 2288 kg/ha. The top yielders included BRB 267/VAX3-14 (2288kg/ha), SEQ11/RMX-19-4 (2162 kg/ha), BRB 267/VAX3-3, SAB 575/VAX 6-3 (both 2150kg/ha) BRB 267/VAX3-5 (2083 kg/ha). Line BRB 265/VAX3-1 though was found to be resistant to most diseases in the field it was susceptible to rust with a score of 7. Line BRB 265/VAX3-8 was the only line with highest CBB score of 5. The mean seed size (100 seed weight) for the lines was 29.0g.

### *2.9 Field ratings of rust and common blight in a root rot trial in Zambia*

Data was taken on rust and common bacterial blight severity on the foliage of 12 bean lines selected from earlier trials of 362 (2013) and 60 (2014) bean lines including the Andean Diversity Panel and Nebraska select lines. The trial also had four local landraces and was a split/split replicated experiment with three reps of granular insecticide preplant treatment, fertilizer applied and no treatment or fertilizer. The stem maggot insecticide treated bean lines in some cases were less rust resistant than the untreated. Eight lines including three local landraces were resistant; four lines were moderately resistant, two lines were moderately susceptible and only one line was considered susceptible. The common bacterial blight reactions were very low intensity with only two lines moderately resistant (4, 3 rating) and the rest were resistant (2, 3 rating) with only an occasional 4 using the 1–9 CIAT scale. The best lines for resistance to both pathogens were Larga Commercial, PI 321094-D, NE 34-12-47, Local Mbbereshi and Local Cim-Climb 03-48.

### *2.10 Mapping resistance genes for anthracnose*

New sources of anthracnose resistance in a highly diverse panel of 226 Andean beans was screened with eight races of anthracnose to identify and map new sources of resistance using a genome-wide association study (GWAS) at MSU. Only one line Uyole 98 was resistant to all 8 races. Outputs from the GWAS indicated major QTL for resistance on three linkage groups: Pv01, Pv02, and Pv04 and minor QTL on Pv10 and Pv11. Candidate genes associated with the significant SNPs were detected on all five chromosomes. A QTL study with the black bean cultivar Jaguar, known to possess resistance to anthracnose race 73, was conducted to determine the basis of the anthracnose resistance commonly used in the MSU breeding program. Resistance to anthracnose was investigated in an $F_{4:6}$ recombinant inbred line (RIL) population developed from a cross between Jaguar and Puebla 152 (landrace cultivar known to be susceptible to race 73). Resistance in Jaguar was determined to be conditioned by the single dominant gene *Co-1*. Using the Illumina BARCBean6K_3 BeadChip, the physical location of the *Co-1* locus was mapped between 50.3Mb on chromosome Pv01. A breeder friendly InDel marker was developed (50.2Mb) that was linked to the Co-1 locus as 3.1cM and could be used in selecting 4 of the 5 resistance alleles at the Co-1 locus. The genomic positions of the numerous resistance loci on Pv01, Pv02, Pv04 and Pv11 identified in Jaguar and in the Andean panel should prove useful for breeding programs interested in improving anthracnose resistance in cultivars using marker assisted selection.

**Objective 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.**

To better understand the genetic architecture of SNF at the molecular level variability three studies were conducted at MSU: (i) genome-wide association study (GWAS), (ii) Quantitative Trait Loci (QTL) mapping study, and (iii) transcriptome profiling study. GWAS was conducted using an Andean Diversity Panel (ADP) comprised of 259 genotypes. The ADP was evaluated for SNF in both greenhouse and field experiments, and genotyped using an Illumina BARCBean6K_3 BeadChip with 5398 single nucleotide polymorphism (SNP) markers. A mixed linear model was used to identify marker-trait associations. The QTL mapping study was conducted using 188 F4:5 recombinant inbred lines (RILs) derived from cross of Solwezi and AO-1012-29-3-3A. These 188 F4:5 RILs were evaluated for SNF in greenhouse experiments, and genotyped using the same BeadChip. Transcriptome profiling was conducted on RILs SA36 and SA118 contrasting for SNF that were selected from the Solwezi x AO-1012-29-3-3A population used in the QTL mapping study. RNA samples were collected from leaves, nodules and roots of SA36 and SA118 grown under N fixing and nonfixing conditions, and sequenced using Illumina technology. Using GWAS, significant associations for nitrogen derived from atmosphere (Ndfa) were identified on chromosomes Pv03, Pv07 and Pv09. QTL mapping identified QTL for Ndfa on Pv02, Pv04, Pv06, Pv07, Pv09, Pv10, and Pv11. The GWAS peak identified on Pv09 for Ndfa overlapped with the QTL on Pv09 for Ndfa identified in QTL mapping study. Previous studies have reported QTL for Ndfa on Pv04 and Pv10. Genes encoding receptor kinases, transmembrane transporters, and transcription factors (TFs) were among differentially expressed genes (DEGs) between SA36 and SA118 under N-fixing condition, but not under nonfixing condition. Out of the 51 genes that were in 400 kb region surrounding the GWAS peak on Pv07, only four including Phvul.007G048000 encoding a MADS BOX TF were identified as expression candidates for SNF in the transcriptome profiling study. In the 400 kb region surrounding the GWAS peak on Pv09 there were 44 genes, but only Phvul.009G137500 encoding a WRKY TF was identified as an expression candidate gene in the RNA-seq study. Using GWAS, QTL mapping and transcriptome profiling, genomic regions and expression candidate genes for SNF have been identified. Once validated, these QTL and genes have potential to be used in marker-assisted breeding to circumvent challenges of phenotypic selection for SNF, and accelerate genetic improvement of common bean for symbiotic nitrogen fixation.

**Objective 4. Develop phenometric approaches to improving the efficiencies of breeding for abiotic stress tolerance, especially drought**

Much of the research focused on examining constitutive differences between drought tolerant and drought susceptible genotypes so that mechanisms contributing to drought tolerance might be discovered and further investigated. To that end, the morphology of a drought tolerant genotype, tepary bean (*P. acutifolius*), and a drought susceptible genotype, common bean (*P. vulgaris*) cultivar Jaguar, were examined. First, the leaf density of both genotypes was measured. Ecologists have observed that species growing in low precipitation areas have sclerophyllous leaves—leaves that are small, thick, and leathery, and because drought tolerant tepary bean exhibited smaller leaf sizes that susceptible Jaguar or common beans in general, it was hypothesized that tepary bean might also have denser leaves. Multiple detached leaves of Jaguar and tepary were photographed, and their leaf areas determined with image analysis software. The detached leaves were also weighed, and from these two parameters, leaf density for both genotypes was determined. Jaguar and tepary were not significantly different from each other in leaf density; both had a leaf density of approximately 0.018 g/cm$^2$. Four bean genotypes contrasting in drought tolerance were also tested with assimilation vs. intercellular $CO_2$ (A-$C_i$) curves, which can give insight into various parameters that limit photosynthesis. Essentially, the photosynthetic rates of a plant are measured at different $CO_2$ concentrations, and the resulting data points can be measured with a simple tool (Sharkey et al., 2007). From the analysis, differences in maximum carboxylation rate of rubisco ($V_{cmax}$) and the electron transport rate (*J*) were found among the varieties (Table X1). $V_{cmax}$ limits photosynthesis under low $CO_2$ conditions such as drought while *J* limits photosynthesis under high light conditions. Zorro is only moderately drought tolerant, but it is a highly productive cultivar, so its higher $V_{cmax}$ and *J* could contribute to its higher productivity and ability to withstand intermittent drought. Tepary is extremely drought tolerant, and its higher *J* could allow it to withstand the higher light intensities coincident with drought stress without being damaged.

Also integral to this objective of the project is developing new methods of evaluating the stress resistance of different genotypes. In pursuance of this aim, a screening method utilizing heat stress was developed. Drought and heat tolerance share many physiological and genetic pathways, so it was hypothesized that heat could be used to indirectly screen for drought tolerance. Heat has the advantage of being easier and quicker to uniformly and reproducibly apply when compared with drought stress. Fifteen bean genotypes contrasting for drought tolerance were gathered: five used in previous research, and ten from a bean drought panel recommended by Carlos Urrea of University of Lincoln – Nebraska and Timothy Porch of the USDA Tropical Agriculture Research Station in Mayaguez, Puerto Rico. Successive replications of the 15 genotypes were grown in a growth chamber at 35° C, and then the temperature was raised to 40° C, and finally to 45° C. After a few days acclimation to the new temperatures, the plants were measured for parameters that respond to stress with a variety of methods: gas exchange, chlorophyll fluorescence, leaf temperature, and qualitative visual assessment. The results show that no significant differences were seen among these genotypes until the most severe stress of 45° C (Figure X1A-F). At that point, drought tolerant genotypes like tepary clearly separated out from susceptible phenotypes like Jaguar and 553. This heat screening method is a fast, effective, and reproducible way of testing many genotypes for drought tolerance specifically and abiotic stress tolerance generally.

**Objective 4. Institutional Capacity Building and Training for doctoral student from Zambia (Kelvin Kamfwa) and Uganda (Isaac Dramadri), and the US (Jesse Traub), and one MS (Grady Zuiderveen) student from the US all in Plant Breeding, Genetics and Biotechnology.**

Activities conducted by Kelvin Kamfwa in Michigan – listed under objective 3

*Activities conducted by Isaac Dramadri.* Mr. Dramadri planted the ADP panel consisted of 250 genotypes, 233 from the global ADP panel and 17 local genotypes and field evaluated during the months May–August, targeting the end of first rainy season at NaCRRI–Namulonge. The aim of the research was to use genomic and phenometric tools for improving selection and breeding for drought tolerance in the large seed bean. The field experiment consisted of two treatments (irrigated and nonirrigated), in two replications planted in the field at NaCCRI. In order to prepare and plan for future field experiments, field evaluations were necessary to assess the performance of the ADP under Ugandan conditions specifically targeting terminal drought stress, optimize the use of photosynq for measuring photosynthetic traits in common bean under field conditions, and multiply seed for the subsequent experiments. During the months of May–August, NaCRRI received unusual high rainfall and no drought stress was observed. These moist conditions however led to multiple disease condition and data was collected on all agronomic traits and on major common bean disease such as ALS, Rust, CBB, and BMCV. In addition, the initial plans of setting field irrigation facilities to provide supplementary irrigation were not implemented or needed. The major finding from this initial trial is that another location in Uganda is needed for drought screening due to the unpredictability of rainfall even in the dry season at Namulonge and the lack of trained field staff prevented the use of the photosyn as most field workers are actual laborers and could not be trained to assist in using the devise.

Activities conducted by Grady Zuiderveen in Michigan – listed under objective 2.10

Activities conducted by Jesse Traub in Michigan are listed under objective 4.

## IV. Major Achievements

The project in Uganda has made some significant achievement towards achieving the breeding objectives especially in the area of germplasm acquisition and utilization. We have also able to forge working relationships between NaCRRI and other institutes like Makerere University, Michigan State University, University of Nebraska, ARC-Grain Crops Institute– Potchefstroom–South Africa where we are able to have exchange visits for both students and researchers and also in the exchange of germplasm See Annex 3 for details.

The Bean Program conducted a Bean Research Methodology training Course at Misamfu research station from 29th March to 3rd April, 2015. The objectives of the training were:

- To share the standard evaluation of bean germplasm
- To identify and score bean diseases and pests in the field
- To learn how to set out experimental plots
- To learn how to manage Bean Trials
- To learn issues related to data collection and related information

Participants were drawn from ZARI stations of; Msekera, Mt Makulu, Kabwe, Mutanda, Mufulira, Mansa and Misamfu. The total number of 19 (15 male and 4 females) participated in the training

## V. Research Capacity Strengthening

The collaborative research has enabled us to build research capacity at NaCRRI not only in terms of breeding activities but also in developing human resource capacity. In this year we were able to continue training and mentoring one PhD and two MSc students. We are also able to train a three research assistant and 5 technicians in Uganda on the use of modern technologies to capture field data and reduce on errors. Also the host country PI–Uganda, was facilitated to attend and participate in a common bean disease workshop on angular leaf spot and root rot where new insights and methods were shared on how to combat these two diseases. We also able to network with other renowned scientists and sharing research information and knowledge. For human capacity building, two short term trainings were organized for Research assistants and technicians in host country–Uganda. This was to strengthen their research capability in as far as data collection is concerned. There was training on the use of new data collection tools as part of breeding management system which tools are being utilized by the project.

# VI. Human Resource and Institution Capacity Development

**Short-Term Training**

Two short training were conducted during this year. The first was on the use of Geographic information systems (GIS) with a special attention to the use of a GPS to capture and map location where data is collected. This was to help in the collection of diseases samples from within the country. This training was conducted by Dr. Michael Otim.

**Purpose of Training:** To introduce the Research Assistant and Technicians with the country's legume program to GIS and its importance in data collection and mapping data point.
**Type of Training:** Illustration using GPS and computer- and hands-on practicals
**Country Benefitting:** Uganda
**Location and Dates of Training:** NaCRRI –Namulonge , Uganda, 25–28$^{th}$ May 2015
**Number receiving training (by gender):** Male–04 and Female– 05 (Table 3)
**Home Institution(s) (if applicable):** NaCRRI
**Institution providing training or mechanism:** NaCRRI

The second training was on the use of the breeding management system for the integrated breeding platform also for Research Assistant and technician. This is a computer based tool that is used manage breeding data and also use of tablets for field data capture and reduce on errors. The training was conducted by Dr. Magni Bjarnason a consultant with the Integrated Breeding Platform who was assisted by Dr. Stanley Nkalubo, the Host country PI.

**Purpose of Training:** To introduce Research Assistant and Technician to the use of the Breeding management system (BMS) and use of computer based tools for field data capture to reduce on errors.
**Type of Training:** Power point presentation and hands-on computer and field practicals
**Country Benefitting**: Uganda
**Location and Dates of Training:** Uganda; 06–09$^{th}$ July 2015.
**Number receiving training (by gender):** Male–04 and Female–05
**Home Institution(s) (if applicable):** NaCRRI
**Institution providing training or mechanism:** Integrated Breeding Platform

**Degree Training**

The PhD student (Ms. Blessing Adogwu), continued to undertake her research work on rust with the project. Through the Norman E. Borlaug Leadership Enhancement in Agriculture Program fellowship, she was also able to travel to MSU and University of Nebraska to undertake hands-on training of the use of molecular markers for screening purposes. In addition two other MSc. students have been taken on by the project to undertake their researchers on under some of our project objectives. The first MSc. students is looking at breeding for resistance to common bacterial blight disease (CBB) while the second student is conducting research on the bean common mosaic virus (BCMV) disease. It hoped that the three students will make positive contribution towards new discoveries and also gain experience in research implementation. Details for the students are given below;

***Student 1***
**Name of trainee:** Blessing Odogwu
**Country of Citizenship:** Nigeria
**Gender:** Female
**Host Country Institution Benefitting from Training:** University of Port Harcourt, Nigeria
**Institution Providing Training:** Makerere University/NaCRRI
**Supervising CRSP PI:** Prof. Jimmy Kelly
**Degree Program:** PhD
**Field or Discipline:** Plant Breeding and Biotechnology
**Research Project Title:** Breeding for rust resistance in common beans in Uganda
**Start Date:** January 2014
**Projected Completion Date:** December 2017
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

***Student 2***
**Name of trainee:** Boris Mahulé Elysé Alladassi
**Country of Citizenship:** Benin
**Gender:** Male
**Host Country Institution Benefitting from Training:** University of Abomey–Calavi, Benin
**Institution Providing Training:** Makerere University/NaCRRI
**Supervising CRSP PI:** None
**Degree Program:** Masters Degree
**Field or Discipline:** Plant breeding and seed systems
**Research Project Title:** Genetic Analysis of Resistance to Common bacterial blight and association of candidate SNP markers of common bean (*Phaseolus vulgaris L.)* in Uganda
**Start Date:** December 2014
**Projected Completion Date:** September 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

***Student 3***
**Name of trainee:** Basil Evarist Kavishe
**Country of Citizenship:** Tanzania
**Gender:** Male
**Host Country Institution Benefitting from Training:** Sokoine University of Agriculture, Tanzania
**Institution Providing Training:** Makerere University/NaCRRI
**Supervising CRSP PI:** None

**Degree Program:** Masters Degree
**Field or Discipline:** Plant breeding and seed systems
**Research Project Title:** Resistance to bean common mosaic virus and its inheritance in selected Ugandan bean genotypes
**Start Date:** December 2014
**Projected Completion Date:** September 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

***Student 4***
**Name of Trainee (First and Last Name):** Kelvin Kamfwa
**Citizenship:** Zambian
**Gender:** M
**Training institution:** MSU
**Host Country Institution Benefitting from Training:** University of Zambia
**Supervising Legume Innovation Lab PI:** James D. Kelly and Karen A. Cichy
**Degree Program for training:** Doctorate
**Program Areas or Discipline:** Plant Breeding, Genetics and Biotechnology
**Thesis Title/ Research Area:** Genetic dissection of biological nitrogen fixation in common bean using genome-wide association analysis and linkage mapping.
**Start Date:** August 2008
**Projected Completion Date:** November 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** Yes
**Training Status:** Active

***Student 5:***
**Name of Trainee (First and Last Name):** Grady Zuiderveen
**Citizenship:** US
**Gender:** M
**Training institution:** MSU
**Supervising Legume Innovation Lab PI:** James D. Kelly
**Degree Program for training:** Masters
**Program Areas or Discipline:** Plant Breeding, Genetics and Biotechnology
**Host Country Institution to Benefit from Training:** US
**Thesis Title/ Research Area:** SNP marker development for major resistance genes
**Start Date:** August 2013
**Projected Completion Date:** September 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

***Student 6:***
**Name of Trainee (First and Last Name):** Jesse Traub
**Citizenship:** US
**Gender:** M

**Host Country Institution to Benefit from Training:** US
**Training institution:** MSU
**Supervising Legume Innovation Lab PI:** Wayne Loescher
**Degree Program for training:** Doctorate
**Field or Discipline:** Plant Breeding, Genetics and Biotechnology
**Thesis Title/ Research Area:** Physiological differences among *Phaseolus vulgaris* cultivars differing in drought tolerance.
**Start Date:** August 2013 on Legume Innovation Funding
**Projected Completion Date:** November 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active.

***Student 7:***
**Name of Trainee (First and Last Name):** Isaac Dramadri
**Citizenship:** Uganda
**Gender:** M
**Host Country Institution to Benefit from Training:** Makerere University
**Training institution:** MSU
**Supervising Legume Innovation Lab PI:** James D. Kelly and Wayne Loescher
**Degree Program for training:** Doctorate
**Field or Discipline:** Plant Breeding, Genetics and Biotechnology
**Thesis Title/ Research Area:** Physiological studies on drought tolerance in Andean beans.
**Start Date:** August 2013 on Legume Innovation Funding
**Projected Completion Date:** September 2017
**Is trainee a USAID Participant Trainee and registered on TraiNet?** Yes
**Training Status:** Active, Partial -BHEARD Fellowship from USAID Mission, Kampala

## VII. Achievement of Gender Equity Goals

For all activities we have undertaken under the project in Uganda we have ensure that women are actively represented at NaCRRI, this has also been shown in all our activities with the farmers and short term training. We have achieved more than the 30 percent women representation that has been set during project planning.

In Zambia we have identified NGOs that we can partner with for outreach and technology dissemination for female farmers which are Kusefya pa Ngw'ena Women's Farmer Group, Shangila Seed Growers Association (SSGA) in Mpika and the Participatory Village Development in Isolated Areas (PaViDIA) in Mporokoso and Luwingu, PaViDIA is working towards empowering women in communities in Income Generating Activities (IGA) and seed and grain production for market sales to elevate income and reduce poverty. In Uganda the NGOs include: Community Enterprise Development Organization (CEDO), Integrated Seed Sector Development (ISSD)–Uganda, CARE, ADRA, SHUPO, SASAKAWA Global 2000; Nyakatozi Growers Cooperative Union, Appropriate Technology (Uganda); Seed companies such as (Pearl, Victoria, NASECO, East African Seed, FICA seed). Many organizations have as objectives to increase women's agriculture skills and leadership roles as well as access to credit for sustainable and profitable farming.

## VIII. Explanation for Changes

There are no changes to set out activities but a few delays may be due to loss of diseases samples due to contaminations. We are currently relying on field screening but we hope that by mid next years all the new isolations would have been completed and characterization completed.

## IX. Self-Evaluation and Lessons Learned

Apart from the setbacks in the poor isolation and characterization, we believe that that project is fairly on course. Considering the unpredictable rainfall patterns, we have learnt we cannot rely on off-season planting to conduct drought trails anymore. We may have to think of other innovative ways of evaluating drought germplasm in the field. We may need to start thinking of constructing rainout shelters in the field.

## X. Scholarly Accomplishments – See Annex 1

## XI. Progress in Implementing Impact Pathway Action Plan

The project is on track toward implementing the impact pathway. All activities listed under step 4.1 of the impact pathway have been met with the exception of disease characterization in country and those activities will be conducted during FY16.

## XII. Data Management

The project is on track toward compliance with USAID standard provisions to make public all data bases generated as part of the project. All published data is available as supplemental files at the journals listed under item X, scholarly achievements

## ANNEXES

## Annex 1

**Scholarly Accomplishments**

Hoyos-Villegas, V., W. Mkwaila, P.B. Cregan and J.D. Kelly. 2015. QTL analysis of white mold avoidance in pinto bean (*Phaseolus vulgaris)*. Crop Sci. 55:2116–2129. doi:10.2135/cropsci2015.02.0106

Isaacs, K.B., S.S. Snapp, L. Butare, and J.D. Kelly. 2015. Genotype by cropping system interactions in climbing bean and maize associations in Northern Province, Rwanda. Euphytica (submitted).

Isaacs, K.B., S.S. Snapp, J.D. Kelly and K. Chung. 2015. Farmer knowledge in the selection of competitive bean genotypes for intercrop systems in Rwanda. Field Crops Research (submitted).

Kamfwa, K., K.A. Cichy and J.D. Kelly. 2015. Genome-wide association study of agronomic traits in common bean. The Plant Genome 8: doi:10.3835/plantgenome2014.09.0059.

Kamfwa, K., K.A. Cichy and J.D. Kelly. 2015. Genome-wide association analysis of symbiotic nitrogen fixation in common bean. Theor. Appl. Genet. 128:1999–2017. doi. 10.1007/s00122-

015-2562-5

Kelly, J.D., G.V. Varner, K.A. Cichy, and E.M. Wright. 2015. Registration of 'Alpena' navy bean. J. Plant Registrations 9:10-14. doi:10.3198/jpr2014.04.0025crc.

Kelly, J.D., G.V. Varner, K.A. Cichy, and E.M. Wright. 2015. Registration of 'Zenith' black bean. J. Plant Registrations 9:15–20. doi:10.3198/jpr2014.05.0035crc.

Kelly, J.D., J. Trapp, P.N. Miklas, K.A. Cichy, and E.M. Wright. 2015. Registration of 'Desert Song' Flor de Junio and 'Gypsy Rose' Flor de Mayo common bean cultivars J. Plant Registrations 9:133–137. doi:10.3198/jpr2014.05.0028crc.

Kelly, J.D., G.V. Varner, S. Hooper, K.A. Cichy, and E.M. Wright. 2015. Registration of 'Samurai' otebo bean. J. Plant Registrations (in press).

Mendoza, F.A, K. A. Cichy, R. Lu, and J. D. Kelly. 2015. Evaluation of canning quality traits in black beans (*Phaseolus vulgaris* L.) by visible/near-infrared spectroscopy. Food Research International Journal (in review).

Sousa, L.L., A. O. Gonçalves, M. C. Gonçalves-Vidigal, G. F. Lacanallo, A. C. Fernandez, H. Awale and J. D. Kelly. 2015. Genetic characterization and mapping of anthracnose resistance of Corinthiano common bean landrace cultivar. Crop Sci. 55:1900–1910. doi:10.2135/cropsci2014.09.0604

Burt, A.J., H. M. William, G. Perry, R. Khanal, K. P. Pauls, J. D. Kelly, A. Navabi. 2015. Candidate gene identification with SNP marker-based fine mapping of anthracnose resistance gene *Co-4* in common bean. PLoS ONE 10(10): e0139450. doi:10.1371/journal.pone.0139450.

**Presentations, Dissertations and Awards**

1. Traub J, Naeem M, Austic G, Kelly J, Kramer D, Loescher L. Assessing and comparing relationships between heat and drought tolerance: analytical approaches. Poster presentation at American Society for Horticultural Science Conference 2015, August 4–7. New Orleans, LA.
2. Traub J, Naeem M, Kelly J, Austic G,Kramer D,Loescher W. Phenotyping (screening) for heat (and drought) tolerance in bean (*Phaseolus* spp.) using new and conventional fluorescence and gas exchange parameters. Poster presentation at American Society of Plant Biologists Conference 2015, July 26–30. Minneapolis, MN.
3. Stanley T. Nkalubo, Pamela Papalu, Michael A. Ugen, Blessing A. Odogwu Clare T. Mukankusi, James Kelly, James Steadman and Carlos Urrea. 2015. Implications of Fungal Pathogens to Bean Production in Uganda. A poster presented at the common bean disease workshop on angular leaf spot and root rot from 20–23 July 2015, Kruger Gate Skukuza, South Africa
4. Reports submitted in the NARO annual report in Uganda

# Annex 2. Literature Cited

Mukankusi C. 2007. Improving resistance to Fusarium root rot [Fusarium solani (Mart.) Sacc. f. sp. phaseoli (Burkholder) W.C. Snyder & H.N. Hans.] in Common bean

(Phaseolus vulgaris L.). Unpublished PhD thesis. University of KwaZulu-Natal, South Africa.

Nkalubo T.S., Melis R, Derera J, Laing D.M, Opio F. 2009. Genetic analysis of anthracnose resistance in common bean breeding source germplasm. *Euphytica* 167(3):303–312

Pastor-Corrales M.A. 2006. Breeding Better Beans: Increasing Disease Resistance in Common Beans. *Agricultural Research Magazine* (*USDA*), 54 (6):12–14.

## Annex 3. Research achievements in Uganda obtained are inclusive but not limited to the following;

- Through the project we have been able to obtain and are utilizing four (4) nurseries including that of rust, CBB, and 2 sets of Drought nurseries and two (2) sets of differentials (Rust and ALS) from collaborating partners.
- We have identified 6 and 5 tentative resistance bean sources for rust and CBB diseases respectively.
- Have made a germplasm collection of close to 500 accessions which are utilizing to identify resistance sources for the different bean foliar diseases.
- Made over 60 different crosses to try and introgress different diseases resistances into the susceptible Uganda market class bean varieties.
- Made selection for over
- We have determined the incidences and severities of the different bean folia pathogen within major bean growing regions of Uganda.
- We have built capacity for 4 research Assistant and 5 technicians in form of data collection and management of breeding system also training and mentoring 3 students (1 PhD and 2 MScs) in breeding methodologies.
- We have engaged 326 farmers in on-farm trials that are evaluating and making selections for the utilization of fast cooking bean varieties.
- One PhD student (Blessing Adogwu) from NaCRRI –Uganda visiting Michigan State University and University of Nebraska to acquire skills in use of marker assisted selection and two PhD from Michigan State University (Dennis Katuramu and Isaac Dramadri) conducting their researchers with NaCRRI–Uganda.
- One poster paper “Implications of Fungal Pathogens to Bean Production in Uganda”presented at the common bean disease workshop on angular leaf spot and root rot from 20–23 July 2015, Kruger Gate Skukuza, South Africa.
- Several sources of common bacterial blight resistance were identified. A common bacterial blight nursery of 50 entries is being tested in 2015 at Uganda and Zambia.
- Several sources of drought tolerance were identified. A drought trial of 60 entries is being tested in 2015 at Uganda and Zambia under normal and drought stress conditions.

# Milestones

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**

Research, Training and Outreach Workplans

(October 1, 2014 -- September 30, 2015)

SEMI-ANNUAL MILESTONES OF PROGRESS BY INSTITUTIONS AND TIME PERIOD

*Project Code and Title:* **S01.A3 Improving Genetic Yield Potential of Andean Beans with Increased Resistances to Drought and Major Foliar Diseases and Enhanced Biological Nitrogen Fixat**

*Provide abbreviated name of institutions in columns below. Start with the U.S. institution.*

*(Tick mark the time period for achieving identified milestones by institution)*

**Objective 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 Andean bean germplasm for the Eastern Africa highlands (Zambia and Uganda), and U.S.

| *Identify Milestones by Objectives* | MSU | | UNL | | NACCRI | | ZARI | | Institution 5 | | Institution 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4/1/2015 | 10/1/2015 | 4/1/2015 | 10/1/2015 | 4/1/2015 | 10/1/2015 | 4/1/2015 | 10/1/2015 | 4/1/2015 | 10/1/2015 | 4/1/2015 | 10/1/2015 |
| 1.1. Evaluation of Integrated Nursery | | | | | x | x | x | x | | | | |
| 1.2. Identification of resistance sources | | | | x | | x | x | x | | | | |
| 1.3. Crossing and backcrossing resistance sources | | | | x | x | x | x | x | | | | |
| 1.4. Evaluation of lines for BNF | | | | | | x | | | | | | |
| 1.5. Population development for genetic studies | | | | x | | x | | x | | | | |
| 1.6. Screening for cooking time | x | | | | | | | | | | | |
| 1.7. Canning evaluation of lines | x | | | | | | | | | | | |
| 1.8. Evaluation of elite lines for cooking time | | x | x | | | | | | | | | |
| 1.9 Assembling a Legume Innovation Lab nurseries for | | | x | | x | | x | x | | | | |
| 1.10 Develop protocol across MA and A and | | | | | x | x | | x | | | | |
| 1.11 Seed multiplication | | | | | x | x | | x | | | | |
| 1.12 Site identification. BNF (sandy soils and low | | | | | | | | | | | | |
| 1.13 Field testing | | | | | x | x | x | x | | | | |

**Objective 2:** Characterize pathogenic and genetic variability of isolates of foliar pathogens collected in Uganda, 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.

| *Identify Milestones by Objectives* | MSU | | UNL | | NACCRI | | ZARI | | Institution 5 | | Institution 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4/1/2015 | 10/1/2015 | 4/1/2015 | 10/1/2015 | 4/1/2015 | 10/1/2015 | 4/1/2015 | 10/1/2015 | 4/1/2015 | 10/1/2015 | 4/1/2015 | 10/1/2015 |
| 2.1. Anthracnose race characterization, screening | | x | | | x | x | x | x | | | | |
| 2.2. Angular Leaf Spot characterization, screening | | | | | x | x | x | x | | | | |
| 2.3. Rust characterization, screening | | x | | x | x | x | x | x | | | | |
| 2.4. Common Bacterial Blight Screening | | x | | x | x | x | x | x | | | | |
| 2.5 Compile data base of past pathogen collections | | | | | x | x | x | x | | | | |

## Milestones, continued

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Objective 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** | | | | | | | | | | | |
| 3.1. SNP marker development linked to major | | x | | | | | | | | | | |
| 3.2. SNP marker associated with BNF | | x | | | | | | | | | | |
| 3.3. SNP markers associated with drought | | | | x | | | | | | | | |
| 3.4. MAS for disease screening using MAS | | x | | x | | | | | | | | |
| 3.5 Plant regional BNF and drought nurseries for genotyping | | x | | | | | | | | | | |
| 3.6 Fingerprinting lines/populations with SNP markers | | x | | | | | | | | | | |
| 3.7. Association mapping | | x | | x | | | | | | | | |
| 3.8 Farmer preference results for fast cooking bean lines | | x | | | | | | | | | | |
| **Objective 4:** | **Focus on phenometric approaches to improving the efficiencies of breeding for abiotic stress tolerance, especially drought** | | | | | | | | | | | |
| 4.1 Initially, assemble selected and small sets of physiologically contrasting genotypes from breeders, and later expand these sets, e.g., Andean diversity panel | x | x | | | | | | | | | | |
| 4.2 Conduct and evaluate the effectiveness of initial phenometric measurements of contrasting genotypes | x | x | | | | | | | | | | |
| 4.3 Identify differences among genotypes with contrasting responses to abiotic (heat, light, and drought) stresses. | x | x | | | | | | | | | | |
| 4.4 Evaluate and continue development of new techniques for measuring plant responses to stress, i.e., photosynthetic fluorescence and gas exchange parameters, and in year 2 hormone levels. | x | x | | | | | | | | | | |
| 4.5 Focus new methodologies on drought stress | | x | | | | | | | | | | |

# Milestones, continued

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Objective 5:** | **Capacity Building** | | | | | | | | | | | |
| 5.1. Graduate Student training | | | | | x | x | | x | | | | |
| 5.2. Short term training for colloborators and technician (SNP Markers applications) | | | | | | x | | | | | | |
| 5.3 Short term training of graduate students/collobarators on phenometrics and bioinformatics | | | | | | x | | | | | | |
| 5.4 Train PhD or Msc students | | | | | x | x | | | | | | |
| 5.5 On-country training (BNF). Collaborate with the MA Legume Innovation Lab. Decide the location. | | | | | | | | | | | | |
| 5.6 Short term training for technicians/project personnel in host countries on the use of different screening protocols (drought and diseases) | | | | x | x | x | | x | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Name of the PI responsible for reporting on milestones** | James Kelly | James Steadman, Carlos Urrea | Stanley Nkalubo | Kennedy Muimui | PI name | PI name |
| **Signature/Initials:** | | | | | | |
| **Date:** | | | | | | |

# Performance Indicators

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**
**REVISED PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 14, FY 15, FY16, and FY 17**

**Project Name:S01.A3 Improving Genetic Yield Potential of Andean Beans with Increased Resistances to Drought and Major Foliar Diseases and Enhanced Biological Nitrogen Fixation (BNF)**

**Summary of all institutions**

| Indic. numbe | Output Indicators | FY 14 Target | FY 14 Revised | FY 14 Actual | FY 15 Target | FY 15 Revised | FY 15 Actual | FY 16 Target | FY 16 Revised | FY 16 Actual | FY 17 Target | FY 17 Revised | FY 17 Actual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (October 1, 2013 - September 30, 2014) | | | (October 1, 2014 - September 30, 2015) | | | (October 1, 2015 - September 30, 2016) | | | (October 1, 2016 - September 30, 2017) | | |
| 1 | 4.5.2(6) Number of individuals who have received USG supported long-term agricultural sector productivity or food security training | 3 | 0 | 2 | 3 | 1 | 6 | 6 | 0 | 0 | 3 | 0 | 0 |
| | Total number by sex | 2 | 0 | 0 | 6 | 1 | 6 | 6 | 0 | 0 | 3 | 0 | 0 |
| | Number of women | 1 | 0 | 0 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| | Number of men | 1 | 0 | 0 | 4 | 0 | 5 | 5 | 0 | 0 | 3 | 0 | 0 |
| | Total number by New/continuing | 3 | 0 | 2 | 3 | 1 | 6 | 6 | 0 | 0 | 3 | 0 | 0 |
| | Number of New | 1 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Number of Continuing | 2 | 0 | 1 | 3 | 1 | 3 | 6 | 0 | 0 | 3 | 0 | 0 |
| 2 | 4.5.2(7) Number of individuals who have received USG supported short-term agricultural sector productivity or food security training | 6 | 0 | 0 | 12 | 13 | 28 | 14 | 0 | 0 | 15 | 0 | 0 |
| | Total number | 6 | 0 | 0 | 12 | 13 | 28 | 14 | 0 | 0 | 15 | 0 | 0 |
| | Number of women | 3 | 0 | 0 | 5 | 6 | 20 | 5 | 0 | 0 | 7 | 0 | 0 |
| | Number of men | 3 | 0 | 0 | 7 | 7 | 8 | 9 | 0 | 0 | 8 | 0 | 0 |
| | Numbers by Type of individual | 6 | 0 | 0 | 12 | 13 | 28 | 14 | 0 | 0 | 15 | 0 | 0 |
| | Producers | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | People in government | 6 | 0 | 0 | 12 | 13 | 26 | 10 | 0 | 0 | 10 | 0 | 0 |
| | People in private sector firms | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 5 | 0 | 0 |
| | People in civil society | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III) | 3 | 0 | 0 | 8 | 1 | 8 | 14 | 0 | 0 | 15 | 11 | 11 |
| | Phase 1: Number of new technologies or management practices under research as a result of USG assistance | 3 | 0 | 0 | 6 | 0 | 4 | 8 | 0 | 0 | 8 | 6 | 6 |
| | Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance | 0 | 0 | 0 | 2 | 0 | 2 | 4 | 0 | 0 | 3 | 3 | 3 |
| | Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 0 | 0 | 4 | 2 | 2 |

**Notes:**

These indicators are developed under the Feed the Future Monitoring System. Please provide 'total' numbers and also disaggregate where applicable. Just providing 'totals' will not be approved.

This table corresponds to the Feed the Future Performance Indicators data collection sheet under the FTFMS system. Where an indicator does not apply to the type of work done under the project, leave it blank.

Please follow the indications in the Legume Innovation Lab Indicators Handbook that will be provided to you by the Management Office. Contact Mywish Maredia (maredia@anr.msu.edu) for further information.

# 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 (S01.A4)

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## I. Abstract of Research and Capacity Strengthening Achievements

Conventional plant breeding techniques and marker-assisted selection were used to develop dry bean cultivars with enhanced levels of disease resistance and greater tolerance to abiotic stresses. During the past few years, the Bean Technology Dissemination project multiplied and distributed seed of improved bean cultivars developed by S01.A4 plant breeders to thousands of farmers in Central America and Haiti. Seed of multiple disease resistant black bean cultivar 'XRAV-40-4' and red mottled bean breeding line PR0737-1 was multiplied in Haiti. The small red cultivar 'Paraisito Mejorado 2- Don Rey' with excellent seed type, disease resistance and abiotic stress tolerance was released in Honduras. The BGYMV and BCMNV resistant black bean line MEN-2201-64ML from Zamorano had superior performance under drought conditions in Haiti, Nicaragua and El Salvador. White bean germplasm lines with BGYMV, BCMNV and rust (*Ur-4, Ur-5 and Ur-11*) resistance were released. Red mottled, cranberry and pinto bean lines with BGYMV and BCMNV resistance are ready for testing in field trials. Black bean breeding lines that combine resistance to BGYMV, BCMNV and bruchids are also ready for field testing. 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. Putative markers for bruchid resistance have been identified. Sources of resistance to BCMNV in tepary bean were identified in a newly developed Tepary Diversity Panel (TDP). Tepary bean populations are under development to increase seed size, improve agronomic traits, and combine disease resistance (BCMNV, rust, common blight). Workshops dealing with bean research techniques and seed production were offered at Zamorano. Héctor Martínez from Guatemala and Iveth Rodríguez from Honduras initiated M.S. degree training at the UPR. Several B.S. degree students have opportunities to work with the bean research program at Zamorano.

## II. Project Problem Statement and Justification

Increased bean production during the past 30 years in Central America and Haiti has been due, in large part, to expansion of production in the lowlands (< 1000 m). Greater heat tolerance combined with resistance to BGYMV increased bean seed yield and production in El Salvador. Bean production in Guatemala and Nicaragua has expanded into more humid lowland regions whereas a significant portion of the beans in Haiti continues to be produced in the lowlands. Bean production in Africa could be expanded if lines with better lowland adaptation were developed. This Legume Innovation Laboratory project will address several of the biotic and abiotic constraints often encountered by bean producers in the tropical lowlands.

BCMNV threatens bean production in warmer bean production regions of Central America, the Caribbean and Africa. The recent arrival of BCMNV in the Caribbean made the selection for resistance to this virus a priority breeding objective in Haiti, the Dominican Republic and Puerto Rico. BCMNV is also a serious disease in lowland bean production regions of southeastern Mexico. Collaborative research supported by the Bean/Cowpea and Pulse CRSP resulted in the development and release of black bean cultivars and breeding lines such as DPC-40, XRAV-40-4 and MEN-2201-64ML that combine resistance to BCMNV and BGYMV. Small red bean breeding lines with the same combination of resistances are currently being developed at Zamorano. These BGYMV and BCMNV resistant black and small red bean lines will be available in the event that BCMNV emerges as a threat to bean production in Central America. The availability of small red bean breeding lines with BCMNV resistance will permit the field testing of this seed type in Eastern Africa.

Small red and black beans tend to have greater yield potential and heat tolerance than Andean beans. Middle American beans also tend to have greater resistance to diseases in Africa, since pathogens in this region have co-evolved with Andean beans. Increased resistance to common bacterial blight and web blight is needed for beans produced in warm and humid lowland regions such as the Petén in Guatemala. This combination of resistances may also permit increased production of beans in Central America during the first growing season when rainfall is generally more abundant and reliable. The previous Dry Grain Pulse CRSP project (UPR-1) developed Middle American and Andean bean breeding lines having adaptation to the lowland tropics and different combinations of resistance to diseases (common bacterial blight, rust, angular leaf spot, web blight and root rot) and tolerance to edaphic constraints (low N soils, high temperature). During the past three years, the Legume Innovation Lab project has used these elite breeding lines as the base for the continued improvement of beans for our target countries. Several improved black and small red bean germplasm lines and cultivars are expected to be released in Central America and the Caribbean during the next two years. This Legume Innovation Laboratory project will continue, in collaboration with CIAT, to support bean research network activities in Central America and the Caribbean. Collaborative activities such as the regional performance nurseries will help to extend the impact of this project through the release of improved cultivars throughout the region.

The project plans to release in Haiti red mottled, yellow and white bean cultivars with enhanced levels of disease resistance. These seed types are produced in regions in Haiti where the CRSP project has had less impact. This effort is consistent with the FTF 2011-2015 multiyear strategy in Haiti to increase the production of staples such as beans to increase food security. In a previous Pulse CRSP project, Dr. Phil Miklas developed Andean bean breeding lines with resistance to BCMNV and anthracnose that should be useful to Legume Innovation Lab breeding projects in Africa and the Caribbean. Yellow, red mottled and white bean breeding lines having BCMNV resistance will be available for Legume Innovation Lab or Feed the Future projects to test in Eastern Africa.

Andean bean breeding lines developed by Dr. Paul Kusolwa at Sokoine University of Agriculture have a unique combination of traits that confer a high level of resistance to bruchids. These breeding lines include the APA locus derived from *P. acutifolius* and possibly the null phaseolin trait from *P. coccineus*. These bruchid resistant breeding lines have been used as progenitors by the University of Puerto Rico bean breeding program to introgress this resistance into black, small red and white beans that also have resistance to BCMV, BCMNV and BGYM. Evaluations will be conducted in Central America and the Caribbean to measure the durability of the resistance when exposed to different genera and ecotypes of bruchids.

The project will continue to screen germplasm to identify additional sources of resistance to diseases that limit bean production in Central America and the Caribbean. For example, more resistance to ashy stem blight, caused by *Macrophomina phaseolina*, is needed to improve adaptation to hot and dry environments such as the dry corridor in Guatemala and southwestern Haiti. Greater resistance to web blight, caused by *Rhizoctonia solani*, is required to increase yield and seed quality of beans produced in more humid environments such as the Petén Department in Guatemala and eastern Nicaragua. Project personnel have the expertise and experience needed to reliably phenotype the Andean and Middle American Diversity Panels for traits of economic importance. This should contribute to the identification of new sources of resistance.

There are regions and/or growing seasons in Central America, Haiti and Africa that are too hot and/or dry to produce common beans. The tepary bean (*P. acutifolius*) is a potential alternative grain legume for these stressful environments. In fact, farmers on the Pacific coast of Central America and some countries of Africa already produce tepary beans on a limited scale. In addition to heat and drought tolerance, tepary bean lines with resistance to common bacterial blight, root rots, BCMV, bruchids and other important traits, such as tolerance to low soil fertility, have been identified. Resistance to BCMV, BGYMV, larger seed size and improved agronomic traits, would increase the potential adoption of tepary beans. In addition to pyramiding these traits within tepary, interspecific crosses with common beans are being used as a long-term effort to introgress these traits into tepary beans. This effort represents the first systematic attempt to genetically improve tepary beans.

Bean breeders were early adopters of marker-assisted selection to identify lines with desired combinations of traits. This resulted in increased efficiency in the development of improved breeding lines. There are, however, molecular markers available for a limited number of traits. Others, such as the SAP6 SCAR marker, are only effective in a specific gene pool. Therefore, there is a need to develop new or more robust markers, particularly for traits of economic importance to bean breeding programs in the tropics. Recent advances by the BeanCAP project, led by North Dakota State University, in sequencing the bean genome and the development of a SNP array and GWAS will facilitate the mapping and development of molecular markers for traits of economic importance, while breeder-friendly InDel markers are a broadly applicable technology. The availability of phenotypic data in appropriate populations is a major factor limiting the development of these markers. This Legume Innovation Lab will assist this effort through the development of the populations and information needed to identify improved markers for traits such as the *Ur-11* gene for rust resistance. Dr. Phil McClean at NDSU will lead the collaborative effort to develop improved molecular markers.

Differences and linkages between S01.A4 and other Feed the Future (FtF) Projects

- The focus of the S01.A4 project is on biotic constraints and abiotic constraints in the tropical lowlands. Successful bean cultivars need resistance/tolerance to both types of constraints. Other FtF projects are focused on beans in the highlands of Africa and Guatemala. Given the expected trends in climate change, breeding beans for adaptation to the lowlands may help to identify bean germplasm with improved adaptation to future highland environments.
- The focus of the S01.A4 project is on Latin America/Caribbean vs. Africa. However, exchange of breeding lines among FtF projects is mutually beneficial.
- Genomic research, development of molecular markers and the sharing of breeding strategies and breeding populations are common links among projects.

# III. Technical Research Progress

**Objective 1. Genetic improvement of common and tepary beans for Central America and Haiti.**

***Development, testing and release of improved bean cultivars***

Conventional plant breeding techniques and marker-assisted selection has been used by Legume Innovation Lab scientists to develop common bean cultivars and breeding lines with enhanced levels of disease resistance and greater tolerance to abiotic stresses. Plant breeders will focus on the most important biotic and abiotic constraints in lowland (< 1000 m) bean production regions in Central America and Haiti. The bean research program at Zamorano has coordinated the regional testing of small red and black bean breeding lines. The University of Puerto Rico has coordinated the development and testing of Andean beans in the Caribbean. These trials have been conducted in collaboration with national bean research programs and CIAT. Promising lines have been tested throughout Central America and the Caribbean, including countries that are not participating in this Legume Innovation Lab project. Testing lines in different countries provides more information concerning the potential performance of the lines and expands the potential impact of the research supported by the Legume Innovation Lab. In addition to yield trials, field trials have been conducted to screen bean lines for resistance to different diseases such as angular leaf spot, powdery mildew and web blight. Testing sites have been chosen to produce reliable results for screening for specific traits.

**Table 1. Bean and other grain legume trials distributed to Central American and Caribbean Bean Research Network collaborators during 2014–2015.**

| Trial name | Small red | Small black | Countries |
|---|---|---|---|
| Regional bean adaptation nursery (VIDAC) | 64 entries + 2 checks | 77 entries + 2 checks | GU, ES, HO, NI, CR, HA |
| Elite line yield trial (ECAR) | 14 entries + 2 checks | 14 entries + 2 checks | ES, HO, NI, CR, GU, HA |
| Regional Rojo de Seda Nursery (VIROS) | 52 entries + 2 checks | -- | ES,HO, NI, CR |
| Bean variety validation trial (COVA) | 8 + 2 checks | | ES, HN |
| Regional angular leaf spot trial (ERMAN) | 24 entries + 2 checks | ES, HO, NI, CR, GU, HA | |
| Regional web blight trial (ERMUS) | 8 entries + 2 checks | ES, HO, CR, GU | |
| Biofortified bean trial (AGROSALUD) | 9 entries + 1 check | ES, HO, NI, GU, CR | |
| Regional BNF trial (ERFBN) | 8 entries + 2 checks | HO | |
| Regional high temperature trial (ERSAT) | 20 entries + 5 checks | HO, CR | |
| Regional drought trial (ERSEQ) | 20 entries + 5 checks | HO, CR | |
| Tepary bean adaptation trial (TAT) | 19 + 1 check | HO, CR | |
| Regional tepary bean trial (ERTEPARI) | 21 entries + 1 check | CR, HO | |

***Greater tolerance to abiotic stress***

Although disease resistance is the primary focus of this project, the performance of bean breeding lines is evaluated in low fertility soils. Honduras has an ideal site for the evaluation of lines for adaptation to low P soils. Puerto Rico has good locations for screening beans for performance in a low N soil, root rot resistance and high temperature. These sites will be used to evaluate the performance of bean breeding lines derived from recurrent selection for increased BNF and/or selected for greater nitrogen use efficiency. These sites will be inoculated with efficient *Rhizobium* strains to allow indirect selection for enhanced BNF.

***Bruchid resistance***

Bruchid resistant bean breeding lines developed by Dr. Kusolwa at Sokoine University of Agriculture have been used to introgress resistance to this pest into commercial seed types (black, small red, red mottled, light red kidney and yellow) produced in the target countries. A laboratory screening technique developed at the University of Puerto Rico has been used to evaluate the resistance of bean breeding lines. The effectiveness of using molecular markers for traits (null phaseolin, arcelin 2 and APA locus) associated with bruchid resistance is under evaluation. An additional breeding objective is to combine bruchid and virus (BCMV, BCMNV and BGYMV) resistance. Bruchid resistant 'Rojo' backcross lines developed in collaboration with Jim Myers (Oregon State University) and Paul Kusolwa (Sokoine University of Agriculture) were identified to also have BCMV and BCMNV ($I + bc\text{-}1^2$) resistance. Considerable progress has also been made toward the development of black beans that combine bruchid and virus resistance.

***Evaluation of bean diversity panels and identification of new sources of disease resistance***

The Middle American (MDP) and Andean Diversity (ADP) panels will be screened in Central America and the Caribbean for specific traits. For example, the Andean Diversity Panel will be screened in Haiti for reaction to powdery mildew and in Honduras for angular leaf spot. Performance of the Middle American Diversity Panel will be evaluated in low N environments in Central America and the Caribbean. The Middle American Diversity Panel has been screened in Puerto Rico for resistance to ashy stem blight.

***Genetic Improvement of Tepary Beans***

Although tepary bean has high levels of abiotic stress tolerance, it is susceptible to viruses such as BGYMV, BCMV, and BCMNV. In order to expand the potential use of tepary bean in abiotic stress prone regions, a primary focus of this project will be to incorporate newly identified resistance in tepary accessions into tepary breeding lines, and to initiate the introgression of virus resistance from common bean into tepary bean. By project end (FY17) we expect to have tepary breeding lines with improved virus resistance that will be available for pyramiding of virus resistance loci in future efforts. A tepary breeding program was initiated at USDA-ARS-TARS in 2008. Advanced breeding lines developed from these previous breeding efforts have been increased and shared with the collaborators for testing in Tepary Adaptation Trials (TAT). New tepary breeding lines have been generated from crosses between promising large and round seeded genotypes from the CIAT collection and breeding lines selected for disease and abiotic stress tolerance. Using leveraged funds, these materials were initially tested through a shuttle breeding program with M. Brick at Colorado State University. This effort will focus on seed size/shape, drought and heat tolerance, and CBB and bruchid resistance in PR; and on photoperiod insensitivity, broad adaptation, rust resistance, and yield in Colorado. Superior lines will then be tested in the host countries for potential future release.

**Objective 2. Develop and implement robust molecular markers for disease resistance genes**

This project will leverage the results from the USDA Common Bean Agricultural Project and the USDA/DOE/JGI common bean sequencing project. The BeanCAP project developed a suite of ~3000 InDel markers distributed across all common bean chromosomes. These markers are codominant and designed to be functional in labs with a simple set of equipment and reagents (Thermal Cycler, gel chambers, and UV lamp). The power of these markers is that they are simple to implement and thus completely portable in all laboratories and are amenable to multiplexing with suites of markers. Multiplexing reduces the cost of genotyping an individual line. The release of the common bean whole genome assembled sequence allows for precise localization of each of these markers. The final key element that facilitates this project is the development, over the last fifteen years, of markers (mostly SCARS) that are linked, from 0–5 cM, to important target disease genes. While useful, there has been some difficulty in the portability of these markers from one laboratory to another. They all have unique experimental conditions that preclude multiplexing, and > 5% recombination reduces effectiveness due to recombination between marker and target gene. In addition, these SCAR markers don't work across different market classes or genetic backgrounds. Contrastingly, most InDel markers developed at NDSU are market class specific, which will facilitate their use and increase their reliability.

***Identify genetic materials for marker evaluation***

Potential targets for improved marker development include:

- Bean golden yellow mosaic virus resistance genes and QTL (*bgm*, SW12, *Bgp*)
- Bruchid resistance genes (*Arc2, Arl3, PHA* and *aAI3*)
- BCMV and BCMNV (*I, bc-3,* $bc\text{-}1^2$)
- Bean rust (Ur-4, Ur-5, Ur-11).

For each of these targets, we will adopt the same procedure. First, we will search the published literature and communicate personally with breeders, geneticists, and pathologists in both Legume innovation Lab projects to identify genetic materials with contrasting phenotypes (resistance, susceptibility) for the specific disease. These could be genetic populations or a collection of lines with known phenotype that can then be used for the identification of closely linked indel markers. Project personnel have already participated in the evaluation of the Middle American and Andean Diversity Panels for reaction to several different diseases.

***Development of InDel markers***

- DNA will be isolated from genetic populations or collections of lines with known phenotypes.
- The physical locations of target genes or markers will be identified using sequence information. If the sequence information is poor or unavailable, the specific marker will be cloned and sequenced.
- <u>InDel marker selection</u>. Once the location of the marker is determined, it will then be compared to the InDel database to discover InDel markers that straddle the physical location of the marker. Those InDel markers will be used in PCR amplification to determine which one acts as a definitive marker that is unambiguous in its predictive

power. If several markers have equal predictive power, then the one that will best work as a multiplexing marker will be selected. Legume Innovation Lab bean breeding programs in Guatemala, Honduras, Ecuador, Tanzania and Uganda have the facilities and technical expertise needed to immediately adopt the use of InDels for marker-assisted selection.

**Objective 3. Institutional capacity building**

Formal and informal training activities will be conducted to enhance the capacity of host country bean research programs to develop and release superior-performing bean cultivars that will increase production or reduce losses in the target countries. At the end of this project, these bean research programs should have the capacity to utilize the newly developed suite of InDel markers for marker-assisted selection. The Ph.D. and M.S. degree students will be provided a broad range of training in conventional and molecular plant breeding techniques so that they can assume roles of leadership in bean research programs in the target countries. Informal training of technicians should improve the reliability and quality of bean research conducted in host countries.

***Informal training***

- In-service training will be provided during FY16 at NDSU for Legume Innovation Laboratory scientists to review recent advances in sequencing the bean genome and the utilization of SNP arrays to develop InDel markers for traits of economic importance.
- A workshop was held in Honduras in April 2015 to train technical personnel from Central America and the Caribbean concerning bean research techniques with the goal of improving the quality of field research. Topics included the development and management of field trials, breeding and selection methods, field evaluation techniques, research with Rhizobium, participatory plant breeding and agroecological techniques.
- The project received Institutional Building Funds to conduct a workshop at Zamorano in August 2015 to discuss with technical personnel from Central America and the Caribbean techniques needed to produce, process and store high quality seed stocks. The training should improve the capacity of the bean research programs in Central America and Haiti to produce basic and foundation seed stocks of recently released bean cultivars.
- A significant amount of information concerning bean research techniques is already available on the Bean Improvement Cooperative (BIC) web site http://bic.css.msu.edu/ResearchTechniques.cfm. This Legume Innovation Lab project will collaborate with the BIC in developing modules for the BIC web site that will describe research techniques for additional traits such as bruchid resistance.

# IV. Major Achievements

**Development, testing and release of improved bean cultivars**

- XRAV-40-4, a multiple disease resistant black bean adapted to the humid tropics, was developed and released cooperatively by the Puerto Rico (UPR) and Nebraska (UNL) Agricultural Experiment Stations, the USDA-ARS, the Instituto Dominicano de

Investigaciones Agropecuarias y Forestales (IDIAF), the Escuela Agrícola Panamericana, Zamorano, Honduras, and the National Seed Service of the Ministry of Agriculture of the Republic of Haiti. 'XRAV-40-4' combines resistance to BGYMV, BCMV, and BCMNV. When planted at higher altitudes, XRAV-40-4 has earlier maturity than the black bean cultivar 'DPC-40'. A description of the release of XRAV-40 was published in the J. of Agric. of the Univ. of Puerto Rico (Beaver *et al*., 2014. JAUPR. 98:83–87). XRAV-40-4 is expected to be released in Central America as 'Azabache 40' and in Haiti as 'Sankara'. XRAV-40-4 performed well in on-farm trials conducted by the NSS with support from FAO.

- The cultivar "Paraisito Mejorado 2- Don Rey" was released in Honduras. This cultivar has a light red seed color similar to its landrace parent "Paraisito" but carries the BGYMV and BCMV disease resistance and greater adaptation to low soil fertility from its recurrent parent, the improved bean cultivar Carrizalito.
- White bean lines were released that combine the *bgm-1* gene and the SW12 *QTL* for resistance to BGYMV, the *I* and *bc-3* genes for resistance to BCMV and BCMNV and resistance to a wide range of rust races. Results from inoculations with specific races of rust conducted by Dr. Pastor-Corrales, USDA-ARS-Beltsville suggest that the white bean lines have a unique combination of the *Ur-4, Ur-5* and *Ur-11* rust resistance genes. A manuscript describing the release of these bean breeding lines as germplasm releases was published in the *J. Plant Registrations* (Beaver *et al.*, 2015. *J. Plant Reg*. 9:208–211). This was the first release of improved bean germplasm that combines multiple virus (BGYMV, BCMNV and BCMV) and rust resistance. An elite white bean nursery will be distributed by Dr. Juan Carlos Rosas to collaborators in Central America and the Caribbean.
- These rust resistant white bean breeding lines were used as parents to introgress high levels of rust resistance into black beans. DPC-40 and XRAV-40-4 were used as parents to insure that progeny from these crosses will also have multiple virus resistance. $F_5$ black bean lines with good agronomic type were selected from these populations. These lines will be screened during second growing season of 2015 at Zamorano for resistance to rust. Previous research has found rust races in Honduras to have high levels of virulence. Dr. Pastor-Corrales (USDA FtF project collaborator) will conduct greenhouse evaluations of lines that are rust resistant in field trials in Honduras. This effort should lead to the development of black bean lines that combine multiple virus resistance and the *Ur-4, Ur-5* and *Ur-11* rust resistance genes. The most promising lines will be included as entries in regional performance trials for Central America and the Caribbean.
- The red mottled bean line PR0737-1 that combines the *bgm-1* allele for resistance to BGYMV and the *I* and *bc-3* alleles for resistance to BCMV and BCMNV, was released as improved germplasm (Prophete *et al*. 2014. *J. Plant Reg.* 8:49–52). Seed of PR0737-1 is currently being multiplied in Haiti and is in the process of being formally released as a cultivar.

- Yellow bean lines that combine the *bgm-1* gene for resistance to BGYMV and the *I* gene for resistance to BCMV were developed and tested in Puerto Rico, Angola and Haiti. One of the lines, PR1146-138, also expressed tolerance to leafhoppers in a trial planted in Damien, Haiti in 2014 and produced a mean seed yield of 1,884 kg/ha over seven environments. Seed of this line has been multiplied for on-farm trials that will be conducted in Haiti during FY16. A manuscript describing the release of PR1146-138 has been submitted to the *J. Plant Reg.*
- An advanced generation yellow bean breeding line, PR1501-162 with good agronomic traits and commercial seed was screened using molecular markers and found to combine the *bgm*-1 allele and the SW12 QTL for resistance to BGYMV, the *I* allele that confers resistance BCMV and the SAP6 QTL for resistance to common bacterial blight. The performance of this line will be evaluated in Haiti and Puerto Rico during the upcoming year.
- Pinto beans gained popularity in Haiti after this market class was imported as food aid. Consumers note that pinto beans have a shorter cooking time than other seed types used in Haiti. During the past year, we multiplied seed of advanced generation lines that have the *bgm-1* allele and the SW12 QTL for BGYMV resistance and the *I* and *bc-3* alleles for resistance to BCMV and BCMNV. All of the lines have commercial pinto seed type and many have an erect growth habit. During the upcoming year, these lines will be evaluated in trials in Haiti, Honduras and Puerto Rico. These pinto lines should segregate for the *Ur-11* gene so special attention will be given to lines that do not develop rust symptoms. Two generations will be planted in Puerto Rico during FY16 to multiply seed of the most promising lines. Because Durango race beans have performed well in Eastern Africa, the pinto lines were sent to Dr. Phil Miklas for evaluation in Tanzania.
- The performance of red mottled and cranberry bean lines with commercial seed type and resistance to BGYMV, BCMV and BCMNV will be evaluated in Puerto Rico and Haiti during the upcoming year. Seed of these lines were also sent to Dr. Karen Cichy for evaluation in Michigan and Africa.
- Determinate black bean lines with resistance to BGYMV, BCMV and BCMNV were selected. There lines are very early in maturity which may help to avoid terminal drought. The performance of these lines will be tested in Honduras, Haiti and Guatemala during the upcoming year.
- Advanced generation black bean lines from Puerto Rico that were identified to possess the *bgm-1* gene for resistance to BGYMV and the *I* and *bc-3* genes for resistance to BCMV and BCMNV were tested in Haiti, Guatemala and Puerto Rico. Many of these lines have progenitors with heat tolerance and resistance to common bacterial blight and web blight. These lines expressed little damage from leafhoppers in Damien, Haiti and Jutiapa, Guatemala although many bean lines in neighboring trials were severely damaged. Black bean lines with resistance to BGYMV, BCMV, BCMNV and rust were selected for in San Jerónimo, Guatemala by ICTA researchers.

- "Beseba" is a Haitian Lima bean from a collection made by the Dry Grain Pulse CRSP and sent to CIAT to be included in the germplasm collection. Dr. Rao, CIAT Physiologist, reported at the 2014 PCCMCA meeting in Nicaragua that 'Beseba' (G 27529) produced the greatest seed yield in a high temperature trial conducted in Colombia. Emmalea Ernest reported at the 2014 BIC meeting that G 27529 had among the greatest amount of pollen shed in a high temperature trial conducted in Delaware (BIC 57:41–42). Heat tolerant Lima beans should be tested as an alternate crop for the dry corridors of Honduras, El Salvador and Guatemala. The CIAT Lima bean germplasm collection should be screened for reaction to BGYMV to attempt to identify a potential source of resistance.
- IICA personnel reported that the black bean variety ICTAZAM, that has a shiny seed coat, is acceptable to consumers in Guatemala. ICTAZAM has resistance to BGYMV, BCMV and web blight and was identified by ICTA researchers to have superior performance in more humid regions such as the Petén region of Guatemala.

**Greater tolerance to abiotic stress**

- INTA and CENTA researchers reported that the black bean line MEN-2201-64ML from Zamorano had superior performance under drought conditions in Nicaragua and El Salvador. This line was also selected for further evaluation in Haiti based on its performance during the dry season. In addition to drought tolerance, MEN-2201-64ML was selected for resistance to BCMV, BCMNV and BGYMV. During the upcoming year, this Legume Innovation Lab project will support the on-farm testing of MEN-2201-64ML in Haiti, Honduras, Guatemala and other Central American countries where drought is a frequent constraint to bean production. The NSS in Haiti multiplied seed of this line during the summer of 2015 to distribute to farmer groups in November.
- The small red bean breeding line IBC-301-204, selected at Zamorano for resistance to BGYMV, BCMV and tolerance to low fertility trials, was released in Nicaragua as INTA Centro Sur.
- The small red bean breeding line SJC 730-79, selected at Zamorano for resistance to BGYMV, BCMV and tolerance to high temperatures, will be released by CENTA in El Salvador.
- Small red and black breeding lines were selected at Zamorano from the second cycle of recurrent selection having greater nodulation, plant growth, seed yield, and resistance to BCMV and BGYMV. The most promising lines were distributed to collaborators in Central America for field evaluation in diverse conditions. Greater nodulation in the low N field (0.08 % N), soil: sand benches (0.06% N) and plastic pouches (nodulation speed) was obtained with Rhizobium tropici (CIAT 899) and R. etli (CIAT 632).
- In collaboration with USDA-ARS FtF, 134 lines from the Andean Diversity Panel were evaluated for nodulation characteristics in pasteurized sand inoculated with Rhizobium tropici strain CIAT 899 and Rhizobium etli CIAT 632 separately. Twelve days after

inoculation lines ADP-186, -225, -302, -368, -390, -444, -456, -477 and -514 were selected for early nodulation and greater nodule number.

**Bruchid resistance**

- Rojo' backcross lines were selected in collaboration with Paul Kulsolwa at Sokoine University and Jim Myers at Oregon State University that combine resistance to bruchids [Acanthoscelides obtectus (Say)] and the I and bc-12 genes that confer resistance to BCMV and BCMNV. AO-1012-29-3-3A yielded as well as USLK-1 and 'Badillo' in trials conducted in Puerto Rico. This breeding will be considered for release as improved germplasm.
- The 'Rojo' backcross lines were used as parents to develop Andean and Middle American lines with bruchid resistance. Black and bean lines were developed that combine resistance to bruchids, the bgm-1 gene for resistance to BGYMV and the I and bc-3 genes for resistance to BCMV and BCMNV. Seed of bruchid resistant black bean lines were sent to Honduras, Guatemala and Haiti where they will be evaluated for adaptation and for resistance to local eco-types of bruchids.
- Many lines selected for bruchid resistance were found to possess the molecular markers developed by Dr. Paul Kusolwa for alpha amylase and phyto-haemagglutinin. These markers, however, did not account for all of the phenotypic variability associated with the bruchid resistance. One of the parents of the 'Rojo' backcross lines has the recessive null phaseolin allele. We are exploring, in collaboration with the USDA-ARS FtF project and Dr. Jim Myers, the possibility that the null phaseolin trait may contribute to bruchid resistance.
- As part of B.S. degree theses research projects at Zamorano, students will evaluate lines selected in Puerto Rico for bruchid resistance. The lines will be infested with Honduran ecotypes of A. obtectus and Zabrotes subfasciatus (the Mexican bean weevil). Results from this research will help to confirm that the bruchid resistance will be effective over a broad geographical region and will suppress the development of both of the genera of bruchids that can cause major postharvest losses in Central America and the Caribbean. Preliminary results indicate that the lines selected for resistance to A. obtectus are also resistant to Z. subfasciatus.

**Evaluation of bean diversity panels and identification of new sources of disease resistance**

- Project personnel were co-authors in a paper published in Crop Science entitled "A Phaseolus vulgaris Diversity Panel for Andean Bean Improvement" (Cichy et al. 2015, Crop Sci. 55: 2149-2160). Legume Innovation Lab project S01.A4 contributed lines to the ADP and collaborated in the evaluation of the ADP for several traits of economic importance.
- The Andean Diversity Panel was screened in the greenhouse at the UPR for resistance to powdery mildew. Although none of the Andean lines were immune to powdery mildew, we did observe differences among lines in severity of infection. We made individual

plants selections at the Isabela Substation in an Andean bean population that appeared to segregate for resistance to powdery mildew. The lines will be screened in the greenhouse during the upcoming year for reaction to the disease.

- The virulence patterns of Pseudocercospora griseola isolates from Honduras and Puerto Rico were studied. One isolate from Honduras was virulent to all of the ALS differential lines (race 63–63). The most virulent isolate from Juana Díaz Puerto Rico was race 63:39. This high level of virulence points to the need to pyramid genes for ALS resistance. Molecular markers SH-13 (Phg-1), SN02 (Phg-2) and E-ACA/M-CTT330 (G10474 dominant gene) were used at Zamorano for marker-assisted selection. Resistance in the field was confirmed using highly virulent races of the ALS pathogen. During the upcoming year, a small red bean line (ALS 0532-6) and a black bean line (ALS 0546-60) that combine resistance to multiple viruses (BGYMV and BCMV), high yield potential and commercially acceptable seed type will be evaluated in validation trials in Central America. ALS resistant white bean breeding lines were developed for Puerto Rico using sources of resistance from Zamorano.
- The National Seed Service in Haiti plans to screen in the field the Andean Diversity Panel for reaction to powdery mildew. Results will be used to conduct an associated mapping analysis for reaction to Erysiphe polygoni in the Andean gene pool.
- In collaboration with the USDA-ARS FtF project, association mapping of the response to Macrophomina phaseolina in the Andean Diversity Panel was conducted. Results from field screening identified a small group of lines in the ADP with resistance to ashy stem blight. Regions on Pv03, Pv09, and Pv11 were significant for charcoal rot resistance in the association mapping analysis.
- Isolates from a root rot nursery in Isabela were identified as Rhizoctonia solani (Rs), Fusarium solani (Fs) and Pythium ultimum (Pu). Inoculation tests were conducted with each fungal pathogen. Interspecific line INB 835 and TARS-LFR1 were found to be resistant to Rs. ADP 518, ADP 508 and ADP 475 were the Andean bean lines with the highest levels of resistance to Rs. Tepary beans inoculated with Fs did not develop symptoms. In contrast, common beans showed reddish lesions on the hypocotyl and browning of the tap root. The lines ADP 475, ADP 518, ADP 269 and LFR-1 had only small reddish lesions on the hypocotyl (disease scores ≤ 3). These results suggest that Rs and Fs independently produced hypocotyl and root rots.
- The Mesoamerican Diversity Panel (MDP) and a set of the Andean Diversity Panel (ADP), resistant to ALS in South Africa, were evaluated for their response to ALS in a trial at Zamorano, HN in collaboration with the FtF-USDA project. Resistant genotypes were identified for breeding efforts in both panels.
- In an attempt to identify a set differential genotypes for Macrophomina phaseolina (Mp), a screenhouse trial was established to evaluate the response of common bean, tepary and and intespecific (common bean x tepary bean) bean lines to Mp isolate Mph-01-JD. TARS- MST1, DOR-364 and BAT 477 were resistant to the isolate.

**Genetic Improvement of Tepary Beans**

- Release of tepary bean selection Tep-22 that combines resistance to common bacterial blight, rust and tolerance to heat and drought (Porch et al. 2013. J. Plant Reg. 7:358-364).
- Tepary bean breeding lines have been developed that should combine virus resistance with superior agronomic and seed traits and resistance to other diseases such as common bacterial blight and rust.
- In collaboration with the USDA-ARS FtF project, UPR graduate student Ana Vargas identified tepary bean germplasm accessions that show necrotic and resistant reactions when inoculated with the NL-3 isolate of BCMNV. BCMV and BCMNV are currently major constraints to tepary bean production.
- Recombinant Inbred Line (RIL) populations are under development to identify genes and molecular markers for this resistance. One of these RIL populations showing a necrotic response to NL3 inoculation is being genotyped using Genotyping-by-sequencing (GBS), phenotyped using visual scoring and ELISA, and QTL analysis will subsequently be completed.
- Putative early generation interspecific lines for combining BGYMV and BCMNV resistance from common bean with tepary bean have been developed and are being advanced for the evaluation of effective hybridization and for virus resistance.
- Tepary adaptation trials have been conducted in Honduras, Nicaragua, El Salvador, and Burkhina Faso.
- Through the USDA-FtF project and a USDA Postdoc, the Tepary Diversity Panel (TDP) composed of 320 accessions was developed and genotyped. The panel represents all currently available tepary accessions between the USDA and CIAT collections. This panel is being evaluated for a number of different traits including morphology, BNF, and response to NL3 inoculation.
- In collaboration with USDA-ARS FtF project, 12 Interspecific hybrid Phaseolus acutifolius/Phaseolus vulgaris INB lines were evaluated in a replicated field trial with inoculation of Bradyrhizobium USDA 3254. A noninoculated control and Nitrogen treatments were included. In addition to that a local check “Verano”, TARS-LFR1 and a non nodulator line “G51496A” were inoculated with Rhizobium tropici CIAT 899 strain. An average of 25 nodules were recorded for line INB 835 and six nodules for line INB 826. The average for line Tepary 1 was 1.5 nodules and for TARS-LFR1 26 nodules.
- Interspecific hybrids between the common bean (Phaseolus vulgaris L.) and the tepary bean (Phaseolus acutifolius A. Gray) were nodulated by different rhizobia; the slow growing Bradyrhizobium sp. and the fast growing Rhizobium spp. Elite strains of Bradyrhizobium (USDA 3254) and Rhizobium tropici (CIAT 899) were studied in their ability to nodule effectively in interspecific hybrids. The experiment was arranged in a split plot design with inoculation of the combination of both strains, a control without inoculation and a NPK treatment in the main plot. The small plot consisted of common beans: “Verano”, LFR-1, tepary bean Tep 23, Tep 32 and the Interspecific hybrids: INB-

817, INB-848, INB 817 and INB-835. The experiment was established in Juana Diaz with a population of 1 x 102 Bradyrhizobium and 1 x 104 Rhizobium per gram of soil. The experiment was replicated four times. Six weeks after sowing nodulation and plant biomass were evaluated and at maturity seed grain yield was measured. Ten nodules were isolated in Yeast-Mannitol-Agar with bromotymol blue from each treatment to differentiate bradyrhizobia and rhizobia base on growth rate and acid production. The hybrids and the common beans differed in nodule numbers from the tepary beans. More than 90 percent of the nodules that were isolated from the hybrids resulted in a fast growing rhizobia. In contrast from the tepary beans nodules the isolations were from a slow growing bradyrhizobia. The lines LFR-1, INB-809 and INB-826 were outstanding in nodule numbers. All genotypes were different from the tepary beans in nodulation. INB-809 was superior in nodulation followed by LFR-1, Verano and INB-826, INB-835, INB-848 and INB-817. The inoculated treatment was different from the NPK and the control in nodule numbers independently of the presence of soil rhizobia. Root dry weight was higher for INB-809 and LFR-1 comparing to the other genotypes. Grain weight differences among treatments suggested that inoculation increased seed yield and INB-817 was superior to the other genotypes. The nodules isolated in media produced fast growing rhizobia and produced acidity in the media that was consistent with the cultural characteristics of Rhizobium tropici.

**Development of InDel markers**

- Populations are under development at Zamorano that segregate for the dominant gene Bgp-1 that confers resistance to pod deformation in the presence of BGYMV. RILs will be phenotyped at Zamorano for pod deformation and the data will be used by Dr. Phil McClean to attempt to identify a molecular marker for this important gene for resistance to BGYMV.
- Lines selected for resistance to bruchids was sent to Dr. Phil McClean to identify candidate markers for resistance genes. They have screened ~20 markers across the APA locus on Pv04. The majority of these are InDel markers. They supplemented the InDel markers with a few SSRs that have been reported in the literature. Two putative markers have been identified at NDSU. The candidate markers will be tested to determine their effectiveness to identify lines with resistance.

## V. Research Capacity Strengthening

Legume Innovation Lab plant breeders are assisting bean research programs in Guatemala and Haiti to develop the capacity to produce populations and test breeding lines that will lead to the release of improved bean cultivars. This should contribute to the long-term sustainability of bean breeding activities in the region. The ICTA bean research team has developed populations and is evaluating bean breeding lines in the field and using marker-assisted selection to identify lines that possess the *Co-4*$^2$ allele for resistance to anthracnose. Dr. Porch provided bulk populations of black beans to Haiti to provide National Seed Service researchers with experience making field selections and managing breeding lines.

The project received Institutional Strengthening Funds to continue to support the bean research network in Central America and the Caribbean. These funds permit bean researchers in the region to attend the annual meeting of the PCCMCA where research results can be shared. The PCCMCA meeting also provides an opportunity for Legume Innovation Lab and CIAT scientists to meet with bean researchers to plan collaboration for the upcoming year. During the upcoming year the project will collaborate with INTA to commemorate the International Year of the Pulse at the PCCMCA meeting in Costa Rica.

This Legume Innovation Lab project continues to collaborate with many CRSP alumni institutions. This collaboration extends the potential impact of Legume Innovation Lab research and generates information that is valuable to the global bean research community. A few of the collaborative research activities are listed below:

- Bruchid resistance research with Paul Kusolwa at Sokoine Agricultural Univ. in Tanzania.
- Evaluation of red mottled and black bean breeding lines by IDIAF in the Dominican Republic.
- Regional performance trials (SISTEVER) in Nicaragua, El Salvador and Costa Rica.
- Evaluation of Andean and pinto bean lines and bulked breeding populations in Angola.
- Rhizobium Inoculant production in Haiti.

# VI. Human Resource and Institution Capacity Development

**Short-Term Training**

**Table 2. Summary of short-term training of Legume Innovation Lab project S01.A4 during FY15.**

| **Purpose of Training:** | Bean research techniques | Bean disease workshop | Technologies for bean seed production |
|---|---|---|---|
| Type of training | Workshop | Workshop | Workshop |
| Countries benefitting | Costa Rica, El Salvador, Nicaragua, Honduras, Guatemala, Haiti | Angola, Argentina, Brazil, Dominican Republic, Ethiopia, Kenya, Malawi, Mozambique, Puerto Rico, South Africa, Tanzania, Uganda, USA, Zambia | Costa Rica, El Salvador, Nicaragua, Honduras, Guatemala, Haiti |
| Location and dates of training | Honduras<br>April 2015 | South Africa<br>July 2015 | Honduras<br>August 2015 |
| Number receiving training (by gender) | 3F, 13M | 22F, 43M | 1F, 16M |
| Home institution(s) | Zamorano | USDA-ARS, ARC Grain Crops Institute | Zamorano |
| Institution providing training | Zamorano, UPR, USDA-ARS | Various | Zamorano, UPR |

**Degree Training**

Table 3. Summary of degree training of Legume Innovation Lab project S01.A4 during FY15.

| Name of trainee | Héctor Martínez | Iveth Rodríguez | Diego Rodríguez | Julian Colley Pabón | Ian Pizarro | Jason Rizo | Johan Gabor | José Martinez | Luis Peñate | Luis Monserrate | Henry Espinoza | Juan Nuñez | Carlos Maldonado | Lucy Lund |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country of **Citizenship** | Guatemala | Honduras | Ecuador | Puerto Rico | Ecuador | Nicaragua | Ecuador | El Salvador | El Salvador | Ecuador | Ecuador | Honduras | Guatemala | U.S. |
| Gender | M | F | M | M | M | M | M | M | M | M | M | M | M | F |
| H.C. institution | ICTA | Zamorano | INIAP | None | None | None | None | None | None | None | None | None | ICTA | None |
| Training institution | UPR | UPR | UPR | UPR | Zamorano | Zamorano | Zamorano | Zamorano | Zamorano | Zamorano | Zamorano | Zamorano | NDSU | NDSU |
| Supervising CRSP PI | J.S. Beaver | J.S. Beaver | J.S. Beaver | C. Estevez | J.C. Rosas | J.C. Rosas | J.C. Rosas | J.C. Rosas | J.C. Rosas | J.C. Rosas | J.C. Rosas | J.C. Rosas | Juan Osorno | Phil McClean |
| Degree program | M.S. | M.S. | M.S. | M.S. | B.S | B.S | B.S | B.S | B.S | B.S | B.S | B.S | M.S. | M.S. |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Field or discipline | Plant breeding | Plant breeding | Plant breeding | Plant Pathology | Plant Science | Plant Science | Plant Science | Plant Science | Plant Science | Plant Science | Plant Science | Plant Science | Plant breeding | Plant genomics |
| Research project title | Web blight resistance | Drought-heat tolerance | ALS resistance | Ashy stem blight resistance | Bruchid resistance | Low fertility tolerance | Low fertility tolerance | Races of P. griseola | Races of P. griseola | Resistance to ALS | Resistance to ALS | BNF | Resistance to anthracnose | Mol. genetics res. to bruchids |
| Start date | Aug. 2015 | Aug. 2015 | Aug. 2015 | Jan. 2015 | May 2015 | May 2015 | May 2015 | May 2015 | May 2015 | May 2015 | May 2015 | May 2015 | Aug. 2015 | July 2015 |
| Completion date | Jul. 2017 | Jul. 2017 | Jul. 2017 | Dec. 2017 | Nov. 2015 | Nov. 2015 | Nov. 2015 | Nov. 2015 | Nov. 2015 | Nov. 2015 | Nov. 2015 | Nov. 2015 | Dec. 2017 | June 2017 |
| Participant trainee and registered on TraiNet? | Yes | Yes | No | No | No | No | No | No | No | No | No | Yes | Yes | No |

## VII. Achievement of Gender Equity Goals

The development and dissemination of improved bean cultivars using conventional techniques and marker-assisted selection should produce greater or more reliable bean yields. This should contribute to economic growth and improve the lives of the families of bean producers in Central America and Haiti. The project also supports the participation of women in formal and informal training activities.

## VIII. Achievement and Progress along the Impact Pathway

**Central America**

Since the majority of bean improved cultivars used in Central America were developed with support from the Legume Innovation Lab, Zamorano continues to be the main source of genetic and foundation seed for the national research institutions, national seed systems, NGOs and farmer organizations. A bean seed production workshop was held at Zamorano in August 2015 to promote the production of breeder and basic seed.

Under the Bean Dissemination Project (2010–13) nearly 27,000 farmers received high quality seed of improved bean cultivars in Honduras, and Zamorano provide foundation seed and Rhizobium inoculant to INTA/Nicaragua, ICTA/Guatemala and NSS/Haiti. In Honduras, several Local Agricultural Research Committees (CIALs), which were involved in this project, continue producing seed using registered seed provided by Zamorano.

Under a similar approach, Zamorano continues to provide foundation seed of improved bean cultivars and *Rhizobium* inoculant to the bean technology dissemination project coordinated by MSU in collaboration with Technoserve and DICTA in Honduras.

**Haiti**

During the summer of 2015, the National Seed Service produced of seed of the multiple disease resistant black bean varieties 'XRAV-40-4', 'DPC-40' and MEN2201-64ML and the red mottled bean PR0737-1. The stationary thresher, purchased with funds from the Pulse CRSP, facilitated the harvest at Savane Zombi and generated interest among bean growers. Project funds will be used to improve seed storage facilities at Savane Zombi. Dry weather during the summer reduced seed yields.

Former collaborators in the Bean Technology Dissemination project continued to produce a significant amount of seed of improved bean cultivars in Haiti during 2015. The NGOs Zanmi Agrikol and Hands Together produced seed of DPC-40 during 2015. This seed was sold to small-scale farmers in the Central Plateau and Gonaives.

## IX. Explanation for Changes

The formal training of Carl Didier Joseph from Haiti was postponed until January 2016. This was due to delays in obtaining documents needed for admission to the UPR.

A second year of drought during the first growing season in Central America and the Caribbean significantly reduced bean yield and caused a severe shortage of seed for the second growing season. During the upcoming year, Zamorano and other bean research programs in Central America will need to increase the production of basic seed to replenish stocks for the 2016 growing seasons.

## X. Self-Evaluation and Lessons Learned

The USAID TraiNet system and the requirement for Legume Innovation Lab trainees to have J-1 visas is time consuming and complex. In addition, it also limits opportunities to match Legume Innovation lab funding with other sources of funding for training.

The second year of drought in Central America and the resulting shortage of bean seed during the second growing season highlights the vulnerability of the seed production system in the region. There may be opportunities for bean seed producers in the U.S. to serve as an alternative source of seed during years when there are shortages in Central America and the Caribbean. Dr. Phil Miklas has demonstrated that small red cultivars such as 'Amadeus 77', 'CENTA Pipil' and 'DEORHO' and black bean cultivars such as 'Aifi Wuriti' and 'DPC-40' produce good seed yields in Prosser, Washington. During the past year, Dr. Porch was invited by the PASA project in Haiti to submit a proposal to increase bean production in Haiti. One of the key components in the proposal is the production of high quality, genetically pure black bean seed in the Western U.S. during the summer months. An initial increase of the black bean cultivar 'Sankara' (XRAV-40-4) was successful.

Bean cultivars initially selected for specific traits using marker-assisted selection need to be monitored for genetic purity. It has been necessary to reselect seed of Aifi Wuriti and PR1146-138 to insure the presence of the bgm-1 allele for BGYMV resistance.

## XI. Scholarly Accomplishments

Beaver, J.S., J.C. Rosas, T.G. Porch, M.A. Pastor-Corrales, G. Godoy-Lutz and E.H. Prophete. 2015. Registration of PR0806-80 and PR0806-81 white bean germplasm with resistance to BGYMV, BCMV, BCMNV and rust. J. Plant Reg. 9:208–211.

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.

Beaver, J.S., Prophete, E., Demóstenes, G. and T.G. Porch. 2015. Desarrollo de la Línea de Frijol Amarillo PR1146-138. Paper presented at the 2015 meeting of the PCCMCA held in Guatemala City from 4 to 7 May 2015.

Bello, M. H., S. M. Moghaddam, M. Massoudi, P. E. McClean, P. B. Cregan, and P. N. Miklas. 2014. Application of in silico bulked segregant analysis for rapid development of markers linked to *Bean common mosaic virus* resistance in common bean. BMC Genomics 15:903

Buruchara, R., Estévez de Jensen, C., Godoy G., Abawi G., Pasche J., Lobo J. and Mukankusi, C. 2015. A review of the root rot diseases of common bean with emphasis in Latin America and Africa. Presentation at the Common Bean Disease Workshop on Angular Leaf Spot and Root Rot held in Skukuza, South Africa from 20 to 23 July 2015.

Chilagane, L.A, S.N Msolla, T. Porch & L.M. Serrato-Diaz. 2015. Towards genetic characterization of *Pseudocercospora griseola*, the causative agent of angular leaf spot of common bean in Tanzania. Presentation at the Common Bean Disease Workshop on Angular Leaf Spot and Root Rot held in Skukuza, South Africa from 20 to 23 July 2015.

Cichy, K.A., T.G. Porch, J.S. Beaver, P. Cregan, D. Fourie, R. Glahn, M.A. Grusak, K. Kamfwa, D.N.

Katuuramu, P. McClean, E. Mndolwa, S. Nchimbi-Msolla, M.A. Pastor-Corrales and P.N. Miklas. 2015. A *Phaseolus vulgaris* diversity panel for Andean bean improvement. Crop Sci. 55:2149–2160.

Estévez de Jensen, C., Porch, T.G. and J.S. Beaver. 2015. Evaluación de híbridos interespecíficos de fréjol tépari x fréjol común con inoculación de Bradyrhizobium y Rhizobium. Paper presented at the 2015 meeting of the PCCMCA held in Guatemala City from 4 to 7 May 2015.

Estévez de Jensen, C., T.G. Porch and J.S. Beaver and O. González. 2015. Root rots of common and tepary beans in Puerto Rico. Common Bean Disease Workshop on Angular Leaf Spot and Root Rot. Protea Kruger Gate. Skukuza, South Africa, July 20–23, USDA/ARS, Proceedings, p 48.

Kusolwa, P.M., M.W. Mwatawala, S.N. Msolla, G. Kananji, G.M. Tryphone, J.R. Myers & J.S. Beaver. 2015. Breeding for bruchid resistance into farmers' preferred common bean (*P. vulgaris*) varieties: Developments and Challenges. Presentation at the Common Bean Disease Workshop on Angular Leaf Spot and Root Rot held in Skukuza, South Africa from 20 to 23 July 2015.

Porch, T.G., S. Valentin, C. Estevez de Jensen and J.S. Beaver. 2014. Identification of soil-borne pathogens in a common bean root rot nursery in Isabela, Puerto Rico. 2014. J. of Agric. of the Univ. of Puerto Rico. 98:1–14.

Porch, T.G, Hart, J., Vargas, A., Brick, M and J.S. Beaver. 2015. Caracterización de un panel de frijol tépari (*Phaseolus acutifolius*) y su aplicación en mejoramiento de este cultivo huérfano. Paper presented at the 2015 meeting of the PCCMCA held in Guatemala City from 4 to 7 May 2015.

Porch, T., Hart. J., Estévez de Jensen, C, 2015. Response of the Andean Diversity Panel to Root Rot in a Root Rot Nursery. Common Bean Disease Workshop on Angular Leaf Spot and Root Rot. Protea Kruger Gate. Skukuza, South Africa, July 20–23, USDA/ARS, Proceedings, p 58.

Porch, T.G., Beaver, J.S., Abawi, G.A., Estevez de Jensen, C.E., Smith, J.R. 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.

Prophete, E., G. Demosthenes, G. Godoy-Lutz, T.G. Porch, and J.S. Beaver. 2014. Registration of PR0633-10 and PR0737-1 red mottled dry bean germplasm lines with resistance to BGYMV, BCMV, BCMNV, and common bacterial blight. J. Plant Reg. 8:49–52.

Rosas, J.C., I. Rodriguez, A. Llano, A. Clará, J.C. Hernandez, J.S. Beaver and S. Beebe. 2015. Resultados del SISTEVER de frijol de grano rojo. Paper presented at the 2015 meeting of the PCCMCA held in Guatemala City from 4 to 7 May 2015.

Rosas, J.C., I. Rodriguez, A. Llano, A. Clará, J.C. Hernandez and S. Beebe. 2015. Resultados del SISTEVER de frijol de grano negro. Paper presented at the 2015 meeting of the PCCMCA held in Guatemala City from 4 to 7 May 2015.

Rodriguez, J.C. Rosas, J.S. Beaver, T. Porch, S. Beebe and J.P. Lynch. 2015. Evaluación de germoplasma de frijol común para la tolerancia a las altas temperaturas. Paper presented at the 2015 meeting of the PCCMCA held in Guatemala City from 4 to 7 May 2015.

Vásquez J., Estévez de Jensen C., Ghising, K., VanderWal, M., Kloberdanz M. and Osorno J.M., 2015. Screening field resistance to the root rot complex within the Andean Diversity Panel (ADP). Presentation at the Common Bean Disease Workshop on Angular Leaf Spot and Root Rot held in Skukuza, South Africa from 20 to 23 July 2015.

Viteri, D. M., H. Terán, M. C. Asensio-S.-Manzanera, C. Asensio, T. G. Porch, P. N. Miklas, and S. P. Singh. 2014. Progress in breeding Andean common bean for resistance to common bacterial blight. Crop Sci. 54: 2084–2092.

**Professional Recognition**

Dr. Juan Carlos Rosas received the 2014 Gamma Sigma Delta Distinguished Achievement in Agriculture Award.

Dr. Juan Carlos Rosas received the 2015 AGEAP (Zamorano Alumni Association) recognition for his contributions to Pan-American agriculture and Zamorano University.

Consuelo Estevez de Jensen, received an USDA/ARS Certificate of Appreciation for outstanding efforts to characterization of bean germplasm for enhanced BNF and root rot response for Feed the Future countries in support of the Feed the Future Grain Legumes Project, South Africa, July 1 2015.

The University of Puerto Rico Bean Research Team (Consuelo Estevez, Mildred Zapata and James Beaver) received a recognition for “Outstanding Dedication and Contribution to Research and Innovation Endeavors during 2014–2015” at the Research and Innovation as Accelerators of New Opportunities in Puerto Rico symposium held in Mayaguez Puerto Rico Campus on 15 May 2015.

## XII. Data Management

A data management plan was submitted to the Legume Innovation Laboratory Management Office in July 2015. A scientist interested in using a data set generated with support from the Legume Innovation Lab should contact the PI or Co-PI responsible for generating the data set to confirm how and for what purpose the data was collected. The PI or Co-PI responsible for maintaining the data set will follow the IPR policies of their institution.

## ANNEXES

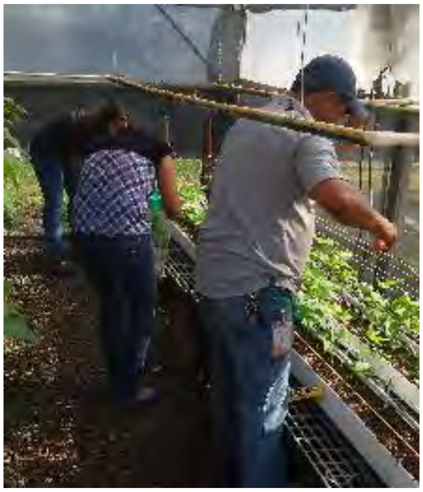
**Annex 1. Tables, Figures, and Photos Cited in the Report**

See below

**Annex 2. Literature Cited**

**None**

PVC gutter with sterilized gravel system (below left) for testing early nodulation in beans at Zamorano.



A soil:sand system (low in total N) for evaluating nodulation and BNF at Zamorano (above right). At the center, a row of plants from a nod nod line; the other rows are from lines selected for superior nodulation under a recurrent selection program.

Nodulation on a line selected at Zamorano for enhanced biological nitrogen fixation (BNF). The image on the right shows a chlorotic no-nod bean line bordered by lines selected for enhanced BNF

# Milestones

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**

**Report on the Achievement of "Milestones of Progress"**

**(For the Period: April 1, 2014 -- September 30, 2014)**

**This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2015**

***Project Title:*** Development and implementation of robust molecular markers and genetic improvement of common and tepary beans to increase grain

| | *Abbreviated name of institutions* | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | UPR | | | USDA-ARS-TARS | | | Zamorano | | | NSS-Haiti | | | ICTA | | | NDSU | | | USDA-ARS-Prosser | | |
| | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | |
| ***Milestones by Objectives*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** |
| | ***(Tick mark the Yes or No column for identified milestones by institution)*** | | | | | | | | | | | | | | | | | | | | |
| **Objective 1** | | | | | | | | | | | | | | | | | | | | | |
| **1.1 Develop and test on research stations and farms bean breeding lines that combine disease and pest resistance with greater tolerance to abiotic stress.** | x | x | | x | x | | x | x | | x | x | | x | x | | | | | x | x | |
| **1.2 Multiply and maintain breeder and foundation seed stocks of recently-released bean cultivars** | x | x | | | | | x | x | | x | x | | x | x | | | | | x | x | |
| **1.3 Regional testing of small red and black bean breeding lines in the lowlands of Central America and Haiti.** | x | x | | | | | x | x | | x | x | | x | x | | | | | x | x | |
| **1.4 Utilize recurrent selection to develop bean populations for better adaptation to low N soils and greater resistance to web blight.** | x | x | | | | | x | x | | | | | | | | | | | | | |
| **1.5 Evaluate pathogen variability and resistance to angular leaf spot, powdery mildew and web blight.** | x | x | | x | x | | x | x | | x | | x | x | x | | | | | | | |
| **Objective 2: Genetic improvement of tepary beans for Central America and Haiti.** | | | | | | | | | | | | | | | | | | | | | |
| **2.1 Pv x Pa hybrids will be completed and embryo rescue will be initiated from the BC1F1 generation material in FY15 through collaboration with the U. of Saskatchewan.** | | | | x | x | | | | | | | | | | | | | | | | |
| **2.2 The CIAT tepary bean germplasm collection will be evaluated for BGYMV in Honduras.** | | | | | | | x | x | | | | | | | | | | | | | |

# Milestones, continued

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.3 Collaborators in Central America and Haiti will initiate testing of breeding lines in Tepary Adaptation Trials (TAT) to test wide adaptation as well as specific adaptation of lines to specific potential growing areas. | | | | | | | x | x | | x | x | | x | x | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Objective 3: Develop and implement robust molecular markers for disease resistance genes** | | | | | | | | | | | | | | | | | | | | | |
| **3.1 Populations will be developed for subsequent identification of improved markers for BGYMV, BCMNV, BCMV and rust.** | x | x | | x | x | | x | x | | | | | | | | | | | x | x | |
| **3.2 Investigate efficacy of available markers for bruchid resistance genes (Arc2, Arl3, PHA and aAI3).** | x | x | | x | x | | | | | | | | | | | | | | | | |
| **3.3 Establish background information for marker development disease resistance through conducting association mapping analysis.** | | | | x | x | | | | | | | | | | | x | x | | x | x | |
| **3.4 Evaluate the genetics of web blight resistance through conducting association mapping analysis** | x | x | | x | x | | | | | | | | | | | x | x | | | | |
| **3.5** | | | | | | | | | | | | | | | | | | | | | |

# Milestones, continued

| | | | | | | | | | | | | | | | | | | | | | |
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| **Objective 4: Institutional capacity building** | | | | | | | | | | | | | | | | | | | | | |
| **4.1 In-service training will be provided at NDSU for two Legume Innovation Laboratory scientists to review recent advances in sequencing the bean genome and the utilization of SNP arrays to develop indel markers for traits of economic importance.** | | | | | | | | | | | | | | | | x | | x | | | |
| **4.2 Workshops will be held in Honduras to train technical personnel concerning bean research techniques with the goal of improving the quality of field research and the capacity to produce high-quality seed.** | | | | | | | x | x | | | | | | | | | | | | | |
| **4.3 Undergraduate students at Zamorano will be provided opportunities to participate in bean research activities related to Legume Innovation Lab project objectives.** | | | | | | | x | x | | | | | | | | | | | | | |
| **4.4 M.S. degree training at the UPR for Iveth Rodriguez (Honduras) and Hector Martinez (Guatemala)** | x | x | | | | | | | | | | | | | | | | | | | |
| **4.5 Ph.D. degree training at NDSU of two bean researchers from Central America or the Caribbean** | | | | | | | | | | | | | | | | x | x | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Name of the PI reporting on Milestons by institution** | James S. Beaver | Timothy G. Porch | Juan Carlos Rosas | Emmanuel Prophete | Julio Cesar Villatoro | Phil McClean | Phil Miklas |

| | |
|---|---|
| **Name of the U.S. Lead PI submitting this report to the MO** | James S. Beaver |

**Signature** **Date**

# Performance Indicators

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**
**REVISED PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 15, FY16, and FY 17**

**Project Name: S01.A4**

**Summary of all institutions**

| Indic. numbe | Output Indicators | FY 15 Target | FY 15 Revised | FY 15 Actual | FY 16 Target | FY 16 Revised | FY 16 Actual | FY 17 Target | FY 17 Revised | FY 17 Actual |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (October 1, 2014 - September 30, 2015) | | | (October 1, 2015 - September 30, 2016) | | | (October 1, 2016 - September 30, 2017) | | |
| 1 | 4.5.2(6) Number of individuals who have received USG supported long-term agricultural sector productivity or food security training | 7 | 8 | 13 | 10 | 10 | 0 | 9 | 9 | 0 |
| | Total number by sex | 7 | 8 | 13 | 10 | 10 | 0 | 9 | 9 | 0 |
| | Number of women | 3 | 3 | 2 | 2 | 2 | 0 | 3 | 3 | 0 |
| | Number of men | 4 | 5 | 11 | 8 | 8 | 0 | 6 | 6 | 0 |
| | Total number by New/continuing | 7 | 8 | 13 | 10 | 10 | 0 | 9 | 9 | 0 |
| | Number of new | 5 | 6 | 13 | 7 | 7 | 0 | 6 | 6 | 0 |
| | Number of continuing | 2 | 2 | 0 | 3 | 3 | 0 | 3 | 3 | 0 |

## Performance Indicators, continued

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **2** | 4.5.2(7) Number of individuals who have received USG supported short-term agricultural sector productivity or food security training | 65 | 65 | 63 | 73 | 73 | 0 | 75 | 75 | 0 |
| | Total number | 65 | 65 | 63 | 73 | 73 | 0 | 75 | 75 | 0 |
| | Number of women | 21 | 21 | 15 | 29 | 29 | 0 | 31 | 31 | 0 |
| | Number of men | 44 | 44 | 48 | 44 | 44 | 0 | 44 | 44 | 0 |
| | Numbers by Type of individual | 65 | 65 | 63 | 73 | 73 | 0 | 75 | 75 | 0 |
| | Producers | 30 | 30 | 17 | 37 | 37 | 0 | 39 | 39 | 0 |
| | People in government | 23 | 23 | 37 | 24 | 24 | 0 | 24 | 24 | 0 |
| | People in private sector firms | 12 | 12 | 9 | 12 | 12 | 0 | 12 | 12 | 0 |
| | People in civil society | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **3** | 4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III) | 115 | 115 | 139 | 109 | 109 | 0 | 105 | 105 | 0 |
| | Phase 1: Number of new technologies or management practices under research as a result of USG assistance | 65 | 65 | 84 | 61 | 61 | 0 | 60 | 60 | 0 |
| | Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance | 37 | 37 | 42 | 34 | 34 | 0 | 31 | 31 | 0 |
| | Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance | 17 | 17 | 17 | 18 | 18 | 0 | 19 | 19 | 0 |

**Notes:**

These indicators are developed under the Feed the Future Monitoring System. Please provide 'total' numbers and also disaggregate where applicable. Just providing 'totals' will not be approved.

This table corresponds to the Feed the Future Performance Indicators data collection sheet under the FTFMS system. Where an indicator does not apply to the type of work done under the project, leave it blank.

Please follow the indications in the Legume Innovation Lab Indicators Handbook that will be provided to you by the Management Office. Contact Mywish Maredia (maredia@anr.msu.edu) for further information.

There is additional guidance on the USAID/Microlinks website: http://agrilinks.org/sites/default/files/resource/files/FY14%20FTFMS%20Guidance_2.pdf

The spreadsheet had errors withotu entering 0 values in some places. Thus you will need to change 0 to actual values where needed.

# Genetic improvement of cowpea to overcome biotic stress and drought constraints to grain productivity (SO1.A5)

### Lead U.S. Principal Investigator and University
Philip A. Roberts, University of California, Riverside, CA 92521

### Collaborating Host Country and U.S. PIs and Institutions
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Benoit Joseph Batieno & Issa Drabo, Institut de l'Environment et des Recherches Agricole (INERA), Koudougou and Kamboinse, Burkina Faso
Francis Kusi & Ibrahim Atokple, Savanna Agricultural Research Institute (SARI), Tamale, Ghana
Ndiaga Cisse, Centre National Recherches Agronomie, Bambey, Institut Senegalais de Recherches Agricole (ISRA) & CERAAS, Thies, Senegal

## I. Abstract of Research Achievements and Impacts
A panel of cowpea accessions was used with uniform test protocols for field and screenhouse testing to characterize resistance to aphids and to identify cowpea aphid biotypes in three African and one US locations. Cowpea populations segregating for insect resistance (pod bugs, Burkina Faso; flower thrips, Ghana and Senegal; aphids, Ghana and California) were advanced, phenotyped and genotyped for QTL discovery for use in marker-assisted breeding. Five large white-seeded CRSP cowpea varieties were formally released in Senegal under the names Lisard, Thieye, Leona, Kelle and Sam after multiyear on-farm demonstration trials, and Breeder and Foundation seed produced and distributed to farmers' organizations. In Burkina Faso 4 pre-release CRSP cowpea lines were selected from on-farm trials and on-station Breeder seed produced in anticipation of their release as improved varieties in 2016. In California, advanced lygus and disease resistant blackeye lines were on-farm and on-station performance tested. Five African students engaged in degree training programs (3 PhD, 2 MS) in the project. Capacity strengthening awards from the MSU management entity supported development of screenhouses, an irrigation system (Ghana and Burkina Faso) and cowpea seed storage (Senegal). Continuous short-term training occurred through iterative data analysis and interpretation cycles using the phenotype and genotype data from each Host Country. A training/planning workshop in 2015 at UCR for scientists from Ghana, Senegal, Burkina Faso, Nigeria, and Mozambique utilized molecular breeding modules.

## II. Project Problem Statement and Justification
The project focus is to 1) discover insect tolerance and resistance QTL for cowpea breeding; 2) increase African and US cowpea productivity by improved varieties with resistance to insect stresses, drought tolerance or disease resistance; 3) expand farmer marketing opportunities with improved cowpea varieties; and 4) provide training and capacity building in modern cowpea breeding. The project is aligned with FTF research strategic priorities 1) crop resistance to heat, drought, salinity and flood; 2) West African Sudano–Sahelian systems emphasizing insect-resistant cowpea; and 3) grain legume productivity. Strategically, our partner countries Ghana, Senegal and Burkina Faso represent primary agroecologies for cowpea production in the Sudano–Sahel.

The project uses genomics and modern breeding to improve cowpea yield by targeting insect tolerance and resistance. By leveraging genomic resources developed with CGIAR Generation Challenge Program and USAID Climate Resilient Cowpea Innovation Lab funding, we apply comprehensive modern breeding tools. Insect pests constrain cowpea productivity in West Africa; the project targets insects attacking early (aphids), midflowering and pod-set (flower thrips), and later pod-filling (pod-sucking bugs) cowpea stages. Discovery work through phenotyping, genetic mapping and QTL identification needs to be done for these insect pests, using high throughput SNP genotyping, genetic maps, and QTL discovery. The project breeding programs have early generation populations with target traits, providing valuable starting points for breeding.

Low productivity of agriculture is central to rural and urban poverty in Africa. On-farm cowpea yields in West Africa average 240 kg/ha, even though potential yields are often five to ten times greater. Most of the loss in yield potential is due to drought, poor soil fertility, and insect pests. By targeting insect tolerance and combining with drought tolerance, cowpea productivity, food security and rural incomes can be increased. To increase marketing options, new cowpea varieties must have features desired by consumers: grain appearance, cooking and processing characteristics. Regionally adapted cowpea varieties with large white grain and large rough brown grain with resistance to pests would increase the marketing opportunities of cowpea farmers and traders in both West Africa and the US.

## III. Technical Research Progress

**Objective 1. Discover QTL for insect resistance and apply in molecular breeding for target regions in West Africa and the US**

***1.1 Aphid resistance***. We are testing the genetic relatedness of five sources of cowpea aphid (*Aphis craccivora*) resistance. Field observations in Africa and California indicate differential effects of resistance sources on aphid populations from different cowpea production areas. Cowpea lines IT97K-556-6, KvX295-2-124-99, an IITA wild donor line (TVNu1158), UCR01-11-52/SARC1-57-2, and 58-77 representing a set of resistance donor genotypes plus known susceptible control lines were seed-multiplied in 2014 and again in 2015. The panel is shown in Table 1. Uniform screens in field locations across all project NARS (Burkina, Ghana, Senegal) and California were conducted in 2014 in field plots or in screenhouses, with four-fold replication, using standard resistance assessment scales across all test sites. The uniform test design and coordination planning for the aphid resistance assessment was developed by the project team in FY13 – FY14. Additional germplasm lines were included in the screening sites to search for more sources of resistance. This multisite phenotype screening for resistance response was repeated in FY15, following additional seed increases in NARS and UCR, to provide a minimum of 2 years of data. The resistance donors and susceptible controls were SNP genotyped in FY14, coordinated by UCR. More seed of TVNu1158 was produced at UCR because of problems with this wild accession in the NARS. In 2015 in Senegal because of a wet season with heavy rain, the aphid population did not become established enough with uniform infestation in the field to discriminate between genotypes. However, enough seeds were produced for later experimentation. In Ghana, the seedling stage screening of the aphid resistance panel at SARI found IT97K-556-6, KvX-295-2-124-99, SARC-1-57-2, 58-77 and CB27 to be resistant to the cowpea aphids in northern Ghana (see Figure 1). In testing the mode of inheritance and the genetic relatedness of these lines, F1 populations have been developed between each of these lines with Apagbaala (aphid susceptible popular variety in Ghana) and in addition, each of these lines found to be resistant has also been crossed to each other. These populations are currently being advanced to the F2 at SARI. They will be genotyped and phenotyped to determine the mode of inheritance of the source of aphid resistance in each of the resistant lines and to determine the uniqueness of the aphid resistance gene(s) in each of these lines.

We are working with Dr. B. Pittendrigh and M. Tamo (Project SO1.B1) in the characterization (molecular fingerprinting) of the aphid isolates representing the different aphid populations at each location. This will be especially valuable if, as expected, aphid biotypes are delineated on the cowpea resistance sources. Samples of aphids were collected and stored for DNA extraction, with a view to developing a DNA sequence based fingerprint to distinguish the isolates. For example, in Burkina Faso, aphids were collected from Kamboinse, Pobe-Mengao and Farako-Ba representing three diverse cowpea production zones. New segregating populations and some existing ones between aphid resistant and susceptible parents will be used to phenotype screen for QTL discovery. Depending on the source, we are at different stages of QTL mapping. We finished a QTL discovery effort for aphid resistance in IT97K-556-6, identifying two resistance QTL. In Ghana we have an F7 population between a susceptible elite line and resistance donor KvX295-2-124-99. This population has been genotyped and phenotyped in FY15 for QTL mapping (see section 1.2). From the wild donor IITA line TVNu1158 a RIL population has been developed for mapping QTL and is currently being genotyped using the 60K SNP iSelect by UCR. This work is being conducted in collaboration with Drs. Fatokun and Boukar at IITA, Nigeria.

***1.2 Flower thrips resistance***. In recent work on QTL discovery, we identified and SNP-mapped loci (*Cft-1* and *Cft-2*) for flower thrips (*Megalurothrips sjostedti*) tolerance donated by Sanzi in the cross Sanzi x Vita 7, and these loci are promising for introduction and selection in breeding progenies but require better definition through phenotyping. Additional sources of thrips tolerance are 58-77 (biparental RIL population from 58-77 x Yacine is available) and Tvx3236. In Senegal, the populations 58-77 x Yacine and Sanzi x Vita 7 were field-screened for flower thrips tolerance with two planting dates at Bambey. Because of insufficient seed quantity for multilocations, the trials were conducted at Bambey only. Field-phenotyping for tolerance to flower Thrips uses the Jackai and Singh (1988) tolerance scale. Screens were designed as a 3-replication (Bambey) RCBD and included the parents, and run by entomologist Ibrahima Sarr. In Senegal the different tolerance sources in Sanzi, 58–77 and Tvx3236 were intercrossed in all combinations by Dr. Cisse in FY14 and each of these populations was advanced to the F3 in FY15. For breeding purposes, the F1 of Sanzi x 58-77 was crossed to Yacine and to the new large seeded varieties ISRA-3178 and ISRA-3217. Also M3 generations of Yacine generated through mutagenesis were evaluated under a no-spray nursery at Bambey for flower thrips reaction. Selections were made between and within families. At SARI, Ghana, Dr. Kusi received seed in FY15 of the two RIL populations, Sanzi x Vita7 and Yacine x 58-77 from Senegal to be phenotyped for QTL refinement for flower thrips tolerance. Given the limited seeds per line received, the populations were planted to increase the seeds and so the thrips phenotyping was not vigorously carried out. Each of the lines in the populations was flower-sampled at 7 days after insecticide spray to generate preliminary data to have a fair assessment of the lines for thrips tolerance. Field preparation is currently in progress to plant the populations under spray and nonspray conditions for vigorous thrips tolerance phenotyping. The aim is to combine the phenotyping data sets from Senegal and Ghana for improved QTL mapping of the thrips tolerance loci.

In Ghana, three Sanzi-derived F7 populations segregating for seed color (including white) and flower thrips resistance are being evaluated for QTL discovery and breeding. One parent is IT97K-499-35, now the popular Ghana variety ‘Songotra’, a high yielding black-eye resistant to Striga but thrips sensitive which can be improved for thrips tolerance via the F7 population. A second parent is SARC1-57-2, which carries aphid resistance. The SARI team is phenotyping these populations using the previously described experimental protocols. The 280 single-seed derived F7 families were leaf sampled and the samples sent to UCR where they were DNA-extracted and sent for SNP genotyping using the Illumina iSelect platform. The seeds produced from each of the single-seed descent plants were phenotyped for both flower thrips and Striga resistance. The populations have now been classified into individuals that recorded Striga emergence on the field and those that did not record Striga emergence. The individuals that did not record a single Striga emergence are currently been prepared for screening in pots infested with Striga seeds to validate the field results by washing the root to check if there was no attachment underground. The thrips phenotyping was not vigorously done because we also wanted to produce more seeds. Therefore, each family was flower-sampled at 7 days after insecticide spray to generate preliminary data on assessment of the lines with thrips resistance. Now with enough seeds available, the populations are being prepared to be planted under spray and nonspray conditions for vigorous thrips phenotyping at Tamale and Manga. These data will be used with the SNP genotyping for QTL mapping. As part of the project effort to offer training opportunities to scientists and technicians, a postgraduate student from Kwame Nkrumah University of Science and Technology has been engaged on this work for his MS thesis.

***1.3 Pod-sucking bug resistance***. The Heteropteran Coreid pod-sucking bugs (*Clavigralla tomentosicollis* complex) are a major yield suppressor in Burkina Faso, Ghana and neighboring countries. We have not yet identified genes or QTL for resistance to pod-sucking bugs but resistant cowpea accessions are available. We started to use biparental resistant x susceptible segregating populations in FY14 to map QTL and initiate their selection as a new breeding target. This work is a focus of effort in Burkina Faso. A primary tolerance source is IT86D-716 (used in Burkina Faso); pods on F2 plants were phenotyped in FY15 to identify the underlying QTL, using standard screens of young pods in petri dishes to score bug viability and fecundity. The 2014 screening was not successful because of poor germination of the first set of F3 seeds. New recombinations were then made in 2015. Four different F2 and BC1F1 populations are available. The rephenotyping is planned for February 2016. The phenotyping will be repeated by July 2016 to provide validated QTL mapping data. Additional potential tolerance donor lines were included in the initial phenotyping screens in FY14, including those in the pedigree of resistance donor IT86D-716, to broaden the knowledge base and potentially identify additional sources of tolerance. Two existing F2 populations generated from resistance donor IT86D-716 with parents Kvx771-10G (Nafi), Tiligre, Gourgou, and IT98K-205-8 enable combining Striga resistance with pod-sucking bug tolerance. The parents have been genotyped through LGC Genomics and the F2 and F3 populations will be phenotyped in FY16 for pod bug resistance in Burkina Faso, in collaboration with Dr. Dabire. Using leaf samples collected from phenotyped plants in Burkina Faso, single F2 plants and F3 family bulks consisting of a minimum of 12 individual plants will be genotyped. The phenotype and genotype data from the F2 and F3 generations will be used for QTL discovery with the ICI Mapping program, which will be conducted at UCR.

For the three insect groups (aphids, thrips, pod bugs), we collaborated with Dr. Pittendrigh and Dr. Tamo (Project SO1.B1) to utilize our project trial sites to collect insect samples for use in molecular characterization of the insect populations. Collections will be made at all test locations, thereby allowing a robust comparative profiling of insect populations. We have tested a protocol for insect DNA collection, in which insects are placed in plastic bags with silica gel packs; this dries the insect samples and preserves the DNA. Tests on aphid DNA with primers for the COX1 gene demonstrated excellent DNA integrity. In Burkina Faso, pod bugs were collected from Kamboinse, Pobe-Mengao and Farako-Ba.

**Objective 2. Complete release and validation of advanced cowpea lines developed under the Pulse CRSP in Burkina Faso, Senegal, and US**

***2.1.*** We continued to use our genotyping capability to advance the BT gene introgression for Muruca resistance with our SNP marker panel. Genotyping was initiated in FY14 primarily focused on background selection with genome-wide markers in segregating progeny of backcross breeding populations in Burkina Faso and Ghana. The goal is to expedite the selection of lines with the highest percentage of elite recurrent parent content in each country (e.g., improvement of elite variety IT97K-499-35 in Ghana and several elite local varieties in Burkina Faso, including Moussa Local, Gourgou 3, 7 and 11, IT98K-205-8 and KVX 745-11P). In Burkina Faso BC3 were genotyped in FY14. In FY15, populations were advanced to the BC3F5 and BC5F3 stages and leaf samples were collected and are awaiting SNP genotyping. In FY15, trials were conducted at three locations for agronomic performance and also a single-site trial was conducted under insect net protection for resistance efficacy of the introgressed lines. The genotyping on sampled plants determined those carrying resistance with the highest level of recurrent parent genotype. Ghana BC2 progenies from FY14 were advanced in FY15 and leaf-sampled for SNP genotyping on the next generation of breeding lines. The phenotyping of the breeding lines for Maruca is being done in the host countries with funding from USAID through African Agricultural Technology Foundation (AATF). The Ghana and Burkina Faso breeders received extensive hands-on training at UCR in March 2014 and were trained further in March 2015 using their own datasets under this objective. The genotyping mostly followed the same general protocol as outlined under the Objective 1 work. Leaf samples from young screenhouse grown plants in the phenotyping and crossing blocks were used for DNA extraction in Burkina Faso and Ghana, and then SNP assayed by LGC Genomics (KASP). The genotype data were analyzed for molecular scores using Backcross Selector software.

***2.2.*** We are capitalizing on the previous Pulse CRSP breeding effort by completing the release requirements of several advanced breeding lines that are in the final stages of performance testing in Burkina Faso, Senegal and California.

In Senegal, five large white grain type cowpeas (at least 25 g /100 grains) developed by Dr. Cisse were submitted as candidates for release by the national variety release committee in FY14. These were performance tested in 20 on-farm demonstration trials in main season FY13, and the data combined with performance data from 2011 and 2012 to support the formal release. The demonstration trials were conducted in the northern cowpea zone (Louga, Mekhe, Thilmakha). In 2015 the five new lines, ISRA-3178, ISRA-3201, ISRA-3205, ISRA-3211 and ISRA-3217, were registered, respectively, as the new varieties Lisard, Thieye, Leona, Kelle and Sam. These are names of locations where the demonstration trials were conducted. Additional Breeder and Foundation seeds were produced during the 2015 off-season on 2000 $m^2$ for each variety; about 500 kg of seeds for each variety were obtained. Seeds were provided to several farmers' organizations (RESOPP, PAFAL, Millennium project, among others) and to the extension service (ANCAR) for large-scale demonstration to generate demand and also for Certified seed multiplication.

In Burkina Faso, 20 prerelease CRSP advanced lines developed by Dr. Drabo were on-farm performance tested in 2013, and a subset of the best nine lines were re-evaluated in 2014. Multilocation tests were conducted at Saria, Pobe, and Kamboinse in Burkina Faso during the 2015 main rainy season. The four best performing of the nine lines plus two standard checks were used for testing and will be re-evaluated off-season in FY16 (October 2015–April 2016), emphasizing yield and grain quality, plus any disease susceptibility. Trial design was based on using 4-row plots, 5 m long and 4 reps arranged in a RCBD. The release petition to the national variety release committee scheduled for mid-FY15 had to be delayed, with rescheduling planned for FY16. Breeder seed of the best lines chosen for release submission based on main season 2014 and 2015 and off-season 2015 performance data was produced at Saria during the main season 2015 (June–October). About 20 kg of Breeder seeds of each of these lines is now available at the INERA Saria Station, and will be used to initiate Foundation seed production in the FY16 off-season.

In California, advanced breeding lines were field tested for release potential, based on performance data collected in previous on-station trials. These represent CRSP developed lines that carry a combination of lygus bug tolerance, and root-knot nematode and Fusarium wilt resistance. For the best advanced blackeyes from 2013, we conducted on-farm yield trials in a Tulare Co. farmer's field and on-station trials at the UC Kearney Station, Fresno Co., in main season 2014 (harvested in October to November 2014) to assess commercial yield performance. Seed size and yield data from the trials are presented in Tables 2 and 3, together with field assays conducted for resistance to three common root-knot nematode species and a greenhouse assay for resistance to Race 4 of Fusarium wilt. The eleven lines plus the standard variety CB46 were tested under insect-protected conditions (Table 2), while a no-insecticide unprotected versus insecticide protected split-plot lygus screening trial was conducted with three lines with lygus bug tolerance. The test design was a four-row fourfold replicated RCBD or split-plot trials with the center two rows machine harvested. Yield weights, 100-seed weights and lygus damage to seed were assayed. All yield and performance data were analyzed by standard ANOVA. Lygus pressure was heavy but arrived late in 2014, resulting in grain yield loss of between 10% and 30% in comparisons between protected and unprotected conditions. The experimental lines had significantly higher protected yield than CB46 indicating they have high innate yield potential. However, the insecticide protection was unable to keep up with the late season lygus attack and this also contributed to the relatively lower yield of CB46 in protected plots. The unprotected yields were significantly higher than CB46 for all three advanced lines, indicating strong yield ability under lygus pressure. From the 2014 trials, we chose the most promising lines (combination of yield, seed quality and resistance) for performance testing in the 2015 main season. These trials were planted in May 2015 in Tulare Co. with four lines (CB46, N2, 10K-29, CB46Rk2) in large 0.5 acre field-length 6-row strips (harvested October 2015), and June 2015 at the Kearney station with five lines (CB46, N2, 10K-29, CB46Rk2, 07KN-74) in four-extended row fourfold replicated RCBD. Harvesting, threshing and seed cleaning is underway at time of reporting.

The Senegal and Burkina Faso releases will represent tangible project outputs, and offer the opportunity for tracking along the impact pathway as new releases that will be entering the seed multiplication and distribution process in each country. During the 2015 main rainy season each of the five new releases were multiplied on 0.5 ha for additional Foundation seed production. The resulting products will be provided to Certified seed producers including new farmer organizations for increase and demonstration in 2016. Opportunities exist to initiate baseline data for the releases through impact analyses under the LIL project led by Dr. Maredia.

**Objective 3. Increase capacity of NARS in Burkina Faso, Ghana and Senegal to serve the cowpea sector.**

***Short-term Training***. Molecular breeding for young trainee breeders and NARS scientists has been conducted. Continuous short-term training occured through iterative data analysis and interpretation cycles using the phenotyping and genotyping data generated by each of the three Host Country partner teams (about 12 participants). To provide periodic intensive training, we convened a training workshop in March 2015 at UCR, using training modules developed by the UCR team and by the CGIAR GCP Integrated Breeding Platform program (IBP) Breeding Management System (BMS). The IBP-BMS is using our tropical legumes project cowpea breeding population data for the training modules development. We conducted our first breeding workshop in FY14 at UCR with great success, and used the same format for the workshop at UCR in FY15 (March 23–27, 2015). The molecular breeding approach is complex and requires a combination of hands-on experience with self-generated data sets, augmented with periodic intensive training workshops to improve knowledge, skills and problem-solving. The technologies underlying the genotyping capability are in a state of frequent enhancement and upgrade, requiring periodic training input. Thus both young breeder trainees new to the programs and experienced breeders from the HC NARS are in need of this training. Training materials and protocols used by the NARS breeders were also used to train the technical staff in the NARS programs after NARS breeders had been trained further on the standardized electronic fieldbook, leaf assay, and field phenotyping protocols.

***Degree Training***. We conducted degree training for two graduate students in the report period at UCR and three in Africa, one with each of the three HC PIs in Burkina Faso, Ghana and Senegal. The trainees are described in detail under Section VI 2.

# IV. Major Achievements

**Under Objective 1.1: Aphid resistance**

A differential cowpea panel of aphid resistance sources and control lines was seed-multiplied and used in multilocation field screening and screenhouse seedling screening during FY15. Using a uniform test protocol for aphid biotype and resistance screening under field and greenhouse conditions, several aphid resistance sources effective against both US and West African aphid populations were identified. These protocols will enable direct comparisons of aphid populations from the West Africa and U.S. target cowpea breeding areas. Sets of F1 and F2 populations were made from aphid resistant x drought tolerant line crosses at SARI, Ghana.

Advanced backcross progenies were developed by adding aphid resistance QTLs into recurrent parents CB27, CB46 and CB50 and field tested, to select for California blackeyes with aphid resistance for the US production system.

**Under Objective 1.2: Flower thrips resistance**

Segregating populations were developed in Senegal and Ghana from mutagenesis or from natural crosses using three sources of thrips resistance. These are in various stages of phenotyping and genotyping for QTL mapping.

**Under Objective 1.3: Pod bug resistance**

Four segregating populations were developed in Burkina Faso for use in QTL mapping for pod bug resistance.

**Under Objective 2.2: Variety releases**

Formal release of five large white-seeded CRSP cowpea varieties was completed in Senegal following final performance testing in on-farm trials and Foundation seed of each variety was produced by ISRA and distributed to Farmers' organizations for Certified seed development. The varieties were released under the names Lisard, Thieye, Leona, Kelle and Sam, which represent the names of the main on-farm testing locations.

Nine prerelease CRSP advanced cowpea lines were evaluated in Burkina Faso in 20 on-farm trials in 2014 with farmers helping in Participatory Variety Selection (PVS). The four best-performing lines were re-evaluated in multilocation tests at Saria, Pobe, and Kamboinse during the 2015 main rainy season and are being retested in the off-season in FY16 (October, 2015 – April, 2016), emphasizing yield and grain quality, plus any disease susceptibility. The release petition to the national variety release committee has been rescheduled for FY16. Breeder seeds of each of these lines were produced at the INERA Saria Station to initiate Foundation seed production in the FY16 off-season.

Five African students have engaged in degree training programs within the project, including three PhD and two MS students. The project was awarded Capacity Strengthening awards from the MSU management entity, which were used for the development of screenhouses for SARI, Ghana and INERA, Burkina Faso, cowpea seed cold storage for ISRA, Senegal, and off-season field irrigation for INERA, Burkina Faso. These capacity projects were completed and in service by Summer 2015 (see Section V).

# V. Research Capacity Strengthening

Approval through the LIL was granted to fund renovation of the 1960's cold room used for seed conservation at the ISRA Bambey research station, Senegal to insure adequate temperature and humidity required for cowpea germplasm conservation. The necessary equipment and its installation were completed in FY15. Approval through the LIL was granted to fund INERA, Burkina Faso breeding activity enhancement at Kamboinse research station by developing an irrigated field for off-season activities (crosses, advancing lines, breeder seed production). This system was completed in FY15 and now a one-ha plot is being managed following implementation of the new drip-irrigation system. Approval through the LIL was granted to fund INERA, Burkina Faso to renovate one screenhouse at Kamboinse Research Station and a second screenhouse at Saria Research Station. The renovations were completed in FY15 and the screenhouses provide prevention of outcrossing during crossing and to advance breeding lines under protection from insect, rodent and rabbit damage. Approval through the LIL was granted to fund a screenhouse at SARI, Ghana to enhance successful crosses and multiplication of breeder seeds during the harmattan period. The facility includes a 16 m x 8 m screenhouse fitted with a 500-gallon poly-tank reservoir for supply of water, a metal frame covered with insect proof net and a polythene sheet for sealing the roof to prevent rain, and benches 80 cm to 1 m high for growth containers. The construction was completed during FY15 and has been in use since summer 2015.

# VI. Human Resource and Institution Capacity Development

**1. Short-Term Training**

***Short-term 1***

**Purpose of Training.**. The molecular breeding approach is complex and requires a combination of hands-on experience with self-generated data sets, augmented with periodic intensive training workshops to improve knowledge, skills and problem–solving. The technologies underlying the genotyping capability are in a state of frequent enhancement and upgrade, requiring periodic training input. Thus both young breeder trainees new to the programs and experienced breeders from the HC NARS are in need of this training.

**Type of Training**. Continuous short-term training occurred in FY15 through iterative data analysis and interpretation cycles using the phenotyping and genotyping data generated by each Host Country partner team. To provide periodic intensive training, we convened a training/planning workshop in March 2015, using molecular breeding training modules developed by the UCR team, or developed by the CGIAR GCP Integrated Breeding Platform (IBP) Breeding Management System (BMS), which uses our tropical legumes project cowpea breeding population data for the training modules.

**Countries** Benefitting**:** Ghana, Senegal, Burkina Faso, Nigeria, Mozambique
**Location and Dates of Training:** March 23–27, 2015, UC–Riverside
**Number receiving training (by gender):** 12 African scientists/students
(11 male; 1 female; a second Ghana female was denied a visa to attend).
**Home institutions:** ISRA, SARI, INERA, Ahmadu Bello U., WACCI, IITA, UCR.
**Institution providing training or mechanism:** UC Riverside

***Short-term 2***

**Purpose of Training:** Cowpea production and seed storage techniques
**Type of Training:** 2 days intensive field-based training
**Country Benefitting:** Burkina Faso
**Location and Dates of Training:** Saria 17–18 October 2014; Pobe 21–22 October 2014

**Number receiving training (by gender):** 45 ladies and 70 men
**Home Institution(s) (if applicable):** INERA
**Institution providing training or mechanism:** INERA

**2. Degree Training**

***Trainee 1:***
**Name of trainee:** Arsenio Ndeve
**Country of Citizenship:** Mozambique
**Gender:** Male
**Host Country Institution Benefitting from Training:** Eduardo Mondlane University
**Institution Providing Training:** University of California – Riverside
**Supervising LIL PI:** Philip A. Roberts & Timothy Close
**Degree Program:** PhD, Plant Pathology
**Field or Discipline:** Plant pathology and genetics
**Research Project Title:** Genomewide selection for disease and drought tolerance in SE African cowpeas
**Start Date:** January 2012
**Projected Completion Date:** December 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

***Trainee 2***
**Name of trainee:** Sassoum Lo
**Country of Citizenship:** Senegal
**Gender:** Female
**Host Country Institution Benefitting from Training:** ISRA
**Institution Providing Training:** University of California – Riverside
**Supervising LIL PI:** Philip A. Roberts & Timothy J. Close
**Degree Program:** MS initially, now PhD, Plant Genetics
**Field or Discipline:** Plant breeding and genetics
**Research Project Title:** MABC for enhanced seed size in cowpea
**Start Date:** March 2014
**Projected Completion Date:** June 2018 (projected)
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

***Trainee 3***
**Name of trainee:** Mame Penda Sarr
**Country of Citizenship:** Senegal
**Gender:** Female
**Host Country Institution Benefitting from Training:** ISRA
**Institution Providing Training:** University of Dakar (UCAD)
**Supervising LIL PI:** Ndiaga Cisse
**Degree Program:** PhD

**Field or Discipline:** Plant Pathology
**Research Project Title (if applicable):** Genetic diversity and temporal dynamics of Macrophomina phaseolina.
**Start Date:** 2010
**Projected Completion Date:** December 2014 (completed)
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Completed

***Trainee 4***
**Name of trainee:** Joel Lalsaga
**Country of Citizenship:** Burkina Faso
**Gender:** male
**Host Country Institution Benefitting from Training:** Burkina Faso
**Institution Providing Training:** INERA
**Supervising CRSP PI:** Issa Drabo and Joseph Batieno
**Degree Program:** PhD program at the University of Ouagadougou
**Field or Discipline:** Plant breeding
**Research Project Title (if applicable):**
**Start Date:** 2014 (field research)
**Projected Completion Date:** Dec. 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

***Trainee 5***
**Name of Trainee (First and Last Name):** Emanuele Yaw Owusu
**Country of Citizenship:** Ghana
**Gender:** male
**Host Country Institution Benefitting from Training:** Ghana
**Institution Providing Training:** SARI and UCR
**Supervising CRSP PI:** Francis Kusi
**Degree Program:** MS Plant Breeding
**Field or Discipline:** Plant breeding
**Research Project Title:** Combining early maturity, seed size and thrips resistance traits in cowpea
**Start Date:** 2015
**Projected Completion Date:** Dec 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

## VII. Achievement of Gender Equity Goals

In Ghana, women farmer groups with a total of 480 women were trained by the SARI team during the reporting period. These were women groups from 15 communities who are in cowpea production and marketing. The project team collaborated with CARE international Ghana, an international NGO operating in Ghana in reaching out to these groups. Current research to develop varieties resistant to insects and drought and integrated strategies to manage insect pests, diseases and drought were main topics in training. In Senegal, with the farmers' organization RESOPP training of its members on seed production and post-harvest operations was continued. More than 200 women producers were trained in FY15. In Burkina Faso, 190 women producers were trained on cowpea production and seed storage.

## VIII. Achievement and Progress Along the Impact Pathway

Under Objective 1, the primary thrust of the impact pathway progress centers on identifying QTLs determining traits for insect tolerance and resistance. As described in the technical section under Objective 1, this involves a combination of phenotype screening in the target areas (combination of greenhouse and field-based screens), together with high-throughput SNP genotyping with genomewide markers and followed by ICI-mapping to identify significant QTLs. The various populations for QTL discovery are at different stages of this process and will require additional years of data collection from the phenotyping trials.

Under Objective 2, the primary impact pathways are release of new cowpea varieties. As reported in the technical section, five all-white large seeded varieties (Lisard, Thieye, Leona, Kelle and Sam) have been formally released in Senegal during the reporting period, and have been launched into the seed development pipeline with Breeder and Foundation seed production. In Burkina Faso, a selected set of 9 white-seed advanced lines tested in on-farm multilocation field performance trials were reduced to four best-performing lines based on 2015 trials, and for which Breeder seed was produced by INERA. After unforeseen delay, these will be processed for national release in 2016. In California, likewise the advanced breeding lines are in different advanced stages of final testing, including on-farm strip trials, to determine which if any lines are suitable for release.

## IX. Explanation for Changes

In Senegal, the aphid biotype identification trials were carried out, but were again not successful because the aphid pest infestations did not occur due to heavy rainfall. They were completed in the other countries, and they will be repeated in the coming year.

The Ghana team started the flower thrips screening of the two RIL populations following seed increase at UCR. They used some of the planted plots with mild insecticide protection to develop more seed for the next test cycle, so the 2015 data are considered preliminary. These populations will be phenotyped fully by SARI in 2016.

In Burkina Faso, the pod-sucking bug phenotype screening is being prepared under direction of Dr. Dabire. Because of seed failures in 2014–15, additional segregating populations were generated and are being grown for phenotyping in February 2016, with a repeat test planned for summer 2016.

Genotyping of cowpea materials by UCR is in various stages of progress using both the KASP and iSelect cowpea SNP genotyping platforms depending on the specific objective, and will be completed to match with the phenotype data for insect resistance.

Funds are available to complete all the above activities.

## X. Self-Evaluation and Lessons Learned

Overall we have had a successful workplan period in 2014–15. The primary challenges to staying on timeline are ones familiar to us in conducting the collaborative cowpea improvement project. Three are worth highlighting: 1) Having enough seed of breeding lines or populations for genetic analysis is a limitation sometimes, because of failure of seed increases due to growing conditions or, in California, due to photoperiod sensitivity of African germplasm requiring short daylength for flowering. 2) Phenotyping for biotic stress resistance under field conditions is dependent on adequate, uniform infestations. This is especially difficult with insect screening, such as in Senegal for the last two years when aphid infestation was too low for data collection due to weather events. Multiple years and locations for testing are built into the planning to mitigate this problem. 3) Technical issues continue to arise occasionally with leaf or DNA sample shipments for SNP genotyping, due to delays, shipment loss, or spoilage of leaf samples from inadequate drying before shipping. Resampling is required to overcome these problems, and the US and HC team have got much better in handling this outsourcing process. Our team of U.S and Host Country partners works very well together, based on established relationships and the seamless integration of the new team from SARI, Ghana. Frequent communication is seen as a key in planning and execution of project activities. Of especial value this period has been the face-to-face meetings at UCR in March 2015, and in Ghana in September 2015.

# XI. Scholarly Accomplishments

Huynh, B.L., Ehlers, J.D., Ndeve, A., Wanamaker, S., Lucas, M.R., Close, T.J., Roberts, P.A. 2015. Genetic mapping and legume synteny of aphid resistance in African cowpea (*Vigna unguiculata* L. Walp.) grown in California. Molecular Breeding 35:36 (1–9). DOI 10.1007/s11032-015-0254-0

Boukar, O., Fatokun, C.A., Roberts, P.A., Abberton, M., Huynh, B.L., Close, T.J., Kyei-Boahen, S., Higgins T.J.V., Ehlers, J.D. 2015. Cowpea. Pp. 219–250 *in* Grain Legumes. Editor: A.M. De Ron. Springer-Verlag, New York.

Lucas, M.R., Huynh, B.L., Roberts P.A., Close, T.J**.** 2015. Introgression of a rare haplotype from Southeastern Africa to breed California blackeyes with larger seeds. Frontiers in Plant Science 6:126. doi: 10.3389/fpls.2015.00126

Huynh, B.L., Matthews, W.C., Ehlers, J.D., Lucas, M.R., Santos, J.R.P., Ndeve, A., Close, T.J., Roberts, P.A. 2015. A major QTL corresponding to the *Rk* locus for resistance to root-knot nematodes in cowpea (*Vigna unguiculata* L. Walp.). Theoretical and Applied Genetics. In press.

Cisse, N. et al. 2015. Formal release of five new cowpea varieties in Senegal with large white seed-type and disease resistance. Variety name registrations Lisard, Thieye, Leona, Kelle and Sam.

# XII. Data Management

As described in the Data Management Plan submitted in August 2015, data sets will be submitted to publicly accessible sites in project years 4 and 5. Data sets for phenotyping traits and genotyping with genomewide SNP markers are being generated for QTL mapping. These are being organized on standard excel spreadsheets designed to capture appropriate trait dictionary names and codes as used in the CGIAR-GCP databasing. Once datasets are analyzed to confirm their usefulness and validity relative to results, and those findings published, then the datasets will be made publicly available.

# ANNEXES

**Table 1**. Details of sources of resistance to the cowpea aphid for the differential panel for determining resistance uniqueness and aphid biotype differences.

| Name | Type | Origin |
|---|---|---|

| | | |
|---|---|---|
| 58-77 | Aphid resistant source | ISRA |
| INIA19 | Aphid resistant source | MSU |
| IT97K-556-6 | Aphid resistant source | IITA |
| KN1 | Aphid resistant source | INERA |
| KvX-295-2-124-99 | Aphid resistant source | INERA |
| SARC-1-57-2 | Aphid resistant source | SARI |
| | | |

| Entry | KREC Yield (lb/ac) | Tulare Yield (lb/ac) | KREC 100 seed wt (g) | Tulare 100 seed wt (g) | Galling M. incognita | Galling M. javanica | Galling M. incognita Muller | Fusarium Race 4 index |
|---|---|---|---|---|---|---|---|---|
| N17 | 5212 | 4121 | 20.4 | 23.0 | 1.1 | 1.2 | 3.1 | 4.8 |
| 10K-77 | 5146 | 4172 | 22.6 | 25.3 | 0.9 | 1.7 | 3.7 | 5.0 |
| N2 | 5106 | 4523 | 19.5 | 22.7 | 1.2 | 1.2 | 3.8 | 0.2 |
| N5 | 4979 | 4132 | 19.5 | 22.4 | 0.8 | 1.5 | 3.5 | 0.8 |
| N20 | 4974 | 4069 | 19.5 | 23.1 | 0.9 | 1.0 | 3.5 | 5.0 |
| CB50 | 4589 | 3840 | 23.4 | 25.1 | - | - | - | 0.0 |
| 10K-29 | 4548 | 4072 | 22.2 | 23.3 | 2.4 | 2.9 | 4.2 | 0.0 |
| N16 | 4499 | 3910 | 20.1 | 23.2 | 0.8 | 0.8 | 3.4 | 4.5 |
| 10K-19 | 4439 | 4144 | 20.8 | 25.0 | 1.3 | 2.9 | 4.1 | 5.0 |
| 10K-115 | 4433 | 3519 | 22.4 | 25.4 | 1.0 | 1.6 | 2.5 | 5.0 |
| CB46Rk2 | 4288 | 4329 | 18.3 | 20.6 | 1.0 | 2.7 | 2.9 | 0.0 |
| CB46 | 3789 | 4243 | 19.2 | 22.1 | 1.6 | 3.4 | 4.2 | 4.9 |
| Mean | 4667 | 4105 | 20.7 | 23.4 | | | | |

| | | |
|---|---|---|
| | Aphid resistant source | IITA |

| | | | | | | |
|---|---|---|---|---|---|---|
| CV(%) | 11 | 9 | 5 | 3 | | |
| LSD(0.05) | 754 | 530 | 1.4 | 1.0 | | |

| | | |
|---|---|---|
| TVNu-1158 | | |
| APAGBAALA | Aphid susceptible check | SARI |
| BAMBEY21 | Aphid susceptible check | ISRA |
| CB27 | Aphid susceptible check | UCR |
| IT82E-18 | Aphid susceptible check | IITA |
| VITA7 | Aphid susceptible chzeck | IITA |

**Table 2**. New blackeye breeding lines and checks tested at Kearney REC and Tulare in 2014: grain yield, 100-seed weight, galling ratings from 2014 field screening with root-knot nematodes *M. incognita, M. javanica,* and *M. incognita* Muller, and 2014 greenhouse screening with Fusarium Race 4.

Kearney REC trial planted on May 29 and cut on October 6 (130 days).

Tulare trial planted on June 6 and hand-harvested on October 2 (118 days).

Root-galling score on scale of 0 (no galling) to 8 (severe galling).

Fusarium wilt disease index (0 to 5; where 0 = no wilt symptoms and 5 = plant death).

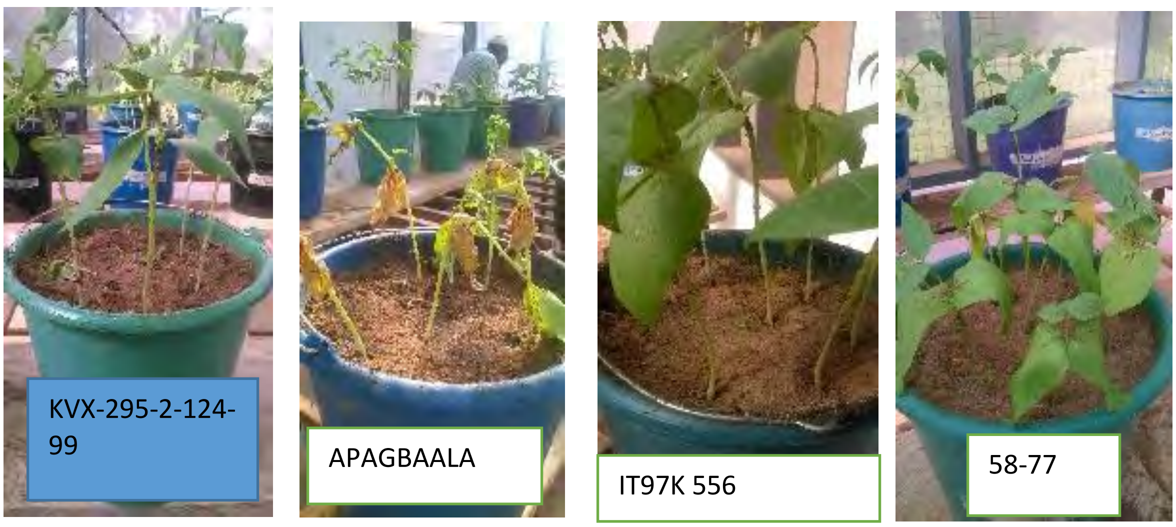
**Table 3**. Grain yield, 100-seed weight, and lygus grain damage of 3 advanced blackeye lines, CB46, CB50 and CB27 when grown under insect-protected and unprotected conditions at Kearney REC in 2014.

| Line | Yield (lbs/ac) | | | 100-seed weight (g) | | *Lygus damage (%) |
|---|---|---|---|---|---|---|
| | Protected | Unprotected | Loss (%) | Protected | Unprotected | |
| 07KN-74 | 3537 | 3083 | 13 | 20.2 | 21.6 | 17 |
| 09KLN-1-9 | 3359 | 2767 | 18 | 18.3 | 19.0 | 15 |
| 09KLN-2-30 | 3340 | 3015 | 10 | 18.8 | 18.8 | 13 |
| CB27 | 3499 | 2764 | 21 | 22.0 | 22.6 | 14 |
| CB46 | 2127 | 1549 | 27 | 19.8 | 20.0 | 16 |

| | | | | | | |
|---|---|---|---|---|---|---|
| CB50 | 2298 | 1612 | 30 | 23.0 | 24.4 | 14 |
| Mean | 3026 | 2465 | 19 | 20.4 | 21.1 | 15 |
| CV(%) | 9 | 15 | 80 | 6 | 5 | 28 |
| LSD(0.05) | 309 | 425 | 18 | 1.4 | 1.3 | 4.9 |

Kearney trial planted on May 29 and hand-harvested on September 2 (96 days). *Lygus damage on grain measured in the unprotected plots.

**Figure 1.** Examples of phenotypes of resistance panel entries infested with aphids at SARI, Ghana (resistant lines compared with susceptible cv. Apagbaala).



## Milestones

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**

**Report on the Achievement of "Milestones of Progress"**

**(For the Period: April 1, 2015 -- September 30, 2015)**

**This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2015**

***Project Title:*** **SO1.A5 Genetic improvement of cowpea to overcome biotic stress and drought constraints to grain productivity**

| | *Abbreviated name of institutions* | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | UC-Riverside | | | INERA B. Faso | | | ISRA Senegal | | | SARI Ghana | | | Institution 5 | | | Institution 6 | | |
| | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | |
| ***Milestones by Objectives*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** |
| | *(Tick mark the Yes or No column for identified milestones by institution)* | | | | | | | | | | | | | | | | | |
| **Objective 1** | **Breeding and Trait Discovery - Aphid Resistance** | | | | | | | | | | | | | | | | | |
| 1.1.1 differential set seed increase | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| 1.1.2 insect samples collected | x | x | | x | x | | x | x | | x | x | | 0 | | | 0 | | |
| 1.1.3 2nd differential test | x | x | | x | x | | x | x | | x | x | | 0 | | | 0 | | |
| 1.1.4 phenotype progenies | x | x | | x | x | | x | x | | x | x | | 0 | | | 0 | | |
| 1.1.5 genotype progenies | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| **Objective 1.2:** | **Breeding and Trait Discovery -Flower Thrips Resistance** | | | | | | | | | | | | | | | | | |
| 1.2.1 phenotype 2 RILs for QTL | x | x | | 0 | | | x | x | | x | x | | 0 | | | 0 | | |
| 1.2.2 insect samples collected | 0 | | | 0 | | | x | | | x | | | 0 | | | 0 | | |
| 1.2.3 phenotype 3 F3 populations | 0 | | | 0 | | | 0 | | | x | | | 0 | | | 0 | | |
| 1.2.4 genotype F3 population | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| 0 | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| **Objective 1.3:** | **Breeding and Trait Discovery Pod-sucking Bug Resistance** | | | | | | | | | | | | | | | | | |
| 1.3.1 phenotype IT86D-716 popns | 0 | | | x | x | | 0 | | | x | x | | 0 | | | 0 | | |
| 1.3.2 insect samples collected | 0 | | | x | x | | 0 | | | x | x | | 0 | | | 0 | | |
| 1.3.3 advance to F3 from 1.3.1 | 0 | | | x | x | | 0 | | | 0 | | | 0 | | | 0 | | |
| 1.3.4 genotype F3 from 1.3.3 | 0 | | | x | x | | 0 | | | 0 | | | 0 | | | 0 | | |
| 1.3.5 QTL discovery - ICI mapping | x | | x | x | | x | 0 | | | x | | x | 0 | | | 0 | | |

# Milestones, continued

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Objective 2:** | **Breeding and Trait Discovery SNP Markers for Bt tracking and variety release** | | | | | | | | | | | | | | | | | |
| 2.1.1 genotype Bt populations | **x** | x | | **x** | x | | **0** | | | **x** | x | | **0** | | | **0** | | |
| 2.2.1 foundation seed of releases | **0** | | | **0** | | | **x** | | | **0** | | | **0** | | | **0** | | |
| 2.2.2 on-farm test & Breeder Seed | **0** | | | **x** | x | | **0** | | | **0** | | | **0** | | | **0** | | |
| 2.2.3 advanced yield trials | **x** | x | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 0 | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| | | | | | | | | | | | | | | | | | | |
| **Increase capacity of NARS in Burkina Faso, Ghana and Senegal to serve the cowpea sector** | | | | | | | | | | | | | | | | | | |
| 3.1 Short term training | **x** | x | | **0** | | | **x** | x | | **0** | | | **0** | | | **0** | | |
| 3.2 Degree training | **x** | x | | **0** | | | **x** | x | | **0** | | | **0** | | | **0** | | |
| 0 | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 0 | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 0 | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| | | | | | | | | | | | | | | | | | | |
| **Name of the PI reporting on milestones by institution** | P. Roberts | | | I. Drabo | | | N. Cisse | | | I. Atokple | | | PI name | | | PI name | | |

| | |
|---|---|
| **Name of the U.S. Lead PI submitting this report to the MO** | P. Roberts |

**Signature** **Date**

# Performance Indicators

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**
**REVISED PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 14, FY 15, FY16, and FY 17**

**Project Name: Genetic improvement of cowpea to overcome biotic stress and drought constraints to grain productivity**

**Summary of all institutions**

| Indic. numbe | Output Indicators | FY 14 Target | FY 14 Revised | FY 14 Actual | FY 15 Target | FY 15 Revised | FY 15 Actual | FY 16 Target | FY 16 Revised | FY 16 Actual | FY 17 Target | FY 17 Revised | FY 17 Actual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (October 1, 2013 - September 30, 2014) | | | (October 1, 2014 - September 30, 2015) | | | (October 1, 2015 - September 30, 2016) | | | (October 1, 2016 - September 30, 2017) | | |
| 1 | 4.5.2(6) Number of individuals who have received USG supported long-term agricultural sector productivity or food security training | 10 | 4 | 7 | 11 | 12 | 12 | 11 | 12 | 0 | 12 | 14 | 0 |
| | Total number by sex | 10 | 4 | 7 | 11 | 12 | 12 | 11 | 12 | 0 | 12 | 14 | 0 |
| | Number of women | 5 | 2 | 4 | 5 | 5 | 5 | 5 | 6 | 0 | 5 | 6 | 0 |
| | Number of men | 5 | 2 | 3 | 6 | 7 | 7 | 6 | 6 | 0 | 7 | 8 | 0 |
| | Total number by New/continuing | 10 | 4 | 7 | 11 | 12 | 11 | 11 | 12 | 0 | 12 | 14 | 0 |
| | Number of New | 5 | 2 | 4 | 5 | 5 | 4 | 5 | 6 | 0 | 5 | 6 | 0 |
| | Number of Continuing | 5 | 2 | 3 | 6 | 7 | 7 | 6 | 6 | 0 | 7 | 8 | 0 |
| 2 | 4.5.2(7) Number of individuals who have received USG supported short-term agricultural sector productivity or food security training | 531 | 333 | 538 | 1910 | 1907 | 2045 | 2520 | 2760 | 0 | 4360 | 4560 | 0 |
| | Total number by sex | 531 | 333 | 538 | 1910 | 1907 | 2045 | 2520 | 2760 | 0 | 4360 | 4560 | 0 |
| | Number of women | 196 | 116 | 191 | 659 | 663 | 878 | 963 | 1050 | 0 | 1753 | 1953 | 0 |
| | Number of men | 335 | 217 | 347 | 1251 | 1244 | 1167 | 1557 | 1710 | 0 | 2607 | 2607 | 0 |
| | Numbers by Type of individual | 531 | 333 | 538 | 1910 | 1907 | 2035 | 2520 | 2760 | 0 | 4360 | 4560 | 0 |
| | Producers | 430 | 270 | 434 | 1670 | 1670 | 1790 | 2145 | 2360 | 0 | 3440 | 3640 | 0 |
| | People in government | 39 | 27 | 38 | 110 | 110 | 110 | 120 | 140 | 0 | 400 | 400 | 0 |
| | People in private sector firms | 24 | 16 | 26 | 78 | 85 | 90 | 195 | 205 | 0 | 365 | 365 | 0 |
| | People in civil society | 38 | 20 | 40 | 52 | 42 | 45 | 60 | 55 | 0 | 155 | 155 | 0 |
| 3 | 4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III) | 141 | 88 | 141 | 202 | 154 | 215 | 238 | 238 | 0 | 282 | 432 | 0 |
| | Phase 1: Number of new technologies or management practices under research as a result of USG assistance | 93 | 68 | 93 | 153 | 128 | 163 | 172 | 172 | 0 | 190 | 340 | 0 |
| | Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance | 40 | 20 | 40 | 39 | 24 | 42 | 51 | 51 | 0 | 66 | 66 | 0 |
| | Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance | 8 | 0 | 8 | 10 | 2 | 10 | 15 | 15 | 0 | 26 | 26 | 0 |

**Notes:**

These indicators are developed under the Feed the Future Monitoring System. Please provide 'total' numbers and also disaggregate where applicable. Just providing 'totals' will not be approved.

This table corresponds to the Feed the Future Performance Indicators data collection sheet under the FTFMS system. Where an indicator does not apply to the type of work done under the project, leave it blank.

Please follow the indications in the Legume Innovation Lab Indicators Handbook that will be provided to you by the Management Office. Contact Mywish Maredia (maredia@anr.msu.edu) for further information.

There is additional guidance on the USAID/Microlinks website: http://agrilinks.org/sites/default/files/resource/files/FY14%20FTFMS%20Guidance_2.pdf

# IPM-omics: Scalable and sustainable biological solutions for pest management of insect pests of cowpea in Africa (SO1.B1)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## I. Abstract of Research and Capacity Strengthening Achievements


Over the past year we have pushed forward our understanding of and solutions for the major pests of cowpeas in four West African countries: Benin, Niger, Burkina Faso and Ghana. We have characterized pest populations both through field-level and molecular tools, specifically focused on mitochondrial polymorphisms. Solutions to these pest problems have been developed and pushed forward including tangible solutions from our biocontrol agent pipeline, as well as a neem and *Maruca*-specific viral combined spray. We have also continued to develop and investigate the use of educational tools, involving animations voice overlaid into local languages, as a scalable system to deploy the outcomes of our research efforts to create and deploy locally sourced pest control solutions. Our capacity building efforts have included undergraduate and graduate training efforts in the host country programs, cross training of technicians across countries, and we have continued to test our animated educational approach, including ICT training sessions and the release of an Android App allowing collaborating organizations to easily access and use these materials in their educational programs. We continued to collaborate with Dr. Maredia's team at MSU and Dr. Mazur's team at ISU towards social science-oriented questions relating to scaling out technologies and approaches for pass-off to other groups.


## II. Project Problem Statement and Justification

Insect pests of cowpeas dramatically reduce yields for cowpea farmers in West Africa, many of who live on less than $2 per day. Arguably, the greatest biotic constraints on cowpea (*Vigna uguiculata* [L.] Walp.) production are insect pests. The major pests of cowpea in the field in northern Nigeria, in Niger, Ghana, and in Burkina Faso include (i) the legume pod borer, *Maruca vitrata* Fabricius; (ii–iii) the coreid pod-bugs, *Clavigralla tomentosicollis* Stäl and *Anoplocnemis curvipes* (F.); (iv) the groundnut aphid, *Aphis craccivora* Koch; and, (v–vi) thrips, *Megalurothrips sjostedti* Trybom. Our program is focused on a three-step approach for (1) defining the pest problems, (2) developing appropriate pest control solutions and (3) exploring the scaling of these solutions. We have continued to develop an in depth understanding of the pest populations through a combination of field experiments and molecular tools to characterize and compare pest populations. We have developed solutions that will allow for the development of local cottage industries that can produce biopesticides for local sale and use – thereby facilitating the potential for local value chains that result in the development and sale of ecologically friendly pest control solutions. We have continued to investigate biological control agents in our biocontrol pipeline and we have promising candidates for scaling in the field, along with approaches to scale their release in a cost-effective manner. Additionally, we have (1) developed scalable educational solutions to train people in many of the pest control strategies in their own languages and for all literacy levels and (2) we are exploring pathways for passing these off to other groups that can deploy these in their educational programs. Finally, in terms of capacity building we (1) have been working with NGOs and local companies for pass off our of outcomes, (2) we have continued undergraduate and graduate training, and (3) a cross-country technician training program to facilitate capacity in biocontrol agent rearing and release as well as biopesticide development, deployment and pass-off to local commercial and noncommercial entities.

# III. Technical Research Progress

Over the past 12 months we have researched, developed, implemented and performed and analyzed datasets around determining the potential for impacts of our strategies for cowpea farmers in West Africa. We have continued to research and develop scalable solutions, with the potential and actualization of larger-scale impact through donor community buy-in. As part of that donor community buy-in the Bill and Melinda Gates Foundation has funded outcomes of our past efforts on *Maruca* – the objectives of that grant do not overlap with the current USAID Legumes Innovations Lab grant. Our objects emerge from the following vision, with three critical major objectives, supported and intertwined with the fourth objective of capacity building. We term this approach IPM-omics – as a system to develop and deploy scalable solutions.

First, we define IPM-omics in the following equation:

IPM-omics = define the pest problems + appropriate solutions + scaling of solutions

In the below objectives and outcomes we outline how we are actualizing each of these steps with institutional capacity building being integral to this overall process. Below are given our four objectives and our accomplishments under those objectives.

**Objective 1. Define the pest problems: (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 drive pest controls strategies.**

***1.1 Scouting and field experiments***

1. The IITA, INERA, INRAN, CRI, and SARI teams all continue to perform surveys of the pest populations during cowpea cropping cycles and outside of these cycles. Insects found on diverse alternative host plants are stored in RNAlater or 70% ethanol to be sent to UIUC for molecular analyses. Additionally, the INERA team has established experiments to understand the pest populations that occur in the dry season in places where an extra cycle of cowpea could occur where irrigation by some farmers is possible. All of these studies are continuing and will continue to contribute to our understanding of the cycles of pest populations on cowpeas.

2. For example, in Ghana (from the SARI team) the results were as follows:

   - Field studies were conducted at the Savanna Agricultural Research Institute (SARI), Nyankpala, Tolon district, northern region, Ghana, between July and September 2014 to identify the major insect pests of cowpea. The cowpea variety used was IT90K-277-2. The results indicated that leafhoppers, Aphis, *Aphis craccivora* Koch; thrips, *Megalurothrips sjostedti* T.; *Maruca vitrata* F.; Pod sucking bugs such as *Clavigralla tomentosicollis*, *Anaplocnemis curvipes*, *Riptortus dentipes* are the major pests. The thrip population was found to increase with the season and peaked with the rain in September. Incidence of *M. vitrata* and pod sucking bugs were low. These results are in keeping with observations form the previous year and this represents year two of multiple year field observations.

- Diagnostic as with FY14, surveys were conducted in farmers fields in 2015 and it was found that *M. sjostedti*, *M. vitrata* and *C. tomentosicollis* populations were high in Krachi West and West Gonja districts which are farther south of Nyankpala in Tolon District.
- As with FY14 the following have been identified as the alternative hosts of *M. sjostedti* and *M. vitrata*; *Grycine max* (L.), *Cajanus cajan* (L.), *Mucuna cochinchinensis* (Lour.), *Canavalia ensiformis*, L. and *Tephrosia* sp.

Our IITA, CRI, INERA and INRAN teams also continued to produce this type of important baseline data.

***1.2 Molecular Analyses of pest populations***

From IITA we have received pest populations for molecular analysis of insects have been collected from numerous host plant populations, for all species tested, across Benin, Niger, Burkina Faso and Ghana. The specimens have been stored at $-80^{o}C$ and the DNA extracts have been shipped to UIUC for further molecular analyses. Similar sample collections of insects have been received from our teams in Burkina Faso, Niger and Ghana. Molecular analyses (SNP and microsatellite analyses) are continuing at UIUC. However, this past year we have focused more intensely on SNP analysis of mitochondrial genes as we have developed a protocol that allows us to determine the relationships between the populations that will be more useful in. One additional series of experiments include populations of aphids collected by the UC-Riverside team (Dr. Phil Roberts) on different lines of cowpeas. We have been comparing these populations of aphids to determine if they are distinct biotypes.

***1.3 Computational Modeling, GIS systems and Online System***

The UIUC and IITA teams have continued to work on a flowchart system that will be used in predictive responses to when and where cowpea farmers can or should intervene in pest control strategies. The IITA team continues to use modeling approaches with the graduate students under Dr. Tamo's direction to better characterize pest populations. The IITA and UIUC teams are continuing to explore the use of GIS systems to couple our other datasets with GIS data.

The UIUC team is continuing to summarize all the published papers that will sit on a website that will be online by the end of the 2015. This website will have fewer features than we first envisage, as collection of data on websites has a set of security challenge issues that are better handled by sharing data between teams through other mechanisms (e.g., e-mail, Dropbox, etc).

***1.4 Insect biology – Sex and aggregation pheromones for pod sucking bugs***

Olfactometric studies have confirmed previous observations that adult males of the coreid bug *Clavigralla tomentosicollis* produce pheromones which attract the egg parasitoid *Gryon fulviventre*. The student who carried out this research has just recently been awarded an *icipe*-ARPPIS PhD fellowship to carry out the chemical ecology part of his thesis at *icipe* in close collaboration with IITA. Also, the student will compare pheromone profiles of West, East and Southern Africa populations of *C. tomentosicollis* and possibly other congeneric *Clavigralla* species, which will be matched by population genetic studies.

Based on the evidence that female egg parasitoids *G. fulviventre* use olfactic cues emitted by adult male *C. tomentosicollis* for locating egg masses in the field, we have developed small field cages which contain the optimum number of *C. tomentosicollis* males as assessed in previous experiments. The cages have been tested in the field using sentinel egg masses of *C. tomentosicollis*, which were indeed parasitized by the parasitoid *G. fulviventre* after an exposure time of 48h. This experiment is now being carried out at larger scale with different treatments to compare parasitism levels due to the attraction of male aggregation pheromones, with the naturally occurring parasitism levels if no pheromones are present. The experiment just started in the second cropping season and will be harvested mid-November.

**Objective 2. Appropriate solutions. We have developed a biocontrol and biopesticide pipeline, in order to develop a series of environmentally and economically appropriate pest control solutions.**

***2.1. Novel Maruca parasitoids available for screening***

Upon the delivery of an official release permit by the Minister of Agriculture, we started to carry out experimental releases of the pod borer parasitoid *Therophilus javanus* as part of an MSc study (female student) looking into the details of the host finding behavior of the parasitoid. We successfully recovered parasitoid pupae both from *Sesbania cannabina* and cowpea in confined cages in the screenhouse at IITA–Benin. Confined field cage releases have been established during the second cropping season and will be inoculated with different densities of the parasitoid at the end of October on experimental fields at the IITA–Benin station as planned.

At the same time, a PhD study has started looking at maternal factors responsible for the parastization success in *T. javanus*. First observations were targeting the specific organs of the female genital tract of *T. javanus*, and particularly the venom gland whose ultrastructure indicates it is of type 2 as observed in Braconidae. Also, there was no sign of virus or virus-like particles (VLP) in the ovaries of this parasitoid, as opposed to the previously studied *Apanteles taragamae.*

This parasitoid is able to discriminate already parasitized larvae and there is a high probability that the Doufour's gland might be involved in secreting marking volatiles. Also, the study confirmed previous preliminary observations that *T. javanus* females prefer 2 and 3 day old *M. vitrata* larvae for oviposition.

Two further MSc studies have been initiated, one looking into intraspecific competition between *T. javanus* and the other parasitoid *Phanerotoma syleptae*, and the other one assessing the detection of the parasitoid *T. javanus* inside *M. vitrata* larvae by the use of molecular techniques (qPCR).

***2.3 PCR techniques for detecting endophytic strains of Beauveria bassiana available***

Three PCR primers available for the detection of *Beauveria bassiana* (Castrillo et al., 2003) were tested: $SCA14_{445}$ (F 5'TCTGTGCTGG CCCTT ATCG 3' R 5' GTACTGACGTG TCTGTGCTGG 3'); $SCA15_{441}$ (F 5' TTCCGAACCC GGTTAAGAGAC 3' R 5' TTCCGAACCC ATCATCCTGC 3') et $SCB9_{677}$ (F 5' TGGGGGACTC GC AAA CAG 3' R 5' TGGGGGACTCAC TCC ACG 3'). $SCB9_{677}$ revealed to be the best one for our *Beauveria bassiana* Bb115 strain, following the standard methodology of incubating the culture broth with conidia, and extracting the DNA from the mycelium. This was done both for the original culture and then for the re-isolated one from the plant tissue after the endophytic inoculation. However, attempts to re-isolate *Beauveria bassiana* mycelium directly form plant tissue has proven to be difficult and unreliable so far, but efforts are continuing in this direction, e.g. by designing more robust and Bb115-specific SCAR primers.

***2.4 Genetic improvement of cowpea to overcome biotic constraints to grain productivity (in***

***collaboration with the UCR cowpea breeding team)***

This activity has taken place in Burkina Faso with the INERA team and in Niger with the INRAN team. Details of the activities are outlined as follows. Screening for resistance or tolerance to *Clavigralla tomentosicollis* occurred, as did screening for aphid attack. Aphids were collected in three agroecological zones: Sahelian zone (< 600 mm), Sudano–Sahelian zone (600–900 mm), Sudanian zone (> 900 mm), to screen 10 cowpea varieties from Botswana (B 301), Burkina (KN-1, NS-1, NS-Farako-bâ and KVX 295-2-124-99), Cameroon (N°2300), Ghana (SARC1-91-1 and SARC1-57-2), Nigeria (IT97K-556-6), USA (CB27). From all of these varieties (IT97K-556-6) was recorded resistant or tolerant to aphid (from all of agroecological zone) attack. This study also showed the existence of two strains of aphids in Burkina Faso. So, their molecular characterization is needed. F1's from the cross between susceptible plant (tiligre) x KVX 299-2-124-99 are ready to screen. The INRAN team in Niger screened over 10 varieties of cowpeas thought to have some level of insect tolerance to *Clavigralla tomentosicollis*, *Maruca vitrata* and aphid.

**Objective 3. Scaling of solutions. When solutions have been developed we need mechanisms to effectively deploy them in a cost effective and sustainable manner. Discovering and testing such scaling pathways will be critical to determine which approaches will be most successful for scaling. Solutions, for scaling, fall into three categories: (3.1) direct release into the environment and natural establishment; (3.2) educational solutions; and (3.3) private sector and NGO involvement.**

***3.1.1. Maruca parasitoids (IITA)***

With regard to scaling out *M. vitrata* parasitoids, we are on track with establishing rearing colonies both for *T. javanus* and *P. syleptae* at the INERA labs in Bobo Dioulasso in Burkina Faso. Experimental releases of both natural enemies are being prepared using satellite pictures/GIS and ecological information with regard to suitable host plant habitats. They are planned as scheduled to be carried out at the onset of the dry season starting November this year, on patches of natural vegetation close to the survey villages used for the socio-economic survey carried out by Dr. Maredia. At the same time, official import permits are being processed for the establishments of similar founding colonies both in Niger and Ghana, which should allow experimental releases to be carried out during the long dry season.

***3.1.2. Thrips parasitoid available for scaling up (IITA, INERA and INRAN)***

According to schedule, pupae of the thrips parasitoids *Ceranisus femoratus* were collected on patches of *Pterocarpus santalinoides* and *Lonchocarpus sericeus* in Southern Benin and hand-carried to the INERA labs at Farokoba, Burkina Faso, where adult parasitoids were subsequently released on *Tephrosia candida* and other host plants bearing populations of flower thrips. Recapture surveys to assess establishment are planned with the onset of the dry season starting at the end of November.

***3.1.3. Feasibility of storing Maruca virus both as liquid and solid substrate (IITA)***

The viral solutions kept for six months both in the deep freezer at -18$^{o}$C and in a normal fridge at 4$^{o}$C were also evaluated in the experimental fields at the IITA station. As already observed for the lab studies, the field evaluation indicated no significant differences in their activity, with a 63.2% and 48.8% reduction of the *M. vitrata* larval population for 4$^{o}$C and -18 $^{o}$C treatments, respectively, as compared to the unsprayed control. Unfortunately, the experiments using the industrial-grade dry freezer at the IITA–Benin station had to be stopped due to a malfunctioning of the vacuum pump, which had become unreliable. Attempts to repair the pump locally in Benin were not successful, so the pump had to be dismantled and sent to our HQ in Ibadan for further repairs.

***3.1.4 Scaling of the neem plus virus control strategies (IITA, INRAN and INERA)***

In Benin, we have established some 54 demonstration plots in farmers' fields covering the whole country, and reaching out to a conservative estimate of 10,000 farmers. We expect to report on impact numbers in the next FY. Treatments consisted not only the targeted MaviMNPV + emulsifiable neem oil mixture, but also neem oil alone, conventional pesticides, an unsprayed control plot, the local concoction of macerated neem leaves, and a combination of the fungal entomopathogen *Beauveria bassiana* Bb115 strain (with endophytic properties) + emulsifiable neem oil. The demonstration plots were also used as experimental fields to assess the presence of different cowpea pests as influenced by the various control approaches, as well as their impact on yield. This is the first time we are able to carry out such an important and country-wide study on the use and impact of biopesticides, which was only possible through cofunding by the BMGF-funded precision-IPM project under the choice experiment scheme. Result from the demonstration plots will be available later in the year. Most notably, the INRAN team has continued to work with neem seed oil and virus sprays in villages in the region of Maradi and Zinder. The intent of this activity is to test the effectiveness of this approach in the hands of farmers.

### *3.1.5 Portable neem oil extraction system (CRI and SARI)*
The CRI and SARI teams have and are continuing to explore the development of a low-cost portable neem oil extraction system for use at the village level. SARI has also explored the establishment of larger neem oil extractor with a Ghana-based entrepreneur, however, the movement of this device has not yet occurred.

### *3.1.5 Studies on the potential for use of biopesticides in the pest control market in Benin (IITA, MSU-Maredia, INRAB, and UIUC)*
The INRAB and IITA teams are continuing to work closely with Dr. Maredia of MSU to perform survey studies to understand the potential for biopesticides in the pest control market in Benin. Data acquired during the survey last year were analyzed as scheduled. In Aplahoué et Klouékanmey in Southern Benin, a total of 120 cowpea producers were interviewed in 4 distinct villages. We particularly wanted to assess the farmer willingness to pay for alternative crop protection products as compared to chemical pesticides. The results show that some 5.8% of the farmers strongly favor the use of biopesticides, which can cost up to 250 CFA more per treatment, even if they do not significantly increase their monetary revenue, while 10% of the interviewed farmers strongly disapproved the same scenario. Some 50% of the interviewed farmers are ready to pay up to 300 CFA more per treatment with biopesticides if their yield is also increased.

With regard to the general perception of biopesticides based on neem leaf extracts (the only ones available at the time of the survey), farmers indicated that they are less toxic, less expensive but difficult if they have to prepare them by themselves, their mode of action is slower and the yields are lower that using synthetic pesticides. They also recognize that chemical pesticides are more efficient, faster in their action, give a good yield but they are well aware of their toxicity and they have given ample examples of poisoning symptoms. They also mentioned that they would be willing to try out new biopesticides which can be sold over the counter, and which are more efficient than aqueous extracts.

IITA is also continuing to work with SENS–Benin, a Benin-based social enterprise that is extracting neem oil for sale. They purchase neem seeds from hundreds of local women, process the neem oil and sell it regionally in Benin, targeting cowpea and vegetable farmers. IITA has been invited to participate at their meetings and workshops, and we are in discussions with them on how to diversify their biopesticide supply (e.g. by including the viral biopesticide MaviMNPV and the fungal entomopathogen *B. bassiana*) through their network of biopesticide retailers.

### *3.2 Educational Solutions*

As part of our “Educational Solutions” we have developed ICT training materials, online and in-country ICT training sessions available for testing with current partners and potential new partners, FFF program available for testing of impact leading to educational packages for scaling. Potential pathways for deployment of educational videos explored, and we have been testing pathways to deploy videos. We have also been exploring pass-off of our educational materials to NGOs and government agencies for scaling. Over the past 18-months all of these have occurred. Due to the Scientific Animations Without Borders (SAWBO) program we now have a significant amount of the required educational materials needed for educating farmers on cultural techniques that they can perform to reduce problems with insect attack. Our team is continuing to make more content and more language variants, so more groups in our target countries can be impacted by these educational materials.

We have ICT training packages and interfaces in development and ready for release to make our materials easily available to outside groups. An ICT training session occurred in Ghana in FY15 and was funded by an outside source with no costs to the Legumes Innovations Lab (funded by the Chancellor’s office at UIUC) (ca. 30 participants), two ICT training sessions have occurred online through Skype with local NGO groups in Ghana (ca. 100 individuals) as well and the SAWBO team has done ICT training sessions in Burkina Faso (under the LIL program) and in Ethiopia (under another grant). Over 3000 “Extension Systems in Your Wallet” (over the past three years) have been created and distributed to educators, government officials, and NGOs globally (with about 700+ of these going out to groups in the four main countries we work in for our Legumes Innovations Lab program). The “Extension Systems in Your Wallet” is a credit card style USB card that holds SAWBO materials. Users can keep the USB drive in their wallet (save some of their own materials on it) and then share our educational materials with others when and where they see fit. Pass off has occurred to country extension programs, FARA, other West African intercountry institutions and many other organizations.

We have created and released “Apps” for cell phones that allow for easy distribution of the SAWBO animations. Over FY14 we spent a great deal of time with the UIUC legal team to make sure all data that we keep track of with the Apps adheres to international standards and does not violate the privacy of those that are using the App. The necessary supporting legal documentation were created and integrated into the Apps. The Apple version of the App has been tested by multiple groups and the supporting instructional video on the App was finalized and released in FY15. The Android version can be downloaded from Google Play at the following website: https://play.google.com/store/apps/details?id=edu.uiuc.sawbo&hl=en. The Apple (iOS version) was also released this past year on iTunes (https://itunes.apple.com/us/app/id949627456).

The App is linked to a database where we can keep track of how many people download the videos and the place in the world where they download them (down to country or city). We do not keep track of any personal data from those using the App and we will purposely not pinpoint where they are using it in terms of the location.

This App allows people to choose the country, the language and the topic of educational materials that they need. If available they can download the needed animation into the App on their cell phone or their tablets when they are connected to WiFi. They can then take the cell phone or tablet out to the target audience (away from WiFi or Internet access) and show the video and in the case of the Android App animations can be transferred, by Bluetooth®, onto other’s cell phones. In the case of the Apple App, Apple restricts Bluetooth® transfers to non-Apple products, so transfer can only be to other Apple products. However, Apple products can still be used as rapid download and portable screens for showing people the content. However, Android phones are far more common in the target countries, so we will focus on the testing and promotion of this App in the countries we are working in.

The fundamental point of these Apps will be to make SAWBO educational content easily available to the end users who can easily access and use these materials in educational programs and in the case of the Android App – easy to take content from our server onto their devices and then easy to share once one reaches the village. The Apps will also provide us with basic information on the use of the Apps and the content in a systematic manner. In FY16 we expect to release a video explaining how outside groups can use these materials.

Interestingly, a significant amount of SAWBO materials are also being used by NGOs and government organizations outside our target countries. For example, animations funded by the ADM Institute for the Prevention of Postharvest loss resulted in animations for the Ethiopian Agricultural Transformation Agency (ATA). ATA purchased 640 tablet computers that were distributed to Extension agents across Ethiopia – with an estimated coverage of 168,000 Teff growers (http://news.illinois.edu/news/14/0519sawbo_BarryPittendrigh.html). Other SAWBO animations have also been used in documentaries on TV (e.g., in the Republic of Georgia – http://www.youtube.com/watch?v=Gh2EhCZOlV8). Of greatest interest is that SAWBO materials, including our cowpea neem animation, are being used on a Hausa speaking TV station (AREWA24) based out of Kano in Nigeria (http://us9.campaign-archive1.com/?u=a2b1b23a8f7e117aa0402399c&id=a7349aa0fa). The animations are played between TV shows and the viewership of the TV station might be as high as in the multiple millions. Within the four target counties we work in we estimate the numbers of people that viewed the animations in thousands to tens of thousands during this past year, based on the use by host country scientists in their educational programs and NGOs that have used these tools. Additionally, an early draft of hermetic sealing animation was used in Mozambique in experiments to understand learning gains from the animations. Under Dr. Mazur's ISU project, Pittendrigh and Bello-Bravo both traveled to Mozambique to partake in learning gain experiments – representing an example of cross-collaboration between programs.

This past year a manuscript was submitted on an experiment performed by the MSU–Maredia, INRAN and UIUC team investigating the potential use of these animations in promoting R4D innovations in rural Burkina Faso.

Our team has continued to explore the use of collaborating with and training of NGOs and other groups to perform farmer field flora. Both INERA and INRAN have used these strategies as a way to scale their technologies. For example, this past year INRAN was able to hold over 16 FFF through this approach.

**Objective 4. Capacity building**

Our capacity building efforts fall into the following categories: (1) undergraduate and graduate student training, (2) technician training, (3) cross-institutional capacity building for biocontrol agents, and (4) systems to easily pass of our outcomes to other groups that can scale the pest control strategies.

### *4.1 Undergraduate and Graduate student training*

Each of our teams continues to play active role in undergraduate and graduate training programs. The complete list of training efforts is given under degree training.

### *4.2 Technician Training*

Online cross-training has occurred (via e-mail, Skype and video exchanges based on videos made by IITA) to share skill sets between technical staff at INERA, INRAN, and IITA and to build upon previous exchange programs of technicians.

***4.3 Cross-Institutional Capacity Building for Biocontrol Agents***
IITA, INERA and INRAN, due to ongoing collaborative efforts are all well-positioned to rear and deploy biocontrol agents on a scale that we expect will significantly impact target pest populations in each of these countries. Additionally, all are also in a position to test, train, and scale the neem plus virus strategy for pest control. We have begun the process of transfer of this knowledge to our new partners in Ghana at CRI and SARI.

***4.4 Systems to easily pass of our outcomes to other groups that can scale the pest control strategies***
Our team has continued to build the necessary sets of networks (e.g., NGOs, companies, FFF organizations, women's organizations, etc.) with whom we can pass off (1) educational materials regarding pest control strategies (through a variety of online and offline systems), (2) neem or neem and virus control strategies, (3) direct deployment of biocontrol agents and (4) FFF training approaches.

# IV. Major Achievements

1. Development of biocontrol agents useful for scaling for management of cowpea pests.
2. Detailed studies on insect behavior, ecology and biology to maximize the impact of biocontrol agents in the field.
3. Neem and viral spray strategy brought forward into country-wide, large scale field-testing with farmers.
4. Experimental analyses of field data has shown animated educational approach to be as effectively as use of extension agent presentations. This strategy allows us the ability to significantly scale our educational content.
5. SAWBO has been able to demonstrate the potential for other organizations to scale their materials. We have released an App that has the potential to make all of the SAWBO materials highly accessible and the use of the system highly scalable. SAWBO received the Award for Entrepreneurial Excellence: Social Venture. Champaign County Economic Development Corporation, 2015.

# V. Research Capacity Strengthening

In FY14–15, CRI and INRAN both received capacity building awards. The CRI project specifically revolved around improvement of laboratory facilities, training of staff and establishing the ability to rear pests and biocontrol agents/biopesticides. The CRI team has reported that the activities have occurred and equipment has been ordered or received. The INRAN project involved the establishment of a medium scale facility for the production of a neem/MaviMNPV virus biopesticide. Training of staff has occurred and in FY15–16 the INRAN team has been working with their administration on equipment orders. INRAN and INERA also received an award for this upcoming funding cycle (end date 9/30/16), contracts are in progress (waiting signatures from INRAN), and funding transfer issues are in progress for INERA.

# VI. Human Resource and Institution Capacity Development

**Short-Term Training**
**Purpose of Training:** Training of NGOs in the use of SAWBO materials
**Type of Training:** ICT training sessions
**Country Benefitting**: Ghana
**Location and dates of training:** Accra, spring 2015
**Number receiving training (by gender):** ca. 75 males and 75 females (training other groups on the use of

SAWBO materials)
**Home institution(s) Funded by NGO (CLCD):**
**Institution providing training or mechanism:** UIUC

**Purpose of Training:** general use of SAWBO materials
**Type of Training:** use of animations
**Country Benefitting** – Ghana, Niger, Burkina Faso, Benin (and Nigeria) as well as online global use
**Location and dates of training:** Ongoing across the above countries
**Number receiving training (by gender):** ca. 2600 males and 2600 females
**Home institution:** UIUC
**Institution providing training or mechanism:** The SAWBO materials have been passed off to NGOs and TV stations in West Africa. A low estimate of number of people being impacted is 2600 males and 2600 females (which is what we are reporting), however, with the TV station in Nigeria alone, these number are definitely much higher by one to two orders of magnitude. However, we are in the process of working with a group on the UIUC campus that is working on getting more accurate estimates of the number of people who have viewed these animations. Additionally, other downloads and online viewing of SAWBOs animations are in excess of the above reported numbers.

**Purpose of Training:** – Train farmers in IPM
**Type of Training:** FFF
**Country Benefitting:**– Burkina Faso and Niger
**Location and dates of training:** Multiple locations in Burkina Faso and locations in Niger – various dates on FY14
**Number receiving training (by gender):** 68 males and 52 females in Burkina Faso and 165 persons including 50 males and 115 females in Niger
**Home institution(s) (if applicable):** INERA and INRAN
**Institution providing training or mechanism**: INERA and INRAN

**Purpose of Training:** – Training of grad student from Iowa State University
Type of Training – 1 week at UIUC
**Country Benefitting**: Mozambique
Location and dates of training – UIUC, spring 2015
**Number receiving training (by gender):** ca. 1 male
Home institution(s) Funded by ISA
**Institution providing training or mechanism:** UIUC

**Examples of Training Performed by Outside Groups as a Collaboration with INRAN**

1. Training in collaboration with MercyCorps NGO working in Maradi and Zinder area and implemented 35 FFS related cowpea production 31 extension agents were trained – Estimated impact of 500 or more farmers with an approximate 50:50 split of women and men.
2. Training in collaboration with the INRAN World bank project on Biopesticide working in Maradi and Zinder area and implemented 66 Demonstration field related cowpea pest control – Estimated impact of 1980 or more farmers.

3. 120 farmers including 40 female farmers were trained related to pest control using bio control methods with Sahel Bio and HEKS.EPER a Swiss land NGO from 01–02 September 2015.

**<u>Degree Training</u>**

**Name of Trainee (First and Last Name):** Laura Steele (this student is not funded in any way from LIL, however, she is contributing to the goals of the project as part of her degree training both on helping with the molecular aspects of the project and in relation to SAWBO)
**Country of Citizenship:** USA
**Gender:** Female
**Host Country Institution Benefitting from Training:** IITA (through collaborations)
**Institution Providing Training:** UIUC
**Supervising CRSP PI:** Dr. Barry Pittendrigh
**Degree Program:** PhD
**Field or Discipline:** Entomology
**Research Project Title (if applicable):** A Genomic Analysis of the Insect Pest Populations of Cowpea in West Africa
**Start Date:** 2009
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Fuseini Abdulai
**Country of Citizenship:** Ghana
**Gender:** Male
**Host Country Institution Benefitting from Training:** Ghana
**Institution Providing Training:** University for Development Studies, Tamale, Ghana
**Supervising CRSP PI:** Stephen Asante
**Degree Program:** Undergraduate
**Field or Discipline:** Entomology
**Research Project Title:** Field evaluation of neem seed extracts from different ecological zones of Ghana in the control of cowpea pests
**Start Date:** September 2014
**Projected Completion Date:** July 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Completed

**Name of trainee:** Deborah Anobil AMOSAH
**Country of Citizenship:** Ghanaian
**Gender:** Female
**Host Country Institution Benefitting from Training:** Ghana
**Institution Providing Training:** Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi
**Supervising CRSP PI:** Haruna Braimah
**Degree Program:** Undergraduate

**Field or Discipline:** Agriculture
**Research Project Title:** Neem control strategies on the pests of cowpea in Northern Ghana
**Start Date:** October 2013
**Projected Completion Date:** September 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Completed

**Name of trainee:** Apolline SANOU
**Country of Citizenship:** Burkina Faso
**Gender:** Female
**Host Country Institution Benefitting from Training:** INERA
**Institution Providing Training:** INERA and University of Ouagadougou
**Supervising CRSP PI:** Dr. Clementine Dabire
**Degree Program:** PhD
**Field or Discipline:** Entomology
**Research Project Title:** Biological control of cowpea pod sucking bug *Clavigralla tomentosicollis* Stäl.
**Start Date:** 2011
**Projected Completion Date:** 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Completed

**Name of trainee:** DRABO Edouard
**Country of Citizenship:** Burkina Faso
**Gender:** Male
**Host Country Institution Benefitting from Training:** INERA
**Institution Providing Training:** INERA and University of Ouagadougou
**Supervising CRSP PI:** Dr. Clementine Dabire
**Degree Program:** MSc
**Field or Discipline:** Entomology
**Research Project Title:** Botanical extracts use for the management of cowpea pests at Soudan–Sahelian and soudanian zones at Kamboinsé and Farako-ba stations
**Start Date:** 2015
**Projected Completion Date:** 2017
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Mariam DERA
**Country of Citizenship:** Burkina Faso
**Gender:** Female
**Host Country Institution Benefitting from Training:** INERA
**Institution Providing Training:** INERA and University of Ouagadougou
**Supervising CRSP PI:** Dr. Clementine Dabire
**Degree Program:** PhD
**Field or Discipline:** Entomology

**Research Project Title:** New pests occurring in dry season on cowpea seed production plots
**Start Date:** 2014
**Projected Completion Date:** 2018
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Élisée DABRÉ
**Country of Citizenship:** Burkina Faso
**Gender:** Female
**Host Country Institution Benefitting from Training:** INERA
**Institution Providing Training:** INERA and University of Ouagadougou
**Supervising CRSP PI:** Dr. Clementine Dabire
**Degree Program:** PhD
**Field or Discipline:** Entomology
**Research Project Title:** To be determined
**Start Date:** 2015
**Projected Completion Date:** 2019
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Pending

**Name of trainee:** Joelle Toffa
**Citizenship:** Benin
**Gender:** Female
**Host Country Institution Benefitting from Training:** IITA, Benin
**Institution Providing Training:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** PhD in Entomology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Fungal entomopathogens as biopesticides against the pod borer *Maruca vitrata*
**Start Date:** 2010
**Projected Completion Date:** 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Completed

**Name of trainee:** Djibril Aboubakar Souna
**Citizenship:** Benin
**Gender:** Male
**Host Country Institution Benefitting from Training:** IITA, Benin
**Institution Providing Training:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** PhD in Entomology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Bioecology of *Therophilus javanus*, a promising biocontrol candidate against

*Maruca vitrata*
**Start Date:** 2014
**Projected Completion Date:** 2018
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Hilaire Kpongbe
**Citizenship:** Benin
**Gender:** Male
**Host Country Institution Benefitting from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** PhD in Chemical Ecology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Population genetics of pod sucking bugs *Clavigralla* spp. and comparison of aggregation pheromone profiles
**Start Date:** 2015
**Projected Completion Date:** 2018
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Judith Honfonga
**Citizenship:** Benin
**Gender:** Female
**Host Country Institution to Benefit from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** MSc in Entomology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Detection and quantification of *Therophilus javaus* parasitism in *Maruca vitrata* larvae using species-specific qPCR primers.
**Start Date:** 2014
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Ruth Afora
**Citizenship:** Benin
**Gender:** Female
**Host Country Institution to Benefit from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** MSc
**Program Areas or Discipline:** Entomology

**Thesis Title/Research Area:** Testing dosage of biopesticide cashew apple oil (*Anacardium occidentalis*) agains cowpea pests
**Start Date:** 2014
**Projected Completion Date:** 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Completed

**Name of trainee:** Cossi Roland Maximilien Belogoun
**Citizenship:** Benin
**Gender:** Male
**Host Country Institution to Benefit from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** MSc in Entomology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Biology and competitiveness of *Phanerotoma syleptae*, a novel parasitoid of the pod borer *Maruca vitrata*
**Start Date:** 2013
**Projected Completion Date:** 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Completed

**Name of trainee:** Nicolette Montcho
**Citizenship:** Benin
**Gender:** Female
**Host Country Institution to Benefit from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** MSc
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Host finding behavior of *Therophilus javanus*, a novel parasitoid of the pod borer *Maruca vitrata*
**Start Date:** 2015
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Arnaud HOUNHOUI-GAN
**Citizenship:** Benin
**Gender:** Male
**Host Country Institution to Benefit from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** MSc

**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Testing of dosage and combinations of MaviNPV and biopesticide neem oil and their residual effects
**Start Date:** 2014
**Projected Completion Date:** 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Completed

**Name of trainee:** Fiacre Agbaka
**Citizenship:** Benin
**Gender:** Male
**Host Country Institution to Benefit from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** MSc in Entomology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Interactions between *Phanerotoma syleptae* and *Therophilus javanus*
**Start Date:** 2015
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Carmel TOSSOU
**Citizenship:** Benin
**Gender:** Male
**Host Country Institution to Benefit from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** MSc
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Host finding behavior of *Therophilus javanus* on selected host plants
**Start Date:** 2015
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Mesmin Alizanon
**Citizenship:** Benin
**Gender:** Male
**Host Country Institution to Benefit from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** MSc
**Program Areas or Discipline:** Entomology

**Thesis Title/Research Area:** Life table studies of *Therophilus javanus* on artificial and natural substrates
**Start Date:** 2015
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Laurent AHONGBONON
**Citizenship:** Benin
**Gender:** Male
**Host Country Institution to Benefit from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** MSc
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Life table studies of *Phanerotoma syleptae* on artificial and natural substrates
**Start Date:** 2015
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Firmine Aizan
**Citizenship:** Benin
**Gender:** Female
**Host Country Institution to Benefit from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** BSc
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Competition between *Phanerotoma syleptae* and *Therophilus javanus* under screenhouse conditions
**Start Date:** 2015
**Projected Completion Date:** 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Débora Adjayi
**Citizenship:** Benin
**Gender:** Female
**Host Country Institution to Benefit from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** BSc
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Effect of different *M. vitrata* larval densities on parasitisation success by

*Therophilus javanus* under screenhouse conditions
**Start Date:** 2015
**Projected Completion Date:** 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Aude GBAGUIDI
**Citizenship:** Benin
**Gender:** Female
**Host Country Institution to Benefit from Training:** IITA, Benin
**Training institution:** IITA
**Supervising CRSP PI:** Tamò
**Degree Program for training:** BSc
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Effect of different *Therophilus javanus* densities on parasitisation rates of *M. vitrata* under screenhouse conditions
**Start Date:** 2015
**Projected Completion Date:** 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Maimouna Abdourahmane
**Citizenship:** Niger
**Gender:** Female
**Host Country Institution to Benefit from Training:** INRAN
**Training institution:** INRAN / University of Maradi
**Supervising CRSP PI:** Baoua / Amadou (academic supervisor Prof Saadou Mahamane, University of Maradi)
**Degree Program for training:** PhD in Entomology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** study on the incidence of *Clavigralla tomentosicollis* on cowpea yield and dissemination of one biopesticide for effective control of the pest in the region of Zinder et Maradi
**Start Date:** 2014
**Projected Completion Date:** 2018
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Ousseina Abdoulaye
**Citizenship:** Niger
**Gender:** Female
**Training institution:** INRAN / University of Maradi
**Host Country Institution to Benefit from Training:** INRAN
**Supervising CRSP PI:** Baoua / Amadou (academic supervisor Prof Saadou Mahamane, University of Maradi)

**Degree Program for training:** PhD in Entomology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** study on the incidence of *Maruca vitrata* on cowpea yield and dissemination of biopesticide (neem seed extract and NPV Mavi virus) for effective control of the pest in the region of Zinder et Maradi
**Start Date:** 2014
**Projected Completion Date:** 2018
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Rahina Souley Mayaki
**Citizenship:** Niger
**Gender:** Female
**Training institution:** INRAN / University of Maradi
**Host Country Institution to Benefit from Training:** INRAN
**Supervising CRSP PI:** Ibrahim Baoua/Amadou
**Degree Program for training:** Bsc in Entomology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** The effects of Neem grain-based biopesticide on the development of *Clavigralla tomentosicollis* at rural level in the region of Maradi
**Start Date:** 2012
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Soumaila Abdou Issa
**Citizenship:** Niger
**Gender:** male
**Training institution:** INRAN / University of Maradi
**Host Country Institution to Benefit from Training:** INRAN
**Supervising CRSP PI:** Ibrahim Baoua/Amadou
**Degree Program for training:** BSc in Entomology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** The effects of Neem grain-based biopesticide on the development of *Clavigralla tomentosicollis* at rural level in the region of Maradi
**Start Date:** 2012
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Nafissatou Illa Boube
**Citizenship:** Niger
**Gender:** Female
**Training institution:** INRAN / University of Maradi

**Host Country Institution to Benefit from Training:** INRAN
**Supervising CRSP PI:** Ibrahim Baoua/Amadou
**Degree Program for training:** BSc in Entomology
**Program Areas or Discipline:** Entomology
**Program Areas or Discipline:**
**Thesis Title/Research Area:** Study of the population dynamics of *Maruca vitrata* on station.
**Start Date:** 2011
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Rakia Gonda
**Citizenship:** Niger
**Gender:** Female
**Training institution:** INRAN / University of Maradi
**Host Country Institution to Benefit from Training:** INRAN
**Supervising CRSP PI:** Ibrahim Baoua/Amadou
**Degree Program for training:** Bsc. in Entomology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Study of the biology of *Clavigralla tomentosicollis* in laboratory
**Start Date:** 2012
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Kader Djibo Amadou
**Citizenship:** Niger
**Gender:** Male
**Training institution:** INRAN / University of Maradi
**Host Country Institution to Benefit from Training:** INRAN
**Supervising CRSP PI:** Ibrahim Baoua/Amadou
**Degree Program for training:** Bsc in Entomology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Study of the development cycle of *Clavigralla tomentosicollis* in laboratory conditions
**Start Date:** 2012
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Haouaou Issaka
**Citizenship:** Niger
**Gender:** Female
**Training institution:** INRAN / University of Maradi

**Host Country Institution to Benefit from Training:** INRAN
**Supervising CRSP PI:** Ibrahim Baoua/Amadou
**Degree Program for training:** Msc in Entomology
**Program Areas or Discipline:** Entomology
**Thesis Title/Research Area:** Effect of biopesticide neem seeds extract for the control cowpea pods pest (*Maruca vitrata and Clavigralla tomentosicollis)* on station
**Start Date:** 2015
**Projected Completion Date:** 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

**Name of trainee:** Eustache Biaou
**Citizenship:** Benin
**Gender:** Male
**Training institution:** INRAB / University of Benin
**Supervising CRSP PI:** Dr. Adegbola/Dr. Tamo
**Host Country Institution to Benefit from Training:** INRAB/IITA
**Degree Program for training:** MSc
**Program Areas or Discipline:** Social Sciences
**Thesis Title/Research Area:** TBD
**Start Date:** 2015
**Projected Completion Date:** TBD
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training Status:** Active

# VII. Achievement of Gender Equity Goals

Throughout all aspects of our efforts we attempt to meet gender equity goals, from undergraduate, graduate student and technician training to field training of female farmers.

# VIII. Progress in Implementing Impact Pathway Action Plan

**Objective 1**

In terms of "Program Logic" also worked on Step 4.2 – Collection of pest populations using scouting throughout the year on cowpea crops and wild alternative host plants in Ghana, Burkina Faso, Niger, and Benin. Insects were genotyped at UIUC to determine pest movement patterns within regions (on cowpeas and alternative host plants). We also worked on developing interfaces to summarize our findings and present our educational steps for implementation in a visual format (ongoing).

**Objective 2**

In terms of "Program Logic" we worked on Step 4.2 for this section: (a) new knowledge about novel parasitoids; b) thrips parasitoid available for releases c) new knowledge about sex and aggregation pheromones of pod bugs; d) endophytic strains of *Beauveria bassiana* available for testing; e) liquid and/or solid *Maruca* virus substrate available for farmer participatory trials.

**Objective 3**

In terms of Program Logic, step 4.2 we 1) developed everything necessary for the releases of biocontrol agents to be scaled out; 2) educational solutions - ICT training materials, online and in-country ICT training sessions available for testing with current partners and potential new partners, FFF program available for testing of impact leading to educational packages for scaling. The potential pathways for deployment of educational videos were explored, and begin testing of pathways to deploy videos; and, 3) private sector/NGO involvement.

# IX. Explanation for Changes

There were no major changes in our work plan.

# X. Self-Evaluation and Lessons Learned

One fundamental issue that we have observed is there is a considerable amount of potential for cross-collaboration between projects. We have passed educational content on to other projects for use in other countries and we have successfully worked with other Legumes Innovation Lab projects on both research and social science assessment. We feel there is considerable opportunity in the coming year to build upon our educational deployment strategies and work with the Iowa State team.

# XI. Scholarly Accomplishments

**<u>Theses</u>**

Agunbiade, T. 2014. A Genomic Analysis of the Insect Pest Populations of Cowpea in West Africa. PhD Thesis, University of Illinois at Urbana–Champaign.

Dandjinou, G. V., 2014. Testing biopesticides: Neem oil dosage and combinations of MaviMNPV: 1st planting season 2014, BSc thesis, Agronomy Faculty/ University of Parakou, FA/UPA, Parakou, Benin.

Akogninou, L., 2014. Behavior of *Therophilus javanus* Bhat & Gupta on larvae from eggs of *Maruca vitrata* (Fabricius) parasited by Phanerotoma syleptae Zettel, BSc thesis, Agronomy Faculty/ University of Parakou, FA/UPA, Parakou, Benin.

Laleye, F., 2014. Determining the host range for the exotic parasitoids Therophilus javanus (Hymenoptera: Braconidae), BSc thesis, Agronomy Faculty/ University of Parakou, FA/UPA, Parakou, Benin.

Agli, C. A. & AGO. D, 2014. Effectiveness of parasitism of *Apanteles taragamae* and *Therophilus javanus* on *Maruca vitrata* pest of cowpea, BSc thesis, Polytechnic School of Abomey-Calavi/ University of Abomey–Calavi, EPAC/UAC, Cotonou, Benin.

Boni fofana, R. & Ahouantchede, H. S., 2014: Effectiveness of *Apanteles taragamae* and Therophilus javanus to control *Maruca vitrata* pest of cowpea, BSc thesis, Polytechnic School of Abomey–Calavi/ University of Abomey–Calavi, EPAC/UAC, Cotonou, Benin.

Sagbo, R., 2015. Evaluation of continuous multiplication of its host Trichogrammatoidea eldanae substitution of *Corcyra Cephalonica* in a release device, MSc thesis, Faculty of Agronomic Sciences / University of Abomey–Calavi, EPAC/UAC, Cotonou, Benin.

Zanzana, K., 2015. Evaluation of the colonization of the various organs of the cowpea by endophitic *B. bassiana* (Ascomycota**:** Hypodreales), MSc thesis, Faculty of Technic Sciences/University of Abomey–Calavi, FAST/UAC, Cotonou, Benin.

Menhinto Toffa, J., 2015. Contribution to sustainable management strategies of *Maruca vitrata* Fabricius (Lepidoptera: Crambidae) of *Vigna unguiculata* L. Walp by using entomopathogenic products in Benin, PhD Thesis, Faculty of Letters, Arts and Humanities Sciences /University of Abomey–Calavi, FLASH/UAC, Cotonou, Benin.

Fuseini Abdulai, 2015. Field evaluation of neem seed extracts from different ecological zones of Ghana in the control of cowpea pests. BSc Thesis, University for Development Studies, Tamale, Ghana

**Selected Presentations**

Bello-Bravo, J. 2015. Scientific Animations Without Borders: LX PCCMCA (Generación de tecnología para la innovación de la agricultura intensiva sostenible), Ciudad de Guatemala, Guatemala, May 4–8, 2015.

***Bello-Bravo, J. 2014. Scientific Animations Without Borders. Expert Consultation on Facilitating the Convergence of ICT, Rhenen, The Netherlands, October 29–31, 2014.***

Belogoun, C. R., Tamò, M, Gbedjissi G., Datinon B. and Dannon E. 2015. Etude de quelques paramètres biologiques et évaluation de capacité compétitive de *Phanerotoma syleptae* Zettel (Hymenoptera: Braconidae), parasitoïde ovo-larvaire de *Maruca vitrata* Fabricius (Lepidoptera**:** Pyralidea). 21th conference of the African Association of Insect Scientists Oct 19–23, 2015 Cotonou, Benin.

Kpongbe H., Tamò M., Datinon B. and Dannon E. 2015. Evaluation de l'effet des pheromones d'agregation de *Clavigralla tomentosicollis* et des substances volatiles produites par le niebe sur la capacite de recherche d'hote par les femelles du parasitoïde oophage *Gryon fulviventris* et la nature de cette pheromone. 21th conference of the African Association of Insect Scientists Oct 19–23, 2015 Cotonou, Benin.

Tamò, M. 2015. Climate change challenges for insect science in Africa. Plenary inaugural keynote presentation. 21th conference of the African Association of Insect Scientists Oct 19–23, 2015 Cotonou, Benin.

Tamò, M. 2015. Biological control, a pillar of sustainable agriculture in Africa. International workshop "Visions for a Sustainable Agriculture" May 4–7, 2015 Neuchatel, Switzerland.

Tamò, M. 2015. Free-air CO2 enrichment (FACE) for research on sustainable pest management in Africa. RIPE/FACE workshop, July 10–13, 2015, Urbana–Champaign, USA.

Tamò M., Onstad D., Pittendrigh B. and Agunbiade T. 2015. Resistance management prospects for the control of legume pod borer. Cowpea Project Annual Review and Planning Meeting. Jan 29 – Feb 4, 2015, Kampala, Uganda.

Tamò M., Datinon B., Dannon E., Srinivasan R., Pittendrigh B., Dabire C., Baoua, I., Braimah H. and Asante S. 2015. Challenges and opportunities for biological control of cowpea pests in Africa. XVIII International Plant Protection Congress, Oct 24–27, Berlin, Germany.

**Publications**

Agunbiade, T.A., B.S. Coates, B. Datinon, R. Djouaka, M.-R. Tsai, W. Sun, M. Tamò, and B. R. Pittendrigh. 2014. Genetic differentiation among Maruca vitrata F. (Lepidoptera: Crambidae) populations on cultivated cowpea and wild host plants: Implications for insect resistance management and biological control strategies. PLoS ONE 9(3): e92072.

Agunbiade, T.A., B.S. Coates, W. Sun, M.-R. Tsai, M.C. Valero, and B.R. Pittendrigh. Defining the species complex of the legume pod borer, Maruca vitrata (Lepidoptera: Crambidae), by comparative mitochondrial phylogenomics. Submitted.

Bello-Bravo, J., and B.R. Pittendrigh. 2014. Scientific Animations Without Borders: Entomological origins and cross-discipline impact. Entomology Society of Canada Bulletin, 46(1): 31–36.

Ihm, J., M. Pena-Y-Lillo, K. Cooper, Y. Atouba, M. Shumate, J. Bello-Bravo, M. Ba, C. Dabire-Binso, and B. Pittendrigh. 2015. The case for a two-step approach to agricultural campaign design. Journal of Agricultural & Food Information, 16: 203–220.

Ihm, J., M. Shumate, J. Bello-Bravo, N. Ba, C. Dabire-Binso, and B. Pittendrigh. 2014. Variance of cognitive social structures between farmers and extension agents in Burkina Faso. VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations, 25(5). Digital Object Identifier (DOI) 10.1007/s11266-014-9515-5

Sokame, B. M., A. K. Tounou, B. Datinon, E. A. Dannon Elie, C. Agboton, S. Ramasamy, B.R. Pittendrigh, and M. Tamò. 2015. Combined activity of the Maruca multinucleopolyhedrovirus, MaviMNPV and oil from neem, Azadirachta indica Juss and Jatropha curcas L., for the control of cowpea pests. Crop Protection 72: 150–157

Toffa Mehinto, J., Atachi, P., Elegbede, M., Douro, K., Tamò, M. 2015. Efficacité comparée des insecticides de natures différentes dans la gestion des insectes ravageurs du niébé au Centre du Bénin. J. Appl. Biosci. 84:7695– 7706.

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

# XII. Data Management

We are currently amassing a list of all published and unpublished work that will need to fit under this category and laying out an action plan to make sure all is in order with data sharing. We have already made all genomics data, associated with genomics-oriented publications, available through online databases as required by each journal and the respective repository number are given in respective papers.

# ANNEXES

**Annex 1. Tables, Figures, and Photos Cited in the Report**

N/A

**Annex 2. Literature Cited**

N/A

# Milestones

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**

**Report on the Achievement of "Milestones of Progress"**

**(For the Period: April 1, 2015 -- September 30, 2015)**

**This form should be completed by the U.S. Lead PI and submitted to the MO by October 16, 2015**

***Project Title:*** **in Africa**

| | Abbreviated name of institutions | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | UIUC | | | IITA | | | INERA | | | INRAN | | | INRAB | | | CRI | | | SARI | | |
| | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | |
| ***Milestones by Objectives*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** |
| | *(Tick mark the Yes or No column for identified milestones by institution)* | | | | | | | | | | | | | | | | | | | | |
| **Objective 1** | **Characterize Smallholder Farmers' Motivations, Current Knowledge and Practices** | | | | | | | | | | | | | | | | | | | | |
| 1.1 Insect scouting | | | | X | X | | X | X | | X | X | | | | | X | X | | X | X | |
| 1.2 Molecular analysis | X | X | | | | | | | | | | | | | | | | | | | |
| **Objective 2:** | **Develop and Refine Models about Smallholder Bean Farmers' Decision Making** | | | | | | | | | | | | | | | | | | | | |
| 2.1 Biocontrol agent study/release Maruca | | | | X | X | | X | X | | X | X | | | | | | | | | | |
| 2.2Thrip parasitoid | | | | X | X | | X | X | | X | X | | | | | X | X | | X | X | |
| 2.3Egg parasitoid | | | | X | X | | | | | | | | | | | | | | | | |
| 2.4 Bio-pesticide production | | | | X | X | | X | X | | X | X | | | | | | | | | | |
| 2.5 Resistant/tolerant varieties | | | | | | | X | X | | X | X | | | | | | | | | | |
| 2.6 | | | | | | | | | | | | | | | | | | | | | |
| **Objective 3:** | **Develop and Validate Diagnostic and Decision Support Aids** | | | | | | | | | | | | | | | | | | | | |
| 3.1 Inoculative release of natural enemies | | | | X | X | | X | X | | X | X | | | | | X | X | | X | X | |
| 3.2 Development&Investigations of Education | X | X | | X | X | | X | X | | X | X | | | | | | | | | | |
| 3.3 Involving private sector and NGO | X | X | | X | X | | X | X | | X | X | | | | | X | X | | X | X | |
| 3.4 Understanding the potential for scaling | X | X | | X | X | | X | X | | X | X | | X | X | | | | | | | |

## Milestones, continued

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Objective 4:** | **Develop and Assess Effectiveness of Innovative Approaches for Dissemination** | | | | | | | | | | | | | | | | | | | | |
| 4.1 Student training | X | X | | X | X | | X | X | | X | X | | X | X | | X | X | | X | X | |
| 4.2 ICT training tools | X | X | | X | X | | | | | X | X | | | | | | | | | | |
| 4.3 Technicican training | | | | X | X | | X | X | | X | X | | | | | | | | | | |
| 4.5 Farmer Field Flora/Farmer Training/Training of trainers | | | | | | | X | X | | X | X | | | | | X | X | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Name of the PI reporting on milestones by institution** | Barry Robert Pittendrigh | Manuele Tamò | Clementine Dabire | Eustache Biaou | Laouali Amadou/Baoua | Haruna Braimah | Stephen Asante |
| **Signature/Initials:** | | | | | | | |

| | |
|---|---|
| **Name of the U.S. Lead PI submitting this report to the MO** | Barry Robert Pittendrigh |

**Signature**

###### **Date**

###### **Date**

# Performance Indicators

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**
**PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 13 (Second Semester only), FY 14, FY 15, FY 16 and FY 17**

**Project Name:SO1.B1 IPM-omics: Scalable and sustainable biological solutions for pest management of insect p**

**Summary of all institutions**

| Indic. numbe | Output Indicators | FY 13 Target (only April 1, 2013 - September 30, 2013) | FY 13 Revised | FY 13 Actual | FY 14 Target (October 1, 2013 - September 30, 2014) | FY 14 Revised | FY 14 Actual | FY 15 Target (October 1, 2014 - September 30, 2015) | FY 15 Revised | FY 15 Actual | FY 16 Target (October 1, 2015 - September 30, 2016) | FY 16 Revised | FY 16 Actual | FY 17 Target (October 1, 2016 - September 30, 2017) | FY 17 Revised | FY 17 Actual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.5.2(6) Degree Training: Number of individuals who have received degree tr | 0 | 0 | 0 | 1 | 0 | 0 | 15 | 31 | 31 | 16 | 17 | 2 | 18 | 17 | 0 |
| | Total number by Sex | 13 | 0 | 0 | 15 | 0 | 1 | 16 | 31 | 31 | 17 | 19 | 2 | 19 | 18 | 0 |
| | Number of women | 7 | 0 | 0 | 9 | 0 | 0 | 9 | 18 | 18 | 9 | 11 | 1 | 10 | 10 | 0 |
| | Number of men | 6 | 0 | 0 | 6 | 0 | 1 | 7 | 13 | 13 | 8 | 8 | 1 | 9 | 8 | 0 |
| | Numbers by New/Continuing | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 31 | 31 | 17 | 19 | 2 | 19 | 18 | 0 |
| | Number of New | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 16 | 16 | 4 | 4 | 1 | 3 | 2 | 0 |
| | Number of Continuing | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 15 | 15 | 13 | 15 | 1 | 16 | 16 | 0 |
| 2 | term training | | | | | | | | | | | | | | | |
| | Total number | 219 | 0 | 0 | 5444 | 0 | 0 | 11354 | 11349 | 11349 | 11356 | 11356 | 0 | 11356 | 11174 | 0 |
| | Number of women | 77 | 0 | 0 | 2692 | 0 | 0 | 5691 | 5696 | 5697 | 5693 | 5693 | 0 | 5692 | 5611 | 0 |
| | Number of men | 142 | 0 | 0 | 2752 | 0 | 0 | 5663 | 5653 | 5652 | 5663 | 5663 | 0 | 5664 | 5563 | 0 |
| | Numbers by Type of individual | 221 | 0 | 0 | 5444 | 0 | 0 | 11354 | 11381 | 11388 | 11356 | 11356 | 0 | 11356 | 11174 | 0 |
| | Producers | 122 | 0 | 0 | 5134 | 0 | 0 | 10694 | 10773 | 10774 | 10695 | 10695 | 0 | 10694 | 10604 | 0 |
| | People in government | 35 | 0 | 0 | 58 | 0 | 0 | 153 | 120 | 120 | 155 | 155 | 0 | 155 | 124 | 0 |
| | People in private sector firms | 18 | 0 | 0 | 34 | 0 | 0 | 144 | 125 | 125 | 145 | 145 | 0 | 146 | 116 | 0 |
| | People in civil society | 46 | 0 | 0 | 218 | 0 | 0 | 363 | 363 | 369 | 361 | 361 | 0 | 361 | 330 | 0 |
| 3 | 4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III) | 36 | 0 | 0 | 38 | 0 | 0 | 36 | 37 | 37 | 31 | 31 | 0 | 31 | 11 | 0 |
| | Phase 1: Number of new technologies or management practices under research as a result of USG assistance | 22 | 0 | 0 | 19 | 0 | 0 | 15 | 16 | 16 | 13 | 13 | 0 | 13 | 3 | 0 |
| | Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance | 13 | 0 | 0 | 16 | 0 | 0 | 14 | 16 | 16 | 12 | 12 | 0 | 12 | 3 | 0 |
| | Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance | 1 | 0 | 0 | 3 | 0 | 0 | 7 | 8 | 8 | 6 | 6 | 0 | 6 | 5 | 0 |

**Notes:**

These indicators are developed under the Feed the Future Monitoring System. Please provide 'total' numbers and also disaggregate where applicable. Just providing 'totals' will not be approved.

This table corresponds to the Feed the Future Performance Indicators data collection sheet under the FTFMS system. Where an indicator does not apply to the type of work done under the project, leave it blank.

Please follow the indications in the Legume Innovation Lab Indicators Handbook that will be provided to you by the Management Office. Contact Mywish Maredia (maredia@anr.msu.edu) for further information.

There is additional guidance on the USAID/Microlinks website: http://agrilinks.org/sites/default/files/resource/files/FY14%20FTFMS%20Guidance_2.pdf

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


## Lead U.S. Principal Investigator and University

Robert Mazur, Iowa State University

## Collaborating Host Country and U.S. PIs and Institutions

Moses Tenywa, Makerere University, Uganda
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## I. Abstract of Research Achievements and Impacts


The team analyzed physical and chemical properties of black, red and stony soil samples from farmers' fields in study communities in key bean production districts in Uganda (Masaka and Rakai) and Mozambique (Gurué). Results guided nutrient omission studies which revealed effects of N, P, K, Mg, Ca, S, and micronutrients on bean plant growth and development; this was complemented with lime requirement studies. Researcher-managed field trials conducted during two seasons used farmer-preferred and researcher-selected bean varieties. Treatments included seeding density, weeding frequency, P, Ca, Mg, Rhizobia, organic fertilizer, and seed and foliar fungicides. Analyses of farmers' resource endowments and social capital guide how we facilitate learning through on-farm experiments and farmer-selected field trials and demonstrations. We are compiling and analyzing data on weekly market prices and marketing patterns. We developed an animated video useful to farmers and for our research in Mozambique comparing the efficacy of three training methods. We assist two emerging multistakeholder bean value chain innovation platforms in Masaka and Rakai districts which share interests, concerns and strategies to address bean productivity and marketing constraints. They participate in project research and training, and will be important in development, testing, disseminating and using our diagnostic and decision support aids.


## II. Project Problem Statement and Justification

Poor soil fertility is a major factor in low bean yields in Uganda and Mozambique, important Feed the Future countries. Both countries have weak extension systems, limiting widespread access to information and materials that enable smallholder bean farmers to improve crop management practices, technologies and yields. This research project is based on two premises: (1) sustainable intensification of agriculture production requires improved soil fertility management in which legumes are an integral part of cropping systems and (2) effectively addressing soil-related constraints involves enhancing smallholder farmers' capabilities in diagnosing and finding solutions to yield constraints, as well as helping to remove barriers to increased access to various types of soil amendments.

Analyses of soil physical and chemical properties, combined with field trials, are revealing soil-specific effects of macro- and micronutrients on bean plant growth and development. Our documentation and analysis of farmers' cropping systems, practices and technologies – and their resource endowments, is essential for identification of strategies likely to be used to address key constraints.

Working with farmer groups and members of multistakeholder bean value chain innovation platforms enables us to engage producers in field experiments that test and demonstrate the impact of the most promising management practices and technologies for improved bean production, and helps researchers learn about critical social, economic, and cultural factors that impact crop management decisions. Our research approach is generating practical results; strengthening social cohesion; collectively transforming farmers' knowledge, beliefs and actions; and stimulating interest among other farmers in learning from trials and demonstrations.

The project team 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 which contribute to higher productivity of beans and associated crops and, over time, to improved soil fertility. We are assessing 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.

# III. Technical Research Progress

**Objective 1: Characterize Farmers' Practices, Problem Diagnoses and Solutions**

Farming system parameters in Uganda and Mozambique have some features in common, but also some significant differences. It will be important to incorporate an understanding of this in our models of decision making. In Uganda, median farm size is 3 acres, with 0.5 acres in beans in both growing seasons. *Food security* crops are cassava (85%), beans (81%), maize (69%), sweet potatoes (53%), and bananas (41%). *Income crops* are beans (72%), maize (64%), coffee (42%), cassava (26%), and groundnuts (22%). In Mozambique, median farm size is much larger – 8.5 acres (3.5 hectares), with 1.7 acres (0.7 ha) in beans during the rainy season and 1.25 acres (0.5 ha) in the dry season. *Food security* crops are maize (100%), cassava (74%), beans (71%), sorghum (25%), and rice (18%). *Income crops* are beans (94%), maize (55%), cassava (35%), soybean (31%), and pigeon pea (22%).

In both countries, most (90%) farmers practice crop rotation in fields where beans are grown. Soil erosion problems are recognized by 70% of farmers in Uganda and 62% in Mozambique. Bean production constraints reflect different emphases in Uganda and Mozambique during the baseline survey in 2014. In Uganda, the major constraints – in descending order, are heavy rains, pests, low soil fertility, insufficient labor, diseases, and lack of improved seed. In Mozambique, the most pressing problems are lack of improved seed, pests, insufficient labor, diseases and low soil fertility. Hiring labor is much more common in Uganda (45%) than in Mozambique (21%). Livestock are more common in Uganda (93%) compared to Mozambique (58%); in Uganda, the most common are chickens (83%), pigs (62%), goats (42%), and cattle (33%), while in Mozambique only chickens (56%) are common. In terms of well-being, food security is a more pervasive problem in Mozambique, with 32% of households having experienced times without enough food to eat during the four weeks preceding the survey, compared to 13% in Uganda.

Following our initial scientist-managed field experiments on farmers' fields with the most common soil types for bean production, our research team in Uganda has been actively engaging the wider community involved in all aspects of bean production and marketing. Multistakeholder bean Innovation Platforms (IPs) – comprised of farmers, input dealers, traders, credit institutions, and former extension agents – are developing in Masaka and Rakai. Goals for IPs include enhancing farmers' interaction, learning, information access and decision making. Through them, our research team is sharing information, experiences and ideas on how to improve the bean value chain, engaging members in the project's on-farm research trials and demonstrations that foster collaborative learning, providing training, and improving bean marketing practices. IP processes involve joint planning and activity coordination with other stakeholders in the districts.

This project-facilitated initiative is essential in Uganda, where district agricultural outreach is characterized by a shortage of personnel, training materials, and transportation, resulting in infrequent interaction with farmers. Technical support for farmers from government extension services is even more limited in Mozambique. The recent restructuring of Uganda's National Agriculture Advisory Services has further exacerbated the problem; all subcounty extension agents have been laid off. The new government program 'Operation Wealth Creation' involves the military in distributing seeds to farmers for priority crops, with no advanced training or advisory services. Externally funded projects and NGOs have central roles in providing extension services to farmers at the district level, but their funding, scope and lifespans are limited. Thus, initiating and strengthening local community members and organizations that comprise IPs are essential for meaningful and sustainable improvement in bean production and marketing. Many farmers use income from bean production to pay for their children's education and to invest in agriculture. Project training activities have covered IP management, leadership, governance—including team and partnership dynamics, and leveraging of common resources while meeting each other's interests in the IP. Social capital, in the form of membership in a farmer or development group, is much more common in Uganda (50%) compared to Mozambique (4%) based on the baseline survey in 2014.

Through the IPs, eight field trials approximately one acre in size have been established in Masaka (n=3) and Rakai districts (n=5). Farmers, extension workers, students and scientists have been involved in site selection and sampling of soils for the field trials by soil type, cropping and fertilizer use history and accessibility. Farmers freely provided the land and have been involved in setting up trials using an improved bean variety (NABE 17) with organic and inorganic fertilizers, management (weeding, spraying) and evaluation (field observations) of crop development at different stages. Men, women and youths were involved in setting up field experimentation trials. These trials serve as learning sites for approximately 30 neighboring farmers at each site. Inputs for each learning site including bean seed, poultry manure, inorganic fertilizers and extension support have been collectively financed and supported by members of the IP, including three nonprofit organizations and the research project team. Development of IPs and their members' interactions with research team members have significantly increased farmers' interest in project research. Preliminary results from initial on-farm trials on the various soil types and tentative implications for improved soil management were shared with farmers during IP meetings in both districts. In Masaka district, farmers requested that another set of trials be run before recommendations can be fully considered and scaled out to other farmers.

The past year in Mozambique has deepened the research team's appreciation of soil-related dynamics. As reported last year, farmers locally considered to be 'innovative' in Mepuaguía identify three types of soils based on their color and by the crop typically planted on that soil that is likely to succeed: (1) Ekotchokwa is red soil, the dominant one at the summit of the terrain which is also found on the back slope; (2) Epupu is black soil, found in small patches at the summit; and (3) N'tchokwa is black soil in the basin. Red soils do not typically exist in the toe slope position; in field observations in June 2015 indicated there was significant evidence of red soil near toe slopes, almost certainly due to major erosive events that transported substantial amounts of soil from the back slope and possibly summit topographic positions with the extreme rains of early 2015 (major supply roads were cut due to bridge washouts). Farmers reported that on the red soils of the summit there is almost no crop grain yield when beans (*Phaseolus vulgaris* L.) are planted. Consequently, on such soils, cassava (*Manihot esculenta)* is planted and more recently pigeon pea (*Cajanus cajan*). This represents an opportunity for the project to illustrate that with appropriate crop and soil management beans can be grown on such positions. In the majority of our recent cropping experiments in Gurué, there is a near ubiquitous response of beans to the addition of nitrogenous fertilizers.

Pulses are usually grown on summit positions of the landscape. Farmers appear to be aware of the problems of erosion and tend not to plant food crops on backslope positions. The backslope may be sandy; if so, it is often planted with pineapple (*Ananus comosus*). The backslope may be comprised of the Ekotchokwa and Epupu soils. In the basin position (typically the N'tchokwa soils), rice is planted during the rainy season, November to February, in rotation with beans during the dry season. During the dry season the summit position soils may be in a relay cropping of maize and climbing bean (locally called 'antenna' bean) during the cold months of June and July. Rice straw is often burned prior to planting beans on N'tchokwa soils.

**<u>Objective 2: Develop and Refine Models of Smallholder Bean Farmers' Decision Making</u>**

Farmers are aware of the different types of soils, their physical properties and their productivity/suitability for different uses. They also know the rainfall patterns in their locations, but are less precisely aware of soil nutrients and pest and disease control regimes. They learn from fellow farmers, extension workers and researchers. Once a given practice is viewed as beneficial and affordable, an innovation's adoption or adaptation depends on its compatibility with their landscape and farming system, its relative advantage (local availability, benefit-cost analysis, multifunctionality), their ability to experiment with the practice, and their household resource endowment. Farmers generally understand the advantages of using good agronomic practices such as timely planting, line planting, fertilizer application, and pest and disease control regimes, and they are concerned with the costs and labor involved in using a given practice.

Upon completion of current on-farm trials and the participatory learning that is an integral part of our research, farmers will be able to decide which soil amendment inputs and practices to adopt or adapt for continued use according to soil type, farming system parameters, resource endowments, and their goals and priorities. Our ongoing analyses regarding farmers' assets (land, livestock, labor, tools, finance, etc.) will be instrumental in identifying differentiated strategies; our baseline household surveys covered 302 households in Uganda and 305 households in Mozambique. In-depth qualitative research in Uganda has revealed that farmers have adopted and adapted strategies to enhance productivity that are appropriate to their socioeconomic circumstances. Farmers constrained in terms of labor and credit access have adapted reciprocal labor sharing approaches as well as saving and borrowing money through village associations and 'merry-go-round' groups, respectively. Interventions targeted to such farmer adaptions will be important in promoting soil and water conservation practices such as timely weeding, planting, application of animal manure and complementing with inorganic fertilizers (Bwambale 2015).

Continued development and effective functioning of Innovation Platforms will be especially important as farmers improve their bean production and soil fertility management. Farmers in Uganda and Mozambique are interested in producing more beans for the market as an important source of income, but nearly all in Uganda (92%) and Mozambique (82%) cite low prices—usually at farm gate—as a major constraint; faulty weighing scales are also a serious problem. Nearly all households sell beans as individuals, with one-half selling at the farm gate. Households in Uganda obtain bean market price information primarily from traders (75%), though some contact fellow farmers (19%) or listen to the radio (14%). In Mozambique, the emphasis is somewhat different: traders (48%), fellow farmers (12%), and the radio (24%).

Arrangements for collective bean marketing linked to markets will be introduced to farmers via the IPs. Several IP members are preparing to train farmers about new market opportunities and how to access them. Arrangements are underway for IPs to formally register as cooperatives. Some IP members are preparing to conduct additional field trials with other bean seed varieties and farm inputs at their own cost, with participation of IP member farmers. IP members in Rakai have accessed improved bean seed from CEDO (Community Enterprises Development Organisation), paying back after harvest. CEDO has offered IP member farmers the opportunity to grow bean seed on a contract arrangement to expand the local supply of quality seed.

In Uganda and Mozambique, the project team is tracking bean prices in local and regional markets on a weekly basis. In Uganda, there are few resources to assist farmers in their marketing pursuits; the District Commercial Officers (DCOs) in Rakai and Masaka each have two staff responsible for 6 and 21 parishes, respectively, to oversee and provide training and support for marketing. DCOs lead weekly one hour radio programs on Radio BUDDU to provide information to farmers about a variety of relevant topics (agricultural management practices, expiration dates of agricultural chemicals, etc.). They also collect weekly commodity market prices which are posted on bulletin boards at subcounty level. We are analyzing baseline household survey data to understand the demographics, production assets and practices, marketing practices, etc. of farmers who received the highest prices for their marketed beans; we expect that this will help us identify strategies that other farmers might adopt or develop. Most farmers lack reliable storage capability and therefore sell their beans soon after harvest. Farmers greatly appreciated the training provided by project researchers in mid-2015 on anaerobic storage (triple bagging and jerry cans) which can allow them to safely store their beans as seed, grain for consumption, and marketing with minimal damage from pests.

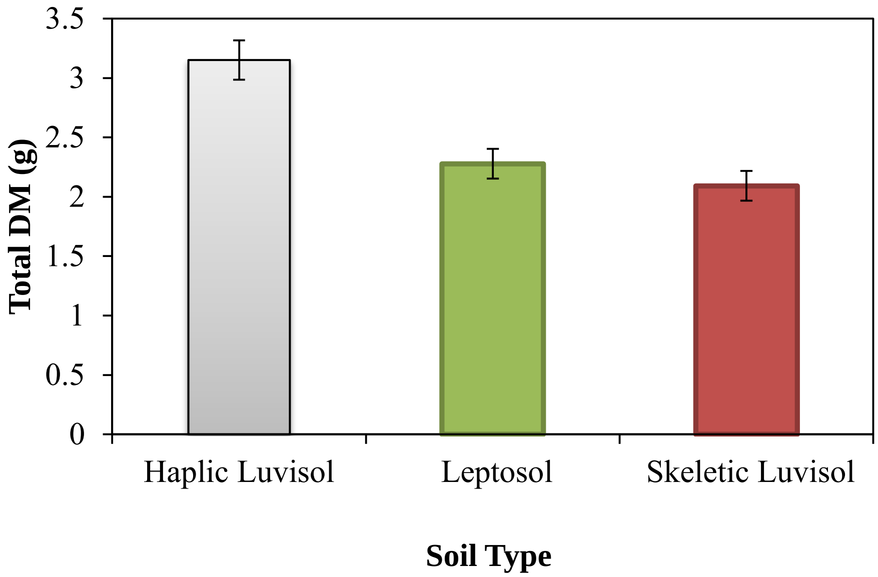
District Agricultural officers and traders cited major challenges and constraints for farmers in production, quality control and marketing of beans. Farmers will benefit from training in seed quality and the importance of single variety beans as well as in record keeping (production costs and sales). Increasing integration of capital-intensive inputs such as fertilizers, foliar spays, pesticides and fungicides into farmers cropping systems will require tracking the various costs and determining returns to investment. Such an approach will help us in developing recommen-dations that cater for heterogeneity in smallholders' resource endowments, particularly land size, livestock ownership and income. Further, in the absence of a vibrant extension service system, men do not consistently share information with women who are thus at risk of being left behind in efforts to improve agricultural practices. Women are involved in most agricultural activities but with variable access and control of household resources and decision making. Women who attend agricultural training sessions are active, with some in leadership positions.

**Objective 3: Develop and Validate Appropriate Diagnostic and Decision Support Aids**

***Uganda***. The Nutrient Omission study conducted in Uganda found the main effects of soil and nutrient omission treatment were significant for aboveground biomass accumulation of common beans, but the interaction of soil × nutrient omission was not significant (throughout this section, 'significant' differences connote $p \leq 0.05$). Plants growing in Haplic Luvisol (*Liddugavu*) accumulated significantly higher biomass than plants grown in other soil types (Figure 1). Plants grown in Haplic Luvisol accumulated 27.7 % and

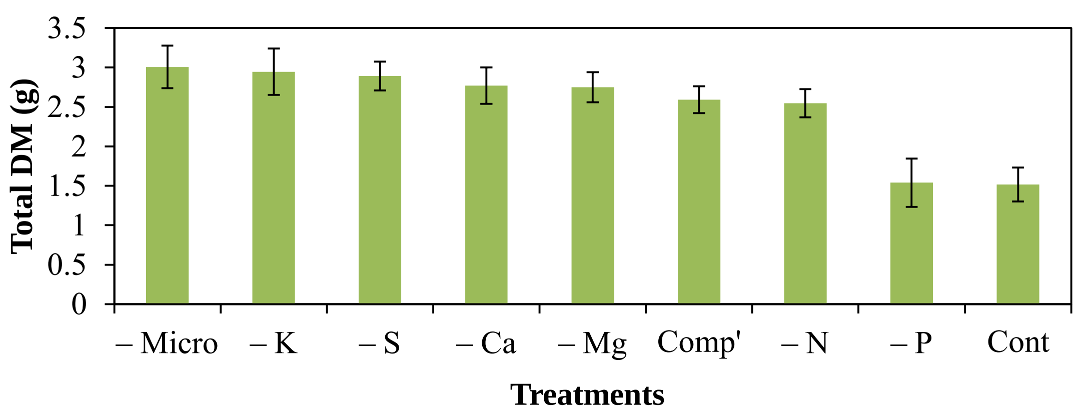
33.6 % greater aboveground biomass than those grown in Leptosol (*Luyinjayinja*) and Skeletic Luvisol (*Limufumyufu*) respectively. Although plants growing in Leptosol accumulated 8.2 % higher above ground biomass than plants growing in Skeletic Luvisol, the difference was not statistically significant (Figure 1).

***Figure 1*** *Mean aboveground biomass (g plant$^{-1}$) for common bean grown on three soils*



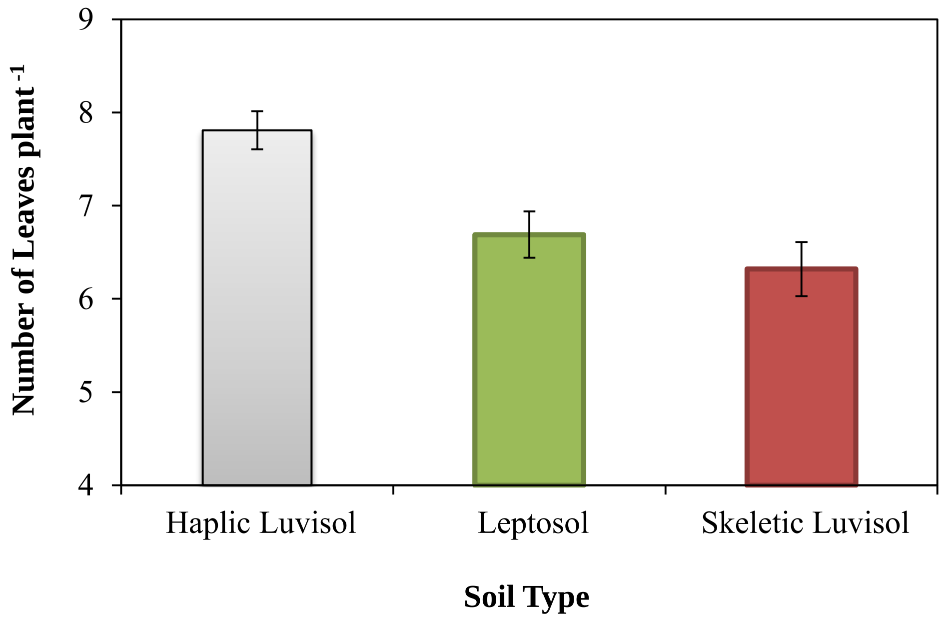

Across soil types, the 'all nutrients supplied' treatment had greater aboveground biomass than the 'phosphorus omission' and the unamended control (Figure 2). However, the 'all nutrients supplied' treatment was not different from all other omission treatments, indicating that phosphorus availability is a primary factor limiting common bean growth in predominant soils in Masaka. Beans grown in 'phosphorus omission' treatment accumulated 39.6% lower above ground biomass than those in the complete treatment. Beans grown in the control treatment accumulated 41.5% less aboveground biomass than the 'all nutrients supplied' treatment.

***Figure 2*** Mean aboveground biomass for nine fertility treatments in a nutrient omission study



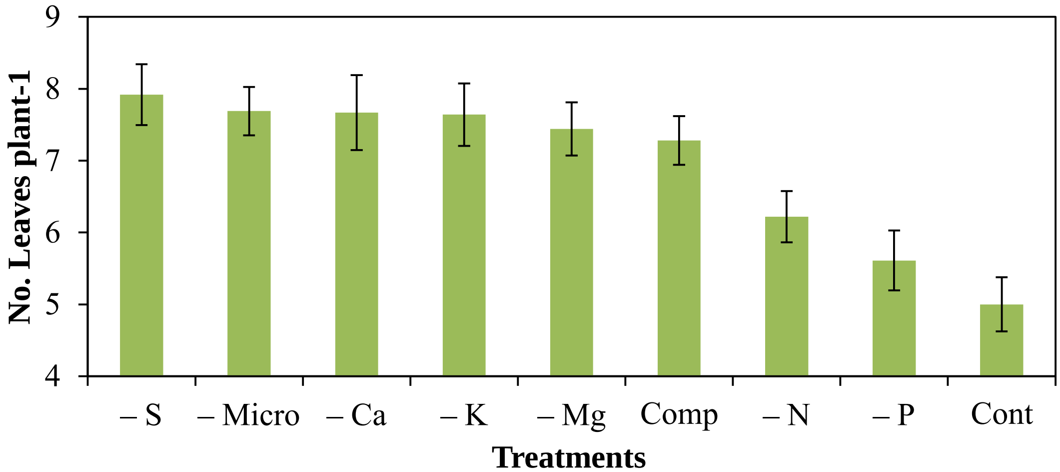

The Nutrient Omission study conducted in Uganda found that the main effects of soil and nutrient omission were significant for mean number of leaves per plant but the interaction of soil × nutrient omission treatment was not significant. Bean plants growing in Haplic Luvisol had more fully expanded leaves than plants grown in Skeletic Luvisol or Leptosol (Figure 3). Bean plants grown in Leptosol had a similar number of leaves to those grown in Skeletic Luvisol.

***Figure 3*** Mean number of fully expanded leaves per bean plant grown in three soil types




Bean plants grown in the 'all nutrients supplied' treatment had more fully expanded leaves than beans grown in the -P and -N treatment. Plants grown in the control (no nutrients added) treatment had the fewest number of fully expanded leaves, significantly fewer than the 'all nutrients supplied' plants (Figure 4). The number of fully expanded leaves in the 'all nutrients supplied' treatment was similar to that for the nutrient omission treatments for K, Ca, Mg, micronutrients, and S (Figure 4).

***Figure 4*** Mean number of leaves per bean plant for nine nutrient treatments over three soils




Our results demonstrate that the Haplic Luvisol has inherently greater fertility than the other two soils. Additionally, improved P and N availability likely will increase bean growth, development, and yield in the predominant soils in Masaka, Uganda.

We conducted a field study in Masaka District to determine whether an improved bean management system could significantly increase bean yield and profitability. The experimental design was a randomized complete block in a split-plot configuration. The main plot factor was three management systems; subplot factor was four bean varieties. Management systems (farmer management system, low-input, and high-input) differed for seed treatment (no vs. yes), seeding density (10 vs. 20 seed $m^{-2}$), plant configuration (broadcast vs. rows), liming (no vs. yes), fertilizer applications (P, K, Ca, Mg, Zn, and S), rhizobium inoculation (no vs. yes), pesticide applications (no vs. yes), and frequency and timing of weeding. Subplots were four popular varieties, the older varieties K132 (red mottled color and large seed size) and NABE 4 (red mottled color and medium seed size), and two newer varieties with improved resistance to common diseases, NABE 14 (red kidney color and large seed size) and NABE 15 (tan color and medium seed size). The study was conducted on two soil types. The black Liddugavu soil type was described as a Phaeozem using the FAO-UNESCO Soil Legend and as a Mollisols using USDA Soil Taxonomy. The red Limyufumyufu soil type was described as a Ferrosol using the FAO-UNESCO Soil Legend and as a Eutrudox using USDA Soil Taxonomy. Both soils had sandy clay loam texture. Specific fertilizer rates differed between sites due to fertility differences between soils. Farmers avoid planting bean on red soil if black soil is available due to the differences in fertility (Table 1).

***Table 1*** Postharvest soil pH, available P, K, and Ca, organic matter, and base saturation from three common bean (*Phaseolus vulgaris* L.) management systems in two soils. Masaka District, Uganda, 2014

| Property | FMS | Low-input | High-input |
|---|---|---|---|
| | Black Liddugavu | | |
| pH | 6.6 | 6.5 | 6.5 |
| P (mg $kg^{-1}$) | 27 | 32 | 27 |
| K (mg $kg^{-1}$) | 89 | 124 | 101 |
| Ca (mg $kg^{-1}$) | 1898 | 2058 | 1910 |
| OM (g $kg^{-1}$) | 39 | 34 | 36 |
| Base Saturation | 89 | 88 | 88 |
| | Red Limyufumyufu | | |
| pH | $5.2^{b}$ | $7.0^{a}$ | $7.1^{a}$ |
| P (mg $kg^{-1}$) | $4^{b}$ | $15^{a}$ | $19^{a}$ |
| K (mg $kg^{-1}$) | $49^{b}$ | $79^{a}$ | $87^{a}$ |
| Ca (mg $kg^{-1}$) | $785^{b}$ | $3138^{a}$ | $3603^{a}$ |
| OM (g $kg^{-1}$) | 38 | 37 | 39 |
| Base Saturation | $54^{b}$ | $94^{a}$ | $95^{a}$ |

Means within property and soil type followed by different letters are significantly different by protected LSD ($P<0.05$).

In 2014, management system and the management system × variety interaction were significant for bean yield on both black (Table 2) and red soil (Figure 5). On black soil in the low-input management system, NABE 4 (1475 kg $ha^{-1}$) produced greater yield than did NABE15 (1175 kg $ha^{-1}$) and K132 (1000 kg $ha^{-1}$) (Figure 6). Additionally, NABE 14 (1351 kg $ha^{-1}$) produced significantly greater yield than K132, the lowest yielding variety. Varieties did not differ for yield in the high-input management system on black soil. Averaged across varieties, beans grown on black soil under the high-input management system had seed yield of 1808 kg $ha^{-1}$, 98% greater than the farmer management system (FMS) which had yield of 912 kg $ha^{-1}$. The low-input and high-input management systems did not significantly differ in yield on black soil, producing 1238 kg $ha^{-1}$ and 1808 kg $ha^{-1}$, respectively.

***Table 2*** Yield, yield components, and pod harvest index (PHI) for bean in three management systems and four varieties for two rainy seasons on Black Soil.[a]

| Treatment | Plant stand R9 (# $m^{-2}$) | Height (cm) | Pods (# $m^{-2}$) | Seed (# $pod^{-1}$) | Seed (mg $seed^{-1}$) | Biomass (g $plant^{-1}$) | Grain (kg $ha^{-1}$) | PHI |
|---|---|---|---|---|---|---|---|---|
| Management System [b] | | | | | | | | |
| CFS | 8 b | 29 | 40 b | 2.9 | 425 | 21 | 593 b | 76 |
| IFS | 17 a | 31 | 67 ab | 2.8 | 387 | 16 | 818 b | 77 |
| HIS | 17 a | 34 | 92 a | 2.9 | 437 | 18 | 1275 a | 75 |
| Variety | | | | | | | | |
| NABE 14 | 15 a | 36 a | 90 a | 3.2 | 417 ab | 22 a | 1212 a | 73 b |
| NABE 15 | 13 b | 23 c | 52 b | 2.6 | 378 a | 18 ab | 668 c | 81 a |
| K132 | 14 a | 34 ab | 62 b | 2.8 | 431 b | 17 b | 803 bc | 74 ab |
| NABE 4 | 14 a | 32 b | 63 b | 2.9 | 439 b | 16 b | 899 b | 76 a |
| Rainy season [c] | | | | | | | | |
| 2014L | 13 b | 38 a | 91 a | 3.3 | 445 a | 27 a | 1318 a | 76 |
| 2015S | 15 a | 25 b | 42 b | 2.5 | 388 b | 9 b | 473 b | 76 |
| Significance | | | | *P* > F | | | | |
| System (S) | *** | NS | * | NS | NS | NS | * | NS |
| Variety (V) | *** | *** | *** | *** | * | * | *** | * |
| S × V | ** | NS | NS | NS | NS | NS | NS | NS |
| Rainy season (R) | *** | *** | *** | *** | *** | *** | *** | NS |
| S × R | NS | ** | * | NS | NS | ** | ** | NS |
| V × R | ** | ** | *** | *** | NS | *** | *** | NS |
| S × V × R | NS | NS | * | NS | NS | NS | * | NS |

[a] Means within treatment and column followed by the same letter , or no letter, are not different at *P*=0.05.

[b] CFS, Conventional Farmer System; IFS, Improved Farmer System; HIS, High Input System
[c] Rainy season: 2014L, long rainy season; 2015S, short rainy season.

***Figure 5*** The interaction of management system × variety × rainy season for (a) pod density and (b) grain yield of bean. Management systems include conventional farmer system (CFS), improved farmer system (IFS), and high input system (HIS) on Limyufumyufu (RED) soil

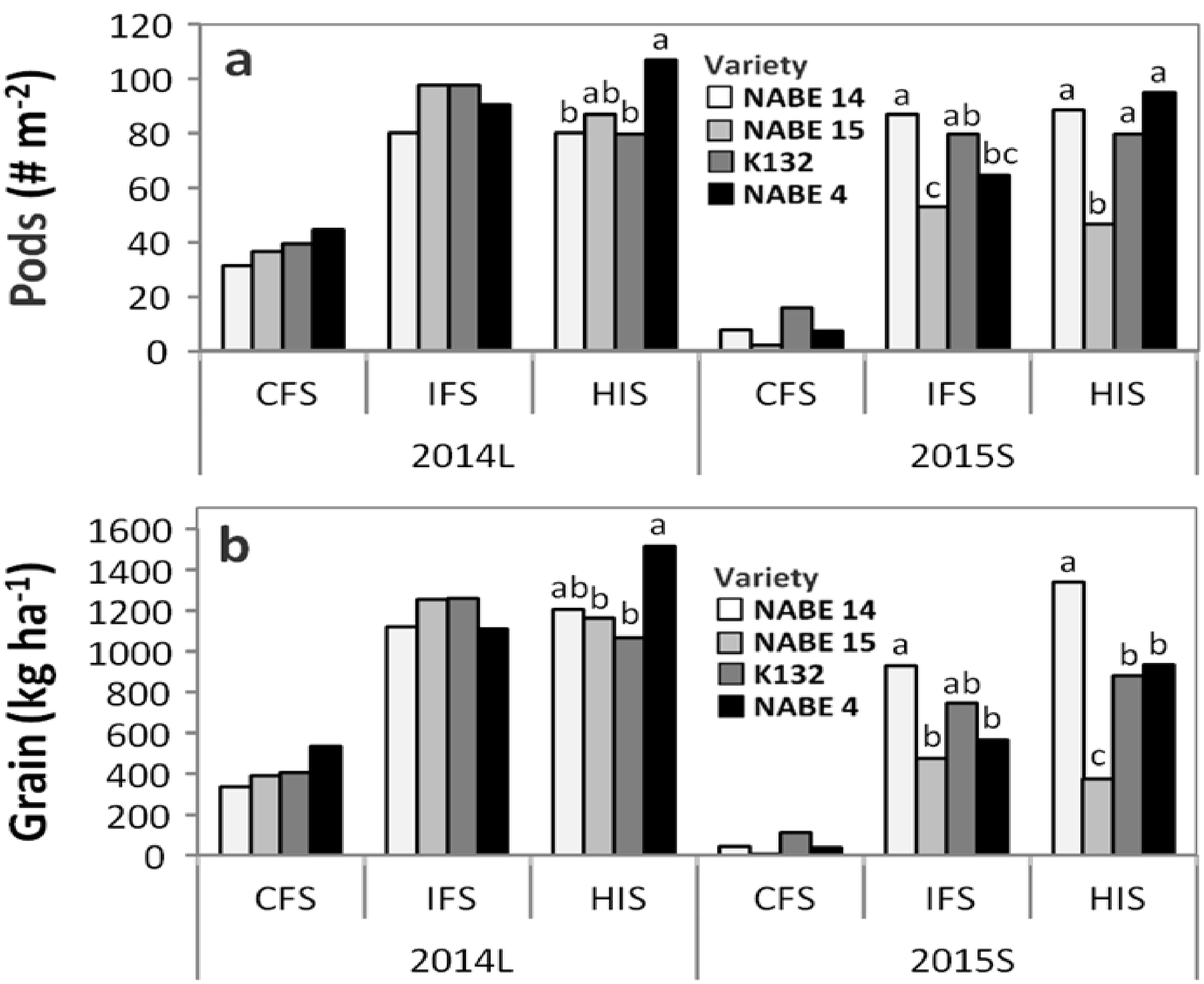
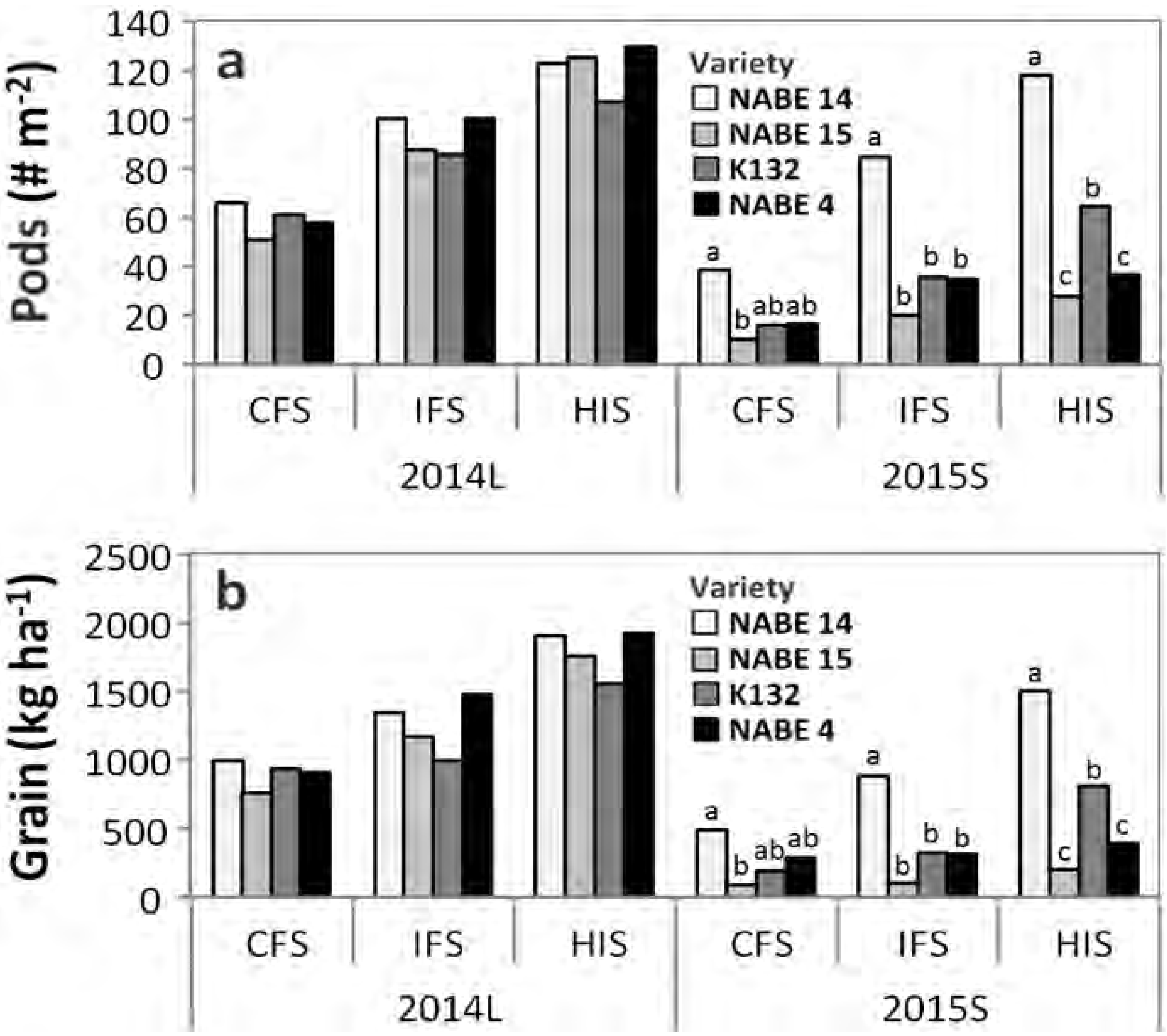


***Figure 6*** Interaction of management system × variety × rainy season for (a) pod density and (b) grain yield of bean. Management systems include conventional farmer system (CFS), improved farmer system (IFS), and high input system (HIS) on Liddugavu (BLACK) soil



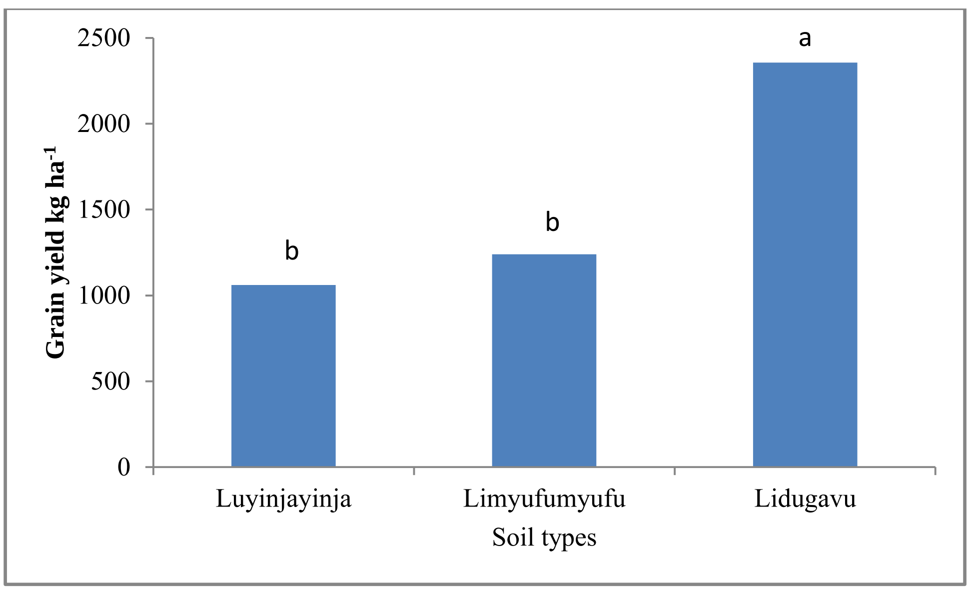

Conversely, on red soil, varieties did not differ for yield in the low-input management system. Averaged across varieties, beans grown on red soil under this system had seed yield of 1188 kg $ha^{-1}$, 184% greater than the FMS which had yield of 418 kg $ha^{-1}$. Bean varieties differed for yield in the high-input management system on red soil where NABE 4 (1516 kg $ha^{-1}$) produced significantly greater yields than NABE 15 (1163 kg $ha^{-1}$) and K132 (1068 kg $ha^{-1}$). Averaged across varieties, beans grown on red soil under the high-input management system had seed yield of 1238 kg $ha^{-1}$, 196% greater than the FMS which had yield of 418 kg $ha^{-1}$.

NABE 4 frequently produced significantly greater yields than the other bean varieties under the improved management systems. The high-input management system produced significantly greater yields than the FMS on black soil. Beans grown on red soil under either of the two improved management systems produced significantly greater yields than the FMS. After one rainy season of production, beans grown on black soil obtained the greatest profits by utilizing either of the two improved bean management systems compared to the FMS (results not presented). Conversely, beans grown on the red soils obtained the greatest profits under the FMS. On the red soil, beans grown on the improved management systems registered a net loss due to the need for greater amounts of expensive agricultural inputs to improve productivity.

Field studies to determine optimum combinations of organic and inorganic fertilizers for beans grown on three contrasting soils—black, red and gravelly—have been ongoing in Masaka since August 2014. Results to date over two seasons indicate a significant grain yield improvement following combined application of organic and inorganic fertilizers compared to either organic or inorganic application alone. These preliminary results will be compared with those during the 2015B season (Sept.–Dec.).

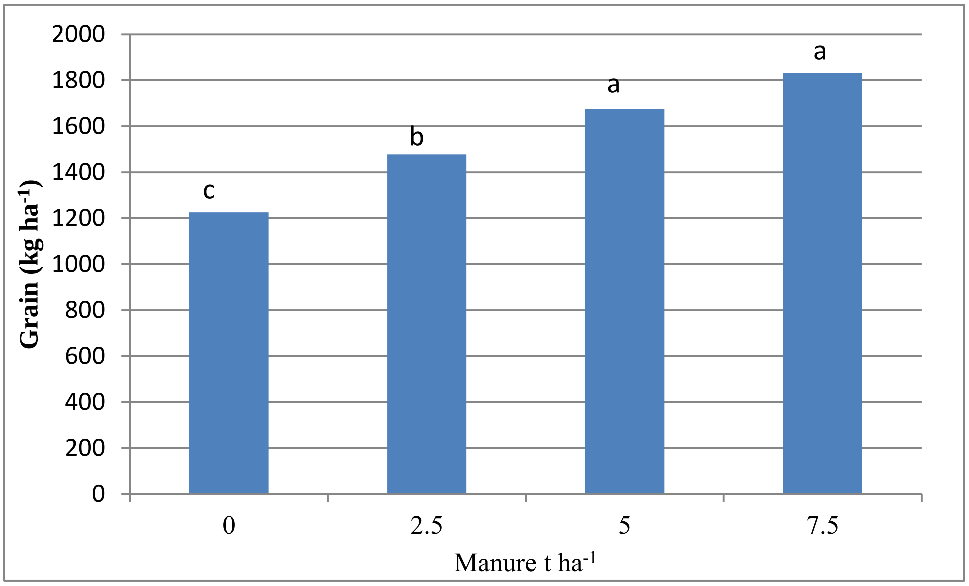
Bean (K131) grain yield for the 2014B rainy season varied for the main effects of soil type and manure rate; however, the interaction of soil type × manure rate was nonsignificant. Bean grain yield was greatest on Liddugavu soil (Figure 7). Yield of beans from Luyinjayinja and Limyufumyufu soils was similar.

***Figure 7*** Bean grain yields as affected by differences in soil types, 2014B season




Across the three soil types, bean yield was greatest for the 7.5 and 5.0 t ha$^{-1}$ manure application rates (Figure 8) which averaged nearly 1800 kg ha$^{-1}$. The 2.5 t ha$^{-1}$ manure application rate resulted in bean yield that was greater than the control where manure was not applied.

***Figure 8*** Effect of manure application on bean grain yields, 2014B season




For 2015A, main effects of soil type, manure, the two-way interaction of soil × manure, and four-way interaction of soil type × manure rate × N rate × P rate were significant for bean yield.

On the gravelly soil, application of 2.5 t manure ha$^{-1}$ (with no N or P applied) increased bean grain yield but not significantly; increasing manure rate to 5 t ha$^{-1}$ increased grain yield significantly over the control (Table 3). Application of 5 t manure ha$^{-1}$ in presence of 15 kg N ha$^{-1}$ and 15 kg P ha$^{-1}$ resulted in a significant increase in beans grain yield over the control.

***Table 3*** Effect of N, P and manure application on the bean grain yield over three contrasting soils, 2015A season

| Soil type | N (kgha$^{-1}$) | P (kgha$^{-1}$) | Manure (t ha$^{-1}$) | | |
|---|---|---|---|---|---|
| | | | 0 | 2.5 | 5 |
| | | | Grain yield (kgha$^{-1}$) | | |
| Luyinjayinja (stony) soil | 0 | 0 | 2097 | 2851 | 3209 |
| (SkeleticLixicMollicUmbrisol) | 0 | 7.5 | 2836 | 2426 | 2317 |
| | 0 | 15 | 2325 | 2488 | 2551 |
| | 7.5 | 0 | 2590 | 2664 | 2571 |
| | 7.5 | 7.5 | 2432 | 2577 | 2591 |
| | 7.5 | 15 | 2424 | 3100 | 2566 |

| | | | | | |
|---|---|---|---|---|---|
| | 15 | 0 | 3052 | 2676 | 2609 |
| | 15 | 7.5 | 2503 | 2535 | 2720 |
| | 15 | 15 | 2210 | 2086 | 3077 |
| Lidugavu (black) soil | 0 | 0 | 1920 | 2662 | 2306 |
| (Cambic LuvicPhaeosem) | 0 | 7.5 | 1605 | 2114 | 2590 |
| | 0 | 15 | 2273 | 2674 | 3251 |
| | 7.5 | 0 | 2271 | 2623 | 3136 |
| | 7.5 | 7.5 | 1715 | 3338 | 2708 |
| | 7.5 | 15 | 1947 | 2789 | 3121 |
| | 15 | 0 | 1943 | 3019 | 2516 |
| | 15 | 7.5 | 1914 | 3041 | 3019 |
| | 15 | 15 | 2005 | 3188 | 2582 |
| Limyufumyufu (reddish) soil | 0 | 0 | 2080 | 2287 | 2307 |
| (EutricSideralicCambisol) | 0 | 7.5 | 1488 | 2424 | 2091 |
| | 0 | 15 | 1739 | 1954 | 2296 |
| | 7.5 | 0 | 2191 | 2283 | 2072 |
| | 7.5 | 7.5 | 1921 | 1848 | 2159 |
| | 7.5 | 15 | 1580 | 1870 | 1974 |
| | 15 | 0 | 1926 | 2212 | 2568 |
| | 15 | 7.5 | 1736 | 1468 | 1914 |
| | 15 | 15 | 1903 | 2775 | 2020 |
| LSD | | | | 782.8 | |
| CV | | | | 20.3 | |

Bean yield from black soil responded to manure addition. Where manure was added at 5 t manure $ha^{-1}$ but no N, application of 7.5 kg P $ha^{-1}$ increased beans grain yield but not significantly; increasing the P rate to 15 kg $ha^{-1}$ significantly increased bean grain yield over the control (Table 3). Application of 5 t manure $ha^{-1}$ in presence of 7.5 kg N $ha^{-1}$ but 0 P added, resulted in a significant grain yield increment over the control. Application of 2.5 t manure $ha^{-1}$

in presence of 7.5 kg N ha$^{-1}$ and 15 kg P ha$^{-1}$ resulted in a significant increase in bean grain yield; increasing the rate to 5 t manure ha$^{-1}$ increased bean grain yield further, although not significantly from the 2.5 t manure ha$^{-1}$ rate. At 15 kg N ha$^{-1}$ and no P applied, grain yields increased significantly on addition of 2.5 t manure ha$^{-1}$. Similarly, at 15 kg N ha$^{-1}$ and 7.5 kg P ha$^{-1}$, application of 2.5 t manure ha$^{-1}$ on the black soil increased beans grain yield significantly over the control. A similar response to manure was observed on treatments with 15 kg N ha$^{-1}$ and 15 kg P ha$^{-1}$ on the black soil. On red soil, the combined application of 15 kg N ha$^{-1}$ and 15 kg P ha$^{-1}$ and 2.5 t manure ha$^{-1}$ significantly increased bean grain yield over the 0 control treatment (Table 3).

Results from the field experiments show that combined application of organic and inorganic fertilizers is more beneficial than either of organic or inorganic fertilizer applied separately. The fertilizer must be applied at planting. Timely planting is crucial. In addition regular monitoring of pests on weekly basis is essential. Timely management activities such as weed control are needed for the recommended fertilizers rates to be effective.

Through the bean Innovation Platforms, farmers are validating the preliminary fertilizer recommendations on selected fields of their choice. A total of nine trial/demonstration plots, three in Masaka and six in Rakai, were set up starting 2015B season. The rest of the management practices such as spacing were based on the scientific recommendations. The demonstrations are managed by farmers themselves, with extension workers and researchers offering requested or necessary technical advice.

***Mozambique*** – Soil acidity is a key limiting factor for crop production in highly weathered Oxisols of Gurué. Increasing crop yield with fertilizer use require soil amelioration and neutralization of potential acidity and hence improving nutrient availability. Soil samples were collected from paddy-rice production areas where beans are grown during the dry season following the rice harvest. Samples were analyzed for pH and color in the laboratory of IMAPEG (Instituto Medio Agropecúario de Gurué) in Gurué. The pH ranged from acidic (5.6–6.5) to very strongly acidic (4.5–5.5). Soil color, an indicator of soil quality, was measured with Munsell Soil-color charts (2009) in wet and dry samples. The color of wet samples color ranged from Dark Reddish Brown (5YR2, 5/2) to Black (5YR2, 5/1–5/2). When dry, the dominant colors are Brown (5YR4/4), Dark Brown (10YR 3/3) and Dark Yellow Brown (10 YR3/4–3/6). Further chemical and physical characterization will be conducted at IIAM's soil and plant tissue lab in Maputo.

Based on preliminary soil analyses, an experiment was conducted to assess the effect of limestone in combination with fertilizer and inoculant on common bean yield using a randomized complete block design in a strip-plot treatment structure with fertilizer, lime or a combination in the main plot and inoculated versus uninoculated seed in strip-plots. Agronomic and phenological data were collected and are being analyzed. Pictures were taken using HD digital camera at vegetative stage, flowering, and harvest for developing visual diagnostic and decision aids.

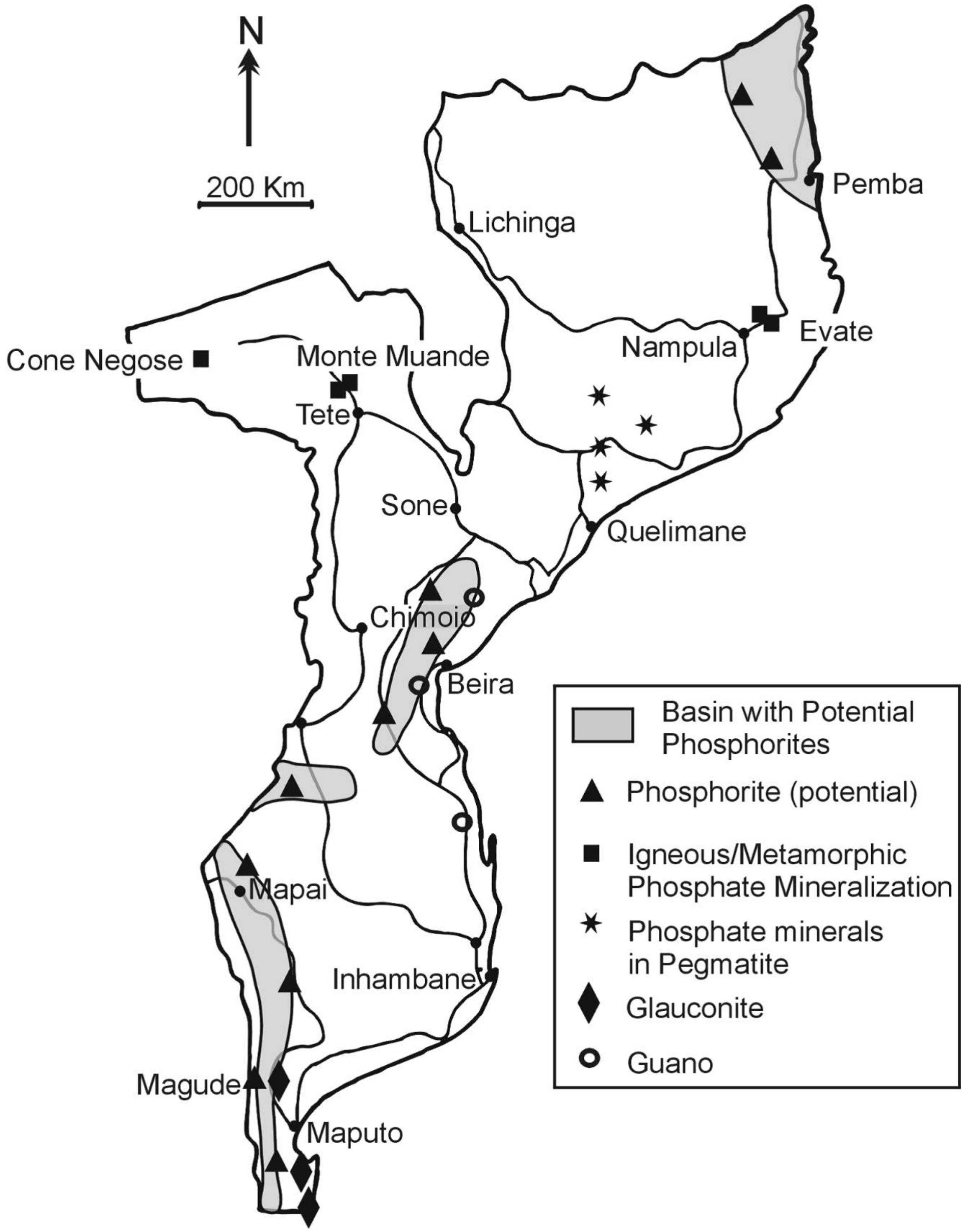
Soil fertility is a limiting factor for bean yield in Gurué exacerbated by a cyclic burning of rice straw after tilling the soil. It is generally known that P and K are the most limiting nutrients for bean production. To diagnose other limiting plant nutrients, an additional experiment was conducted on-farm in a paddy rice production system. A randomized complete block design with three replications was used in a split plot treatment structure. In one experiment, fertilizer applications were assigned to the main plot and two promising improved bean varieties were assigned to a subplot. An additional experiment with a local preferred bean variety was used with same experimental design. Tested plant nutrients were control (no fertilizer added), PK, NK, NP, NPK, NPKS, NPKS+Zn + ZnB, and 7NPKS+ ZnB. Nutrients used were Urea, Diammonium Phosphate (DAP), SOP, triple superphosphate (TSP), Muriate of Potash (MOP), Zinc oxide and Borax at 30 kg N $ha^{-1}$, 34.5 kg $P_2O_5$ $ha^{-1}$, 24.0 kg $K_2O$ $ha^{-1}$, 2.5 kg ZnO $ha^{-1}$, 0.5 kg B $ha^{-1}$. Agronomic and phenological data were collected and are being analyzed for diagnosing limiting plant nutrients and performing comparisons among treatments.

Pictures were taken in each treatment during vegetative growth, flowering and harvesting. For developing a decision aid and documenting differences in crop performance among treatments, photos were taken from horizontal, vertical positions and leaf at plot level for a single replicate. Vertical pictures will allow us to measure an index of canopy cover and leaf pictures will allow us to measure the greenness and leaf size for each given fertilizer use. A comprehensive database is being developed using MS Access as a project information management system for easy retrieval and future reference.

Soil fertility is declining due to continuous cultivation without nutrient replenishment through fertilization. Building more resilient production systems requires better understanding of farmers' constraints and opportunities for improving crop productivity. To understand farmers' perceptions about differences in crop performance for experiments and treatments, a two-day field day was organized in Mepuagíua. The aims of the field day were to create awareness among farmers about soil fertility problems through differences in crop performance; compare and contrast crop responses in different soils; exchange ideas and views among farmers, researchers, agricultural college faculty members and students, and local community leaders; and identify research issues for future study. Approximately 60 participants attended the field day which was followed by a meeting with the community to review field observations and identify how to improve implementation of project activities. During the field day, it was evident that there is a lack of understanding among farmers about basic aspects of agroecosystem of bean production, including implications of plant density for pest management and crop productivity and cause and effect of different treatments on crop performance. Farmers considered the event a learning opportunity and recommended this kind of interaction in future project activities.

There are extensive deposits of high quality rock phosphate and limestone in Mozambique, both of which are typical major inputs leading to sustainable increases in crop productivity. There are several extensive phosphate deposits of sedimentary, metamorphic and igneous origin which could be used for small-scale agromineral development. The very extensive phosphate deposit of Evate (with more than 155 million tons of phosphate-bearing ore) (van Straaten 2002) and other deposits are suitable for large-scale phosphate extraction, and perhaps small- to medium-scale development (Figure 9). With Gurué District's acid soils, the potential direct application of rock phosphate should be researched. The extensive glauconite-bearing Eocene Cheringoma Formation with fossil fish and teeth beds is another naturally occurring deposit that certainly merits further characterization (van Straaten 2002) and may provide an excellent source of potassium which also is deficient in many farmed soils in Mozambique.

Figure 9




Recent studies suggest that the Evate rock phosphate contains up to 19% phosphorus (Momade 2012). Samples of the Evate rock phosphate have been exported to Hawaiʻi and will be used for laboratory incubation studies to determine efficacy as P source for bean (Figures 10 and 11).

Figure 10

Figure 11

Limestone/dolomite resources are also abundant throughout the country (Figure 12). Given the extensive acid soils, as characterized by analysis of our data (Table 4) and reports from others, the limestone resources should be characterized for quality and quantity. Preliminary IIAM experiments indicate that extensive agricultural areas of the country are affected by low soil pH and inadequate levels of nutrients, especially phosphorus. The presence of limestone and dolomite, along with its potential provision of magnesium, present additional excellent potential benefits from wisely used local resources for local agriculture.

Figure 12


N
200 Km
Lichinga
Pemba
Nampula
Tete
Sone
Quelimane
Chimoio
Beira
Mapai
Inhambane
Maputo
Limestone and Dolomite

***Table 4***. Preliminary results of soil analysis. Gurué District Mozambique

| Location | Soil pH | Clay % | ECEC, $cmol_c\ kg^{-1}$ |
|---|---|---|---|
| Tetete | 6.2 | 12.7 | 12.7 |
| Lioma | 6.0 | 12.9 | 11.4 |
| Ruace | 6.1 | 13.3 | 13.8 |
| Mepuagiua | 5.7 | 13.3 | 6.4 |

| Location | Soil P | - - $cmol_c\ kg^{-1}$ - - | |
|---|---|---|---|
| | | K | Ca |
| Tetete | 118 | 0.71 | 9.27 |
| Lioma | 65 | 0.49 | 8.05 |
| Ruace | 165 | 0.83 | 10.2 |
| Mepuagiua | 8 | 0.31 | 3.86 |

| Location | Mg, $cmol_c\ kg^{-1}$ | OM $g\ kg^{-1}$ | N, $g\ kg^{-1}$ |
|---|---|---|---|
| Tetete | 2.17 | 40.5 | 1.5 |
| Lioma | 2.12 | 37.9 | 1.6 |
| Ruace | 2.71 | 46.3 | 1.7 |
| Mepuagiua | 1.66 | 47.3 | 1.9 |

Current experimental plans include conducting an official total analysis of the Evate rock phosphate by the International Fertilizer Development Center. A detailed analysis of the Evate rock phosphate from Eastern Nampula Province, Mozambique is underway. These studies will be conducted in collaboration with Dr. Debbie Hellums senior scientist, IFDC as well as Dr. I. Momade, IIAM, Nampula. Apparently there has never been an analysis of the heavy metal content of the Evate rock phosphate. Such an analysis is in progress and will include determination of total quantities of the heavy metals of concern: Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, and Zn. Knowledge of heavy metal concentration is necessary because some phosphate deposits have high levels of toxic Cd and Co, which can be taken up by plants and concentrated in seed. Initial laboratory incubations are designed to test a range of rates of dissolution of the apatite in the Evate rock phosphate and measure its effects on plant availability of phosphate. The possibility of evaluating the effectiveness of the addition of microorganisms (*Thiobacillus thiooxidans*) to facilitate rock phosphate dissolution is under discussion with Dr. Sounder Rajan, New Zealand. These experiments and an anticipated field experiment during the next growing season constitute a key portion of the M.S. thesis research of project trainee António Rocha.

**Objective 4: Develop and Assess Effectiveness of Innovative Approaches for Dissemination of Information and Decision Support Aids, Training, and Follow-up Technical Support**

Farmers will benefit from having a variety of means to access information to learn about ways to improve bean production, storage and marketing. This suggests considering all available information platforms to address agricultural related issues at different stages of the agricultural cycle. Established means of communication are being considered—radio programs, demonstration plots and simple training materials in the form of posters and handouts in local languages; all of these can foster information dissemination and uptake. Our project is exploring the efficacy of video, particularly animated videos.

In advance of having content based on project field results that will serve as soil fertility diagnostic and decision support aids, it is important to begin to understand communication patterns and dynamics in the study communities in both countries. For this, we enhanced training materials for a technique that was promoted in a previous project – anaerobic storage using triple bags and sealed plastic jerry cans. Prototype messages and training approaches were developed for both Uganda and Mozambique. This included two main approaches: (1) expert extension hands-on presentations in which an agent demonstrated postharvest bean storage (using triple bagging and jerry can storage in Uganda, and jerry can storage in Mozambique); and (2) video of each step of the postharvest process, and animations showing the steps of the process. In all cases, farmers viewing the training were asked to actually carry out the tasks in a demonstration following the training.

Extension training, video shot locally in the local language, and an animation developed by SAWBO (Scientific Animations Without Borders) were tested. Animations were created, reviewed by experts, and translated into the local language. In Uganda, groups of key farmers from both Masaka and Rakai were brought together for the training. In Masaka, farmers received the extension training first, and then the video and animation training. They were then asked to demonstrate what they had learned. In Rakai, farmers received the video and animation training first, and then the extension training. In both cases, farmers were asked to evaluate all forms of training, and to indicate which they preferred. In Mozambique, a field experiment was conducted with 314 randomly selected farmers from ten communities out of two different Administrative Posts in Gurué (Tetete and Mepuagiua) to compare the effectiveness of the extension-only approach and an animation approach delivered via smartphones. The animation, translated into Lomwe (see https://www.youtube.com/watch?v=ACIyKKEkpgc to view the English language version), shows the jerry can postharvest storage technique for preserving beans.

Farmers received one of three treatments: (1) extension only; (2) animation only; (3) both—the order was varied. Following all of the treatments, farmers were asked to carry out the task of filling the jerry cans with beans for storage. In both Uganda and Mozambique, beans were sealed in triple bags or jerry cans; the farmers will gather again in mid-November or December to open them and evaluate the results of the test. At that time, an assessment will be made of how many farmers have already adopted this storage technique, or plan to do so in the future.

Already, some male and female Innovation Platform farmers in Uganda have run their own experiments, and have trained other farmers in airtight storage, particularly using the jerry can method. Those passing on the knowledge to others particularly in Rakai are mainly women. In Gurué, the Administrator of the district and the local Agriculture Director met and officially authorized the research team to proceed with testing the prototype, and shared their enthusiasm and willingness to see positive results being implemented beyond randomly selected communities. Additionally, the Kings (and local leaders) of both Tetete and Mepuagíua were instrumental in providing the list of bean growing farmers region from which the 314 participants were randomly selected.

The purpose of the training was to test the communication system for reaching farmers with information about how to improve their farming or postharvest practices. In Uganda, the key farmers and innovation platform committee members attending the training will be used in future communication campaigns (via radio, smartphones, extension presentations and demonstrations) to multiply the messages. The baseline household survey documented the importance of these 'fellow farmers' in adoption of many soil fertility and bean practices in the country. Video and animations were both well-received by these farmers, so they can be included in future communication approaches. In Mozambique, early results show that the smartphone animated videos were at least as effective as the extension-only approach, and that farmers learned significantly about specific steps to follow by viewing either approach. Because of the lack of extension agents in Gurué, animations delivered by smartphones will be an important part of future communication efforts.

As other project team members identify priority messages for improvement of soil fertility and bean production in the coming six months, the communication team will create appropriate messages and message strategies building on the testing already conducted of the communication system. Although messages and approaches will depend on what is recommended and what channels are best for communicating these messages, it is expected that animations will play a role since they demonstrated their effectiveness during the trials. Communication campaigns will include multiple channels and approaches, and will be pretested with farmers and experts.

## IV. Major Achievements

- Our experiments and analyses of soils and cropping system treatments are progressing well in both countries, with clear and actionable results expected by June 2016.
- We have broadened and deepened our understanding of farmers' resource endowments and social capital; this guides how we generate interest and cooperation, and facilitate learning through on-farm experiments and farmer-selected field trials and demonstrations, and will promote adoption and adaptation of improved management practices and technologies.
- We are compiling and analyzing data on weekly market prices, and analyzing marketing patterns. This will be incorporated in development of decision support aids and training.
- Multistakeholder Bean Innovation Platforms in Masaka and Rakai are rapidly developing in membership size, diversity, enthusiasm and capability and as formal organizations.

- Our training in anaerobic storage methods (triple bags and jerry cans), using extension personnel and a newly developed animated video, meets an important need identified by farmers. In Mozambique, our research is comparing the efficacy of three training methods.

## V. Research Capacity Strengthening

The breadth of our team spans soil and crop sciences, sociology, economics, extension and communications, contributing significantly to conceptualizing our research objectives, methods, data collection, analysis and interpretation. In addition, members from various institutions and disciplines contribute significantly to mentoring and guiding the research of graduate students.

Naboth Bwambale, M.S. student in Sustainable Agriculture and Sociology at Iowa State University, defended his thesis and will graduate in December. Title: "Farmers' Knowledge, Perceptions, and Socioeconomic Factors Influencing Decision Making for Integrated Soil Fertility Management Practices in Masaka and Rakai Districts, Central Uganda."

- Prossy Kyomuhendo, M.Sc. student in Soil Science at Makerere U. conducted research in limiting nutrients and lime requirements for bean production in Leptosols and Luvisols. She submitted her thesis for examination and she is working on the paper for publication.
- Lance Goettsch, M.S. student in Crop Production & Physiology at ISU, plans to graduate in May 2016. His thesis involves two manuscripts in preparation: (1) "Practical management systems to alleviate yield constraints of common bean on Liddugavu soil in Uganda" for *Field Crops Research* and (2) "Practical management systems to alleviate yield constraints of common bean on Limyufumyufu soil" for *Field Crops Research.*
- Stewart Kyebogola, M.Sc. student in Soil Science at Makerere U., is conducting research on the effect of integrating organic with inorganic fertilizers on bean yield on three contrasting soils in Masaka district.
- Sostino Mocumbe, M.S. student in Communications at ISU, is conducting research on "Use of Animated Videos through Mobile Phones to Enhance Agricultural Knowledge and Adoption among Bean Farmers in Gúruè District, Mozambique."
- António José Rocha, M.S. student in Soil Science at U. of Hawaii, is conducting research on Alternative Management Practices for Improving Bean Production in Gurue.
- Jafali Matege, M.Sc. student in Extension Education at Makerere U., is conducting research on Gender Dimensions of Bean Farmers' Decision Making for Soil Fertility Management.
- Chrysostom Muyanja, B.Sc. Agriculture student at Makerere University, is carrying out a survey on the use of foliar fertilizers.
- Abbas Isabirye, Ph.D. student in Agricultural and Rural Innovations at Makerere University, is examining the efficacy of the bean Innovation Platforms in Masaka and Rakai.

***Short-Term Training of Technical Staff***

The project team benefitted from four Institutional Capacity Strengthening grants. The first involved close collaboration among Makerere University, Uganda's National Agricultural Research Laboratories, and the University of Hawaii. It focused on combining indigenous and scientific knowledge of soils. The second enabled the Institute of Agriculture Research of Mozambique to record, analyze and interpret GIS associated data with biophysical, economic, and social data. Work with the funds from these supplemental grants began early in 2015. The third involved training workshop for IIAM, Instituto Medio Agropecúario de Gurué (IMAPEG), UniZambeze (University of Zambézia) researchers in survey techniques to learn how farmers identify local indigenous soil types and use that information in their selection of cropping systems and crop and soil management. It also involved training on spatial data management. The fourth supported training of scientists, technicians, students and district staff in GIS and geospatial skills for distinguishing toposequencing, chronosequencing and lithosequncing of soil catena in Uganda in September 2015. Through this field and lab-based activities, trainees acquired practical skills and detailed understanding of soil variability along selected landscapes of the Buganda catena using characteristics identified locally by farmers and related it to modern scientific approaches (GIS, geostatistics and the FAO World Reference systems). Trainees also developed practical skills to enhance farmer decision making for soil fertility management through combined use of indigenous and modern scientific soil classification. Two project scientists from IIAM participated in this training. This activity is anticipated to assist in the understanding and documentation of the high importance of geomorphology and topography of soils and its importance in the farmers' classification or grouping of soils of the project villages. Knowledge gained in Uganda will enhance the training workshop for mapping indigenous soil classification in project interventions in Mozambique.

In addition, during June–August 2015, Mr. Rocha, provided supervision and training on a variety of research tasks in Gurué, Mozambique, including soil sampling and crop harvesting techniques. Eng. Ricardo Maria conducted several field demonstrations of a portable soil pH test kit to EMAPEG students. Three project graduate students at Makerere (Prossy Kyomuhendo, Stewart Kyebogola, and Jafali Matege) benefitted from training in designing and carrying out gender sensitive research under a project on Gender Responsive Researchers for Agricultural Transformation (GREAT). Dr. Richard Miiro participated in Legume Innovation Lab sponsored training in Lusaka, Zambia on impact assessment of projects.

# VI. Human Resource and Institution Capacity Development

<u>Short-Term Training</u>

***GIS and Geo-Spatial Skills***

1. **Purpose of Training:** GIS and geospatial skills
2. **Type of Training:** computer lab and field observations
3. **Country Benefitting**: Uganda
4. **Location and Dates of Training:** Kampala, Masaka and Rakai; Sept. 2015
5. **Number receiving training (by gender):** 10 female, 24 male
6. **Home institution(s):** Makerere University and National Agric. Research Lab.
7. **Institution providing training:** Iowa State University and Makerere University
8. **Spatial Data Management:**
9. **Purpose of Training:** indigenous soil types and spatial data management
10. **Type of Training:** computer lab and field observations
11. **Country Benefitting**: Mozambique

12. **Location and Dates of Training:** Mocuba; June 2015
13. **Number receiving training (by gender):** 6 female, 26 male
14. **Home institution(s):** Institute of Agricultural Research of Mozambique
15. **Institution providing training:** U. of Hawaii & Instit. Ag. Research of Mozambique

***Innovation Platform***

1. **Purpose of Training:** innovation platform strengthening
2. **Type of Training:** participatory methods
3. **Country Benefitting:** Uganda
4. **Location and Dates of Training:** Masaka and Rakai; ongoing
5. **Number receiving training (by gender):** 58 female, 79 male
6. **Home institution(s):** Makerere University and National Agric. Research Lab
7. **Institution providing training or mechanism:** Makerere University, National Agricultural Research Laboratories, Iowa State University & University of Illinois

**Degree Training**

*Trainee #1*
**Name:** Naboth Bwambale
**Citizenship:** Uganda
**Gender:** Male
**Training institution:** Iowa State University
**Supervising Legume Innovation Lab PI:** Robert Mazur
**Degree Program for training:** M.S.
**Program Areas or Discipline:** Graduate Program in Sustainable Agriculture *and* Sociology
**If enrolled in the US, is Trainee a USAID 'Participant Trainee' and registered in TraiNet?** Yes
**Host Country Institution to Benefit from Training:** Makerere University
**Thesis Title/Research Area:** Farmers' Knowledge, Perceptions, and Socioeconomic Factors Influencing Decision Making for Integrated Soil Fertility Management Practices in Uganda
**Start Date:** August 2013
**Projected Completion Date:** December 2015
**Training Status:** (active, completed, pending, discontinued or delayed): Active
**Type of USG Support (full, partial or indirect) for training activity:** Full

*Trainee #2*
**Name:** Lance Goettsch
**Citizenship:** United States
**Gender:** Male
**Training institution:** Iowa State University
**Supervising Legume Innovation Lab PI:** Andrew Lenssen
**Degree Program for training:** M.S.
**Program Areas or Discipline:** Agronomy
**If enrolled in the US, is Trainee a USAID 'Participant Trainee' and registered in TraiNet?** No
**Host Country Institution to Benefit from Training:** Makerere University
**Thesis Title/Research Area:** Practical Methods to Alleviate Constraints Limiting Common Bean

Production in Masaka, Uganda
**Start Date:** August 2013
**Projected Completion Date:** May 2016
**Training Status:** (active, completed, pending, discontinued or delayed): Active
**Type of USG Support (full, partial or indirect):** Partial

*Trainee #3*
**Name:** Prossy Kyomuhendo
**Citizenship:** Uganda
**Gender:** Female
**Training institution:** Makerere University
**Supervising Legume Innovation Lab PI:** Moses Tenywa
**Degree Program for training:** M.S.
**Program Areas or Discipline:** Soil Science and Crop Production
**If enrolled in the US, is Trainee a USAID 'Participant Trainee' and registered in TraiNet?** N/A
**Host Country Institution to Benefit from Training:** Makerere University
**Thesis Title/Research Area:** Limiting Nutrients and Lime Requirements for Bean Production
**Start Date:** January 2014
**Projected Completion Date:** August 2016
**Training Status:** (active, completed, pending, discontinued or delayed): Active
**Type of USG Support (full, partial or indirect) for training activity:** Partial

*Trainee #4*
**Name:** Sostino Mocumbe
**Citizenship:** Mozambique
**Gender:** Male
**Training institution:** Iowa State University
**Supervising Legume Innovation Lab PI:** Eric Abbott
**Degree Program for training:** M.S.
**Program Areas or Discipline:** Communications
**If enrolled in the US, is Trainee a USAID 'Participant Trainee' and registered in TraiNet?** Yes
**Host Country Institution to Benefit:** Institute of Agricultural Research of Mozambique (IIAM)
**Thesis Title/Research Area:** Sociotechnical Approaches for Dissemination of Information and Decision Support Aids
**Start Date:** July 2014
**Projected Completion Date:** August 2016
**Training Status:** (active, completed, pending, discontinued or delayed): Active
**Type of USG Support (full, partial or indirect):** Full

*Trainee #5*
**Name:** Jafali Matege
**Citizenship:** Uganda
**Gender:** Male
**University to provide training:** Makerere University
**Supervising Legume Innovation Lab PI:** Richard Miiro

**Degree Program for training:** M.S.
**Program Areas or Discipline:** Agricultural Extension Education
**If enrolled in the US, is Trainee a USAID 'Participant Trainee' and registered in TraiNet?** N/A
**Host Country Institution to Benefit from Training:** Makerere University
**Thesis Title/Research Area:** Gender Dimensions of Bean Farmers' Decision Making for Soil Fertility Management in Masaka and Rakai Districts, Uganda
**Start Date:** July 2014
**Projected Completion Date:** August 2016
**Training Status:** (active, completed, pending, discontinued or delayed): Active
**Type of USG Support (full, partial or indirect):** Partial

*Trainee #6*
**Name:** Stewart Kyebogola
**Citizenship:** Uganda
**Gender:** Male
**Training institution:** Makerere University
**Supervising Legume Innovation Lab PI:** Onesimus Semalulu
**Degree Program for training:** M.S.
**Program Areas or Discipline:** Soil Science and Crop Production
**If enrolled in the US, is Trainee a USAID 'Participant Trainee' and registered in TraiNet?** N/A
**Host Country Institution to Benefit from Training:** National Agricultural Research Laboratories
**Thesis Title/Research Area:** Effect of integrating organic with inorganic fertilizers on bean yield on three contrasting soils of Masaka district
**Start Date:** July 2014
**Projected Completion Date:** August 2016
**Training Status:** (active, completed, pending, discontinued or delayed): Active
**Type of USG Support (full, partial or indirect):** Partial

*Trainee #7*
**Name:** António José Rocha
**Citizenship:** Mozambique
**Gender:** Male
**Training institution:** University of Hawaii–Manoa
**Supervising Legume Innovation Lab PI:** Russell Yost
**Degree Program for training:** M.S.
**Program Areas or Discipline:** Agronomy and Tropical Soils
**If enrolled in the US, is Trainee a USAID 'Participant Trainee' and registered in TraiNet?** Yes
**Host Country Institution to Benefit:** Institute of Agricultural Research of Mozambique (IIAM)
**Thesis Title/Research Area:** Alternative Management Practices for Improving Bean Production
**Start Date:** January 2015
**Projected Completion Date:** September 2017
**Training Status:** (active, completed, pending, discontinued or delayed): Active
**Type of USG Support (full, partial or indirect) for training activity:** Full

## VII. Achievement of Gender Equity Goals

The project team has actively promoted participation of women farmers during research activities and trainings in Uganda and Mozambique. In our short-term training, 64 women have benefited (out of 172) and one woman is benefitting from long-term training. Extension research in Mozambique involved 140 women (and 174 men).

## VIII. Achievement and Progress Along the Impact Pathway

The project team is making excellent progress in implementing the action plan. (1) project research activities are on track to determine soil and crop system improvements that should be recommended, and to develop and refine appropriate models of farmer decision making strategies; (2) we are compiling materials that will be useful for development of diagnostic and decision support aids using observable characteristics that enable farmers to make site-specific management decisions; and (3) we have started to assess the appropriateness of existing methods and media for information dissemination to intermediate and end users.

## IX. Explanation for Changes

We significantly exceeded the planned number of short-term training participants/beneficiaries.

## X. Self-Evaluation and Lessons Learned

Our collegial multidisciplinary multicountry team is responsive in multiway communications and collaborates well in planning and implementing all project activities in Uganda and Mozambique. Researchers from all institutions are actively involved in mentoring all of our graduate students in their research. This generates high quality scientific data, engages diverse teams in analysis and making critical decisions, and following through. We continue to build on our diverse experiences and expertise to make wise decisions with our resources and achieve meaningful outputs and impacts. We have adapted to weather-related challenges in our field experiments, and are responding to the partnership opportunity provided by Bean Innovation Platforms in Uganda to advance our work and its long term impact.

## XI. Scholarly Accomplishments

Goettsch, L. & A. Lenssen. 2014–2015. 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. 2013–2016. Louis Thompson Endowment Graduate Fellowship. Agronomy Department (its premium assistantship). Iowa State University.

Mazur, R., N.Bwambale & V. Salegua. 2015. Land Rights and Integrated Soil Fertility Management in Uganda & Mozambique. Paper presented at LANDac Conference 2015–Land Governance for Equitable and Sustainable Development. Utrecht, Netherlands.

Bwambale, N. 2015. Farmers' Knowledge, Perceptions, and Socioeconomic Factors Influencing Decision Making for Integrated Soil Fertility Management Practices in Uganda. (M.S. thesis)

## XII. Data Management

All databases will be archived and publicly accessible at Iowa State University's Digital Repository, and some will also be available through the Soil Health Consortium Database of the Institute of Agriculture Research of Mozambique.

# Milestones

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**

**Report on the Achievement of "Milestones of Progress"**

**(For the Period: April 1, 2015 -- September 30, 2015)**

**This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2015**

***Project Title:*** **Systems**

| | ***Abbreviated name of institutions*** | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Iowa State University | | | University of Hawaii | | | University of Illinois | | | Makerere University | | | Nat'l Ag. Res. Lab - Ug. | | | Inst. Ag. Res. - Moz. | | |
| | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | |
| ***Milestones by Objectives*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** |
| | ***(Tick mark the Yes or No column for identified milestones by institution)*** | | | | | | | | | | | | | | | | | |
| **Objective 1** | **Characterize Smallholder Farmers' Motivations, Current Knowledge and Practices** | | | | | | | | | | | | | | | | | |
| 1.1 Report participation in field experiments | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| 1.2 Report changes farmer knowl., attit., pract | 0 | | | 0 | | | 0 | | | X | X | | X | X | | X | X | |
| **Objective 2:** | **Develop and Refine Models about Smallholder Bean Farmers' Decision Making** | | | | | | | | | | | | | | | | | |
| 2.1 Report resources, access, costs, constrai | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| 2.2 Report implications for modeling-1 | X | X | | 0 | | | 0 | | | X | X | | 0 | | | X | X | |
| 2.3 Report goals, resources, strategies, succe | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| 2.4 Report implications for modeling-2 | X | X | | 0 | | | 0 | | | X | X | | 0 | | | X | X | |
| 2.5 Analysis local organiz. & extension servic | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| 2.6 Recommendations for training & support | X | X | | 0 | | | 0 | | | X | X | | 0 | | | X | X | |
| **Objective 3:** | **Develop and Validate Diagnostic and Decision Support Aids** | | | | | | | | | | | | | | | | | |
| 3.1 Field study crop mgmt., soil fert., bean var | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| 3.2 Analyze soil samples after each season | X | X | | X | X | | 0 | | | X | X | | X | X | | X | X | |
| 3.3 ID diagnostic criteria & methods | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| 3.4 Apply diagnostic criteria & methods | X | X | | X | X | | 0 | | | X | X | | X | X | | X | X | |
| **Objective 4:** | **Develop and Assess Effectiveness of Innovative Approaches for Dissemination** | | | | | | | | | | | | | | | | | |
| 4.1 Dev. prototype message & media | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| 4.2 Test prototype message & media | X | X | | 0 | | | X | X | | X | X | | 0 | | | 0 | | |
| 4.3 Identify priority issues | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| 4.4 Develop first message & media | X | X | | X | X | | X | X | | X | X | | X | X | | X | X | |
| **Objective 5:** | **Enhance Institutional Research Capacity Relative to Grain Legumes** | | | | | | | | | | | | | | | | | |
| 5.1 Students continue graduate studies | 0 | X | | 0 | X | | 0 | | | 0 | | | 0 | | | 0 | | |
| 5.2 Short-term training of technical staff | 0 | | | 0 | | | 0 | | | X | X | | X | X | | X | X | |
| **Name of the PI reporting on milestones by institution** | Robert Mazur | | | Russell Yost | | | Barry Pittendrigh | | | Moses Tenywa | | | Onesimus Semalulu | | | Ricardo Maria | | |
| **Name of the U.S. Lead PI submitting this report to the MO** | Robert Mazur | | | | | | | | | | | | | | | | | |

**Signature** **Date**

** Please provide an explanation for not achieving the milestones on a separate sheet.*

# Performance Indicators

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**
**REVISED PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 14, FY 15, FY16, and FY 17**

**Project Name: Farmer Decision Making Strategies for Improved Soil Fertility Management in in Maize-Bean Production Systems**

**Summary of all institutions**

| Indic. numbe | Output Indicators | FY 14 Target | FY 14 Revised | FY 14 Actual | FY 15 Target | FY 15 Revised | FY 15 Actual | FY 16 Target | FY 16 Revised | FY 16 Actual | FY 17 Target | FY 17 Revised | FY 17 Actual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (October 1, 2013 - September 30, 2014) | | | (October 1, 2014 - September 30, 2015) | | | (October 1, 2015 - September 30, 2016) | | | (October 1, 2016 - September 30, 2017) | | |
| 1 | 4.5.2(6) Number of individuals who have received USG supported long-term agricultural sector productivity or food security training | 0 | 0 | 0 | 7 | 6 | 6 | 8 | 0 | 0 | 4 | 0 | 0 |
| | Total number by sex | 5 | 5 | 5 | 7 | 6 | 6 | 8 | 0 | 0 | 4 | 0 | 0 |
| | Number of women | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| | Number of men | 4 | 4 | 4 | 6 | 5 | 5 | 7 | 0 | 0 | 4 | 0 | 0 |
| | Total number by New/continuing | 0 | 0 | 0 | 7 | 6 | 6 | 8 | 0 | 0 | 4 | 0 | 0 |
| | Number of New | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Number of Continuing | 0 | 0 | 0 | 6 | 5 | 5 | 8 | 0 | 0 | 4 | 0 | 0 |
| 2 | 4.5.2(7) Number of individuals who have received USG supported short-term agricultural sector productivity or food security training | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total number | 7 | 5 | 5 | 8 | 8 | 172 | 71 | 0 | 0 | 43 | 0 | 0 |
| | Number of women | 2 | 2 | 2 | 3 | 3 | 64 | 26 | 0 | 0 | 21 | 0 | 0 |
| | Number of men | 5 | 3 | 3 | 5 | 5 | 108 | 45 | 0 | 0 | 22 | 0 | 0 |
| | Numbers by Type of individual | | | | | | 172 | 71 | | | 43 | | |
| | Producers | 0 | 0 | 0 | 0 | 0 | 57 | 14 | 0 | 0 | 14 | 0 | 0 |
| | People in government | 7 | 5 | 5 | 8 | 8 | 78 | 43 | 0 | 0 | 15 | 0 | 0 |
| | People in private sector firms | 0 | 0 | 0 | 0 | 0 | 17 | 6 | 0 | 0 | 6 | 0 | 0 |
| | People in civil society | 0 | 0 | 0 | 0 | 0 | 20 | 8 | 0 | 0 | 8 | 0 | 0 |
| 3 | 4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III) | 2 | 1 | 1 | 2 | 2 | 1 | 2 | 0 | 0 | 2 | 0 | 0 |
| | Phase 1: Number of new technologies or management practices under research as a result of USG assistance | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| | Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 |
| | Phase 3: No. of new technologies or management practices made available for transfer as a result of USG assistance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Notes:**

These indicators are developed under the Feed the Future Monitoring System. Please provide 'total' numbers and also disaggregate where applicable. Just providing 'totals' will not be approved.

This table corresponds to the Feed the Future Performance Indicators data collection sheet under the FTFMS system. Where an indicator does not apply to the type of work done under the project, leave it blank.

Please follow the indications in the Legume Innovation Lab Indicators Handbook that will be provided to you by the Management Office. Contact Mywish Maredia (maredia@anr.msu.edu) for further information.

There is additional guidance on the USAID/Microlinks website: http://agrilinks.org/sites/default/files/resource/files/FY14%20FTFMS%20Guidance_2.pdf

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


### 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, Kansas State University
Kara Ross, Kansas State University


## I. Abstract of Research Achievements and Impacts


During FY2014–2015, the research team conducted electronic discrete choice experiments in each of the three target countries: Zambia, Malawi, and Tanzania. Over 2,300 surveys were completed in the three countries. The lead US PI facilitated two workshops on entrepreneurial activities and strategic alliances in the food and agribusiness industries in each of the three focus countries. In total, 157 people attended the strategic alliances workshops and 131 attended the three entrepreneurial workshops. During each of the country visits, the US PIs and HC PIs met with key industry partners to establish a partnership and start planning an industry wide conference in each of the focus countries for FY2016. The first round of recruited students have either graduated or are close to graduation and have completed reports on each country's situational analysis. Key findings from these students' reports indicate that, on average, bean shares of total food expenditure was about 3.5%, with individuals in the high income class allocating a smaller share of the food expenditure to beans. Interestingly, urban consumers allocated a higher proportion of their food expenditure to beans than rural consumers. To date, almost twenty students have been recruited to work on this project for their degree training requirements.


## II. Project Problem Statement and Justification

Grain legumes are not traditional staples in Zambia, Malawi and Tanzania despite having significant nutritional benefits. Thus, increase consumption to support smallholder producer economic well-being must be based on clear appreciation of how consumer characteristics and food attribute-level combinations shape that consumers' decisions and choices. The fundamental problem of this project, therefore, is to develop new understanding of the forces and factors shaping and influencing consumers' food choice decisions in eastern and southern Africa and use this understanding to facilitate improvements in legume value chains. The project has three integrated dimensions. First, it develops an empirical foundation for understanding the factors and the extent that these factors influence food choices. This will be the first empirical evaluation of the complex factors influencing consumer choice of grain legumes in eastern and southern Africa. The research then employs the results of these factors and their extent of shaping consumer choices to engage industry stakeholders and public institutions in a search for value creation and value expansion opportunities as well as solutions to challenges preventing value chain effectiveness. The third dimension involves using the information collected on industry capacity gaps to carefully develop and deliver training and outreach programs aimed at enhancing strategy development, management and decision-making. In the end, the project provides innovative and unique pathways that bring smallholder producers and other stakeholders into specific value chain alliances to help smallholder producers improve their economic well-being.

The research's geographic scope covers Zambia, Malawi and Tanzania, all Feed the Future focus countries. These countries represent the different changes that are occurring in eastern and southern Africa, which are increasing urbanization; economic growth and increasing, but unequally distributed incomes; and changing demographics, including in agricultural production. This research's findings will provide insights into how and where these changes are affecting legume consumption. They will provide insights into how to overcome domestic consumption barriers and build stronger value chains to seize new markets.

# III. Technical Research Progress

**Objective 1: Identify and analyze the principal factors shaping bean/cowpea consumption and their relative positions in consumers' food rankings in the selected countries.**

***Approaches and Methods***

A discrete choice experiment method to compete Objective 1. This method is superior to others (such as conjoint analysis) in that it is rooted in stated preference theory, which has its foundation in random utility theory. Additionally, statistical methods are employed to conduct the ranking of beans/cowpeas in consumers' food baskets in Zambia.

Two groups of variables are included in the experiment (1) The different product attributes (availability, accessibility, perceived nutritional characteristics (fiber, protein, etc.), preparation time and preparation options, color, storage characteristics, taste and size as well as prices); (2) Consumer characteristics (including frequency of consumption, quantities consumed and expenditure shares) and preference influencers (cultural, and biologic ecologic variables). Its unique theoretical strength is that the choice set always includes at least one feasible alternative.

Because there is random component in random utility theory, preferences are inherently stochastic. Therefore, the foregoing analytical approach facilitates only the prediction of the probability that an individual *i* will choose beans/cowpeas. The approach, thus, leads to the development of a family of probabilistic discreet choice models that describe how probabilities respond to changes in the choice options (attributes) and/or the covariates representing differences in individual consumers. Therefore, the probability (ρ) that individual *i* chooses option *j* from her set of competing options, $C_i$, equals the probability that systematic (*V*) and random (ε) components of option *j* are larger than the systematic and random components of all other options competing with *j*. That is:

$$\rho(j|C_i) = \rho[(V_{ji} + \varepsilon_{ji}) > \max(V_{ki} + \varepsilon_{ki})] \quad \forall \text{ j,k} \in \{C_i\} \qquad (1)$$

The systematic components include attributes explaining differences in the choice alternatives and covariates explain differences across individuals. The random components, a fundamental aspect of the model's authenticity, capture all the unidentified factors that influence choices. Together, they define the latent utility, $u_{ji}$, individuals associate with each alternative as follows:

$$u_{ji} = V_{ji} + \varepsilon_{ji} \quad (2)$$

**Results, Achievements and Outputs of Research**

- A two-day long training session regarding the survey and the enumerators was conducted in Spring 2015 in each of the three focus countries: Zambia, Malawi, and Tanzania. Although the selected enumerators were experienced with the traditional survey approach, it is important that they be introduced and become familiar with the discrete choice approach since they will be administering the survey. By having an understanding of how the discrete choice experiment is designed, the enumerators will accurately administer the survey to guarantee valid and unbiased responses. Also, it was important to have the enumerators practice using the electronic devices, i.e., the tablets, and becoming familiar with the computer assisted personal interview approach. US PIs facilitated the training on the discrete choice approach and using the tablets.
- During the enumerator training, the host country PI facilitated the translation of the survey into the local languages to ensure that the survey questions were clear and logical, and the language and context used for the questions were appropriate to elicit unbiased and informative responses.
- A pretest involving the selected enumerators were conducted as part of the enumerator training in each of the three focus countries. Feedback and suggestion for improving the survey were received incorporate into the survey.
- All the surveys were conducted in the focus countries over a period of 4–6 days in Spring 2015. Seven hundred and thirteen (713) surveys were collected in Malawi, 766 in Tanzania, and 884 in Zambia.
- Survey data has been collated, organized, and cleaned for all three surveys.
- Background research and literature reviews have been or are being conducted to provide support for the research methods and survey design and to develop the framework for the research reports and policy briefs that will be generated from the findings of these discrete choice experiments. The recruited students in Malawi, Tanzania, and Zambia are working on the following research projects, respectively:
    - "Consumer Choice and Preferences for Beans in Lilongwe**:** A Discrete Choice Modeling approach";
    - "Bean Production and Marketing in Tanzania"; and
    - "Consumer Preferences for Beans in Zambia".
- All three studies investigate consumer preferences for different food types and identify the socioeconomic and demographic characteristics that influence the consumption of beans.

**Objective 2: 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.**

***Approaches and Methods***

Objective 2 employs econometric analyses on secondary data collected by various institutions in the partner countries to develop a deeper appreciation of the grain legume production environment, including the gender issues underscoring the environment. The World Bank's nationally-representative Living Standards Measurement Survey – Integrated Survey on Agriculture (LSMS-ISA) data for Malawi and Tanzania and the Food Security Research Project (FSRP) dataset for Zambia will be used to conduct the situation analyses. Primary data will also be collected and used in the situational analyses.

***Results, Achievements and Outputs of Research***

- Recruited students in Zambia are working on completing a number of reports on the situational analysis of production and consumption of common beans in Zambia.
- Drafts of these Zambian reports are expected to be completed by the end of December 2015.
- Newly recruited students in Malawi and Tanzania are expected to expand on the completed research studies conducted by last year's students.
- These reports and research studies are also expected to be a part of the students MS theses, which is a requirement for completing their degrees.

**Objective 3: 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.**

***Approaches and Methods***

Research partners in the three countries will recruit MS students for their projects in-line with the workplan. Each host country PI is planning to have two MS students recruited by the beginning of the 2015/2016 academic session, in addition to the current MS students recruited in the previous academic year. At the same time, active recruitment for qualified participants from the food and agribusiness communities in Zambia, Malawi, and Tanzania to join the Masters of Agribusiness program at Kansas State University has begun. The research partners will be primarily responsible for the process of searching for qualified candidates and work with the US PIs to facilitate their recruiting.

***Results, Achievements and Outputs of Research***

- Each of the focus countries have recruited *at least* one male and one female student. Zambia has recruited a number of upper level undergraduate students to focus on this legume research project for their Honors projects.
- Zambia has recruited another student for the Master of Agribusiness program.

- Tanzanian PI and his department (Department of Agricultural Economics and Agribusiness) recruited candidate pool of two students for the Master of Agribusiness program, and will be selecting one student to sponsor for Spring 2016 enrollment in the program. The selection is expected to conclude by mid November 2015.
- Malawian PI and his department (Department of Agricultural and Applied Economics) recruited candidate pool of four students for the Master of Agribusiness program, and have selected one student to sponsor for Spring 2016 enrollment in the program.
- Malawian PI and his department (Department of Agricultural and Applied Economics) have partnered with the Department of Agribusiness to train agro-dealers, including members of the Association of Agribusiness Women.
    - As part of the training program, a Training is expected to start in Spring 2016. The training sessions will be based on the results of the Needs Assessment questionnaire. The questionnaire has been developed and translating the questionnaire into local languages is in process. The questionnaire is expected to be administered in the first quarter of FY2016.
    - The US PIs and other host country PIs are providing guidance and support towards this training initiative, and the research team plans on developing similar needs assessment and training sessions in Tanzania and Zambia.

# IV. Major Achievements

During this reporting period, two major achievements occurred. The first achievement was completion of the discrete choice experiment in each of the focus countries. The second achievement was the facilitation of industry wide workshops on entrepreneurial activities and strategic alliances. These workshops created an opportunity for the PIs to meet key industry players and develop partnerships to future activities. These partnerships are crucial to the success of future activities, since these partners have a wealth of knowledge about the bean industry and are deep network within the industry. These partners will play an important role in analyzing the Needs Assessment questionnaire results and determining which knowledge gaps and skills training will be addressed in each of the three focus countries. These partners will also provide valuable support in disseminating information to all bean producers, industry players, and interested parties by helping with translating information into local languages, organizing and promoting training sessions, and developing distribution channels to share information with those unable to attend the training sessions and other future activities.

# V. Research Capacity Strengthening

**Training the Enumerators**

Kansas State University PIs lead the Training the Enumerators, which was also considered to be a part of the research team's training on discrete choice experiments. The host country PIs helped facilitate the enumerator training in Malawi and Tanzania. Since the Enumerator Training in Zambia occurred last fiscal year, a short training session for the Zambian enumerators was provided by the Kansas State University PIs and the host country PIs before going into the field to refamiliarize themselves with the discrete choice experiment section of the survey.

## VI. Human Resource and Institution Capacity Development

__Short-Term Training__

**Purpose of Training:** Enhancing Performance through Strategic Alliances
**Type of Training:** Workshop
**Country Benefitting:** Malawi
**Location and Dates of Training:** January 29th, 2015
**Number receiving training (by gender):** 26 (F) and 43 (M)
**Home Institution(s) (if applicable):**
**Institution providing training or mechanism:** KSU

**Purpose of Training:** Entrepreneurial Action in Food and Agribusiness Companies
**Type of Training:** Workshop
**Country Benefitting:** Malawi
**Location and Dates of Training:** January 30th, 2015
**Number receiving training (by gender):** 18 (F) and 25 (M)
**Home Institution(s) (if applicable):**
**Institution providing training or mechanism:** KSU

**Purpose of Training:** Enhancing Performance through Strategic Alliances
**Type of Training:** Workshop
**Country Benefitting:** Tanzania
**Location and Dates of Training:** Dar Es Salaam, March 3rd, 2015
**Number receiving training (by gender):** 10 (F) and 32 (M)
**Home Institution(s) (if applicable):**
**Institution providing training or mechanism:** KSU

**Purpose of Training:** Entrepreneurial Action in Food and Agribusiness Companies
**Type of Training:** Workshop
**Country Benefitting:** Tanzania
**Location and Dates of Training:** Dar Es Salaam, March 4th, 2015
**Number receiving training (by gender):** 10 (F) and 32 (M)
**Home Institution(s) (if applicable):**
**Institution providing training or mechanism:** KSU

**Purpose of Training:** Strategic Alliances and Entrepreneurial Action in Agribusiness
**Type of Training:** Workshop
**Country Benefitting:** Zambia
**Location and Dates of Training:** Lusaka; March 31, 2015
**Number receiving training (by gender):** 22 (F) and 24 (M)
**Home Institution(s) (if applicable):**
**Institution providing training or mechanism:** KSU

**Degree Training**

Masters students will be supervised by the respective HC PI and their program area of study will be agricultural economics or agribusiness. They will not be enrolled in US institution and their projected completion dates will be academic year 2016. The support provided will be partial of the total cost of their training cost.

**First and Other Given Names:** Marynia Tumeo
**Last Name:** Mazunda
**Citizenship**: Malawian
**Gender:** Female
**Training institution:** Lilongwe University of Agriculture & Natural Resources (LUANAR), Bunda College, Malawi
**Supervising CRSP PI:** Dr L. Mapemba
**Degree Program for training:** Master of Science
**Program Areas or Discipline:** Agricultural and Applied Economics
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** N/A
Lilongwe University of Agriculture & Natural Resources (LUANAR), Bunda College, Malawi
**Thesis Title/Research Area:** Consumer Choice and Preferences for Beans in Lilongwe**:** A Discrete Choice Modeling approach
**Start Date:** June 2014
**Projected Completion Date:** Dec 2015
**Training status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Emily
**Last Name:** Malunga
**Citizenship:** Malawian
**Gender:** Female
**Training institution:** Lilongwe University of Agriculture and Natural Resources (LUANAR)
**Supervising CRSP PI:** Dr. Lawrence D. Mapemba
**Degree Program for training:** Bachelors Degree
**Program Areas or Discipline:** Agricultural economics
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID and included in Trainet ?** Not in US University
**Host Country Institution to Benefit from Training:** LUANAR
**Thesis Title/Research Area:** Determinants Bean Consumption at Household Level
**Start Date:** 2014
**Projected Completion Date:** 2015
**Training status (Active, completed, pending, discontinued or delayed):** Active
**Type of Legume Innovation Lab Support (full, partial or indirect) for training activity:** Partial

**First and Other Given Names:** Wupe
**Last Name:** Msukwa
**Citizenship:** Malawian
**Gender:** Male

**Training institution:** Lilongwe University of Agriculture and Natural Resources (LUANAR)
**Supervising CRSP PI:** Dr. L. Mapemba
**Degree Program for training:** Masters degree
**Program Areas or Discipline:** Agricultural economics
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID and included in Trainet ?** N/A
**Host Country Institution to Benefit from Training:** LUANAR
**Thesis Title/Research Area:** Bean Consumption Patterns
**Start Date:** 2014
**Projected Completion Date:** 2016
**Training status (Active, completed, pending, discontinued or delayed):** Pending
**Type of Legume Innovation Lab Support (full, partial or indirect) for training activity:** Partial

**First And Other Given Names:** Dinah Tuwanje
**Last Name:** Banda
**Citizenship:** Malawian
**Gender:** Female
**Training institution:** Lilongwe University of Agriculture and Natural Resources (LUANAR)
**Supervising CRSP PI:** Dr. L. Mapemba
**Degree Program for training:** Masters
**Program Areas or Discipline:** Agriculture And Applied Economics
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID and included in Trainet ?** N/A
**Host Country Institution to Benefit from Training:** LUANAR
**Thesis Title/Research Area:** Bean Consumption Expenditure
**Start Date:** 2014
**Projected Completion Date:** 2014
**Training status (Active, completed, pending, discontinued or delayed):** Active
Type of Legume Innovation Lab Support (full, partial or indirect) for training activity: Partial

**First and Other Given Names:** Adelina
**Last Name:** Mfikwa
**Citizenship:** Tanzania
**Gender:** Female
**Training institution:** Sokoine University of Agriculture
**Supervising CRSP PI:** Fredy T. M. Kilima
**Degree Program for training:** M.Sc.
**Program Areas or Discipline:** Agric. Econ.
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? N**/A
**HC Institution to Benefit from Training:** Ministry of Agriculture Food Security and Cooperatives
**Thesis Title/Research Area:** Bean Production and Marketing in Tanzania
**Start Date:** Sept, 2013
**Projected Completion Date:** Aug, 2015
**Training Status:** Active

**Type of Support for training activity:** Partial

**First and Other Given Names:** Ocran
**Last Name:** Chengula
**Citizenship:** Tanzania
**Gender:** Male
**Training institution:** Sokoine University of Agriculture
**Supervising CRSP PI:** Fredy T. M. Kilima
**Degree Program for training:** M.Sc.
**Program Areas or Discipline:** Agric. Econ.
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** N/A
**HC Institution to Benefit from Training:** Ministry of Agriculture Food Security and Cooperatives
**Thesis Title/Research Area:** Market Participation Among Smallholder Bean Farmers In Tanzania
**Start Date:** Sept. 2013
**Projected Completion Date:** Aug. 2015
**Training status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Ezekiel
**Last Name:** Swema
**Citizenship**: Tanzania
**Gender:** Male
**Training institution:** Sokoine University of Agriculture
**Supervising CRSP PI:** Fredy T. M. Kilima
**Degree Program for training:** M.Sc.
**Program Areas or Discipline:** Agric. Econ.
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** N/A
**HC Institution to Benefit from Training:**
**Thesis Title/Research Area:**
**Start Date:**
**Projected Completion Date:**
**Training Status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Charles
**Last Name:** Lungu
**Citizenship:** Tanzania
**Gender:** Male
**Training institution:** Sokoine University of Agriculture
**Supervising CRSP PI:** Fredy T. M. Kilima
**Degree Program for training:** M.Sc.
**Program Areas or Discipline:** Agric. Econ.
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** N/A
**HC Institution to Benefit from Training:**

**Thesis Title/Research Area:**
**Start Date:**
**Projected Completion Date:**
**Training status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Mabvuto
**Last Name:** Zulu
**Citizenship:** Zambian
**Gender:** Male
**Training institution:** University of Zambia
**Supervising CRSP PI:** Dr. Gelson Tembo
**Degree Program for training:** Master of Science
**Program Areas or Discipline:** Agricultural Economics
**Program Areas or Discipline:**N/A
**HC Institution to Benefit from Training:** University of Zambia
**Thesis Title/Research Area:** Consumer Preferences For Common Beans In Lusaka, Zambia. A
**Stated Preference Approach:**
**Start Date:** April 1, 2015
**Projected Completion Date:** March 31, 2016
**Training Status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Leah
**Last Name:** Banda
**Citizenship:** Zambian
**Gender:** Female
**Training institution:** University of Zambia
**Supervising CRSP PI:** Dr. Gelson Tembo
**Degree Program for training:** Master of Science
**Program Areas or Discipline:** Agricultural Economics
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** N/A
**HC Institution to Benefit from Training:** University of Zambia
**Thesis Title/Research Area:**
**Start Date:**
**Projected Completion Date:**
**Training status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Protensia
**Last Name:** Hadunka
**Citizenship:** Zambian
**Gender:** Male
**Training institution:** University of Zambia

**Supervising CRSP PI:** Dr. Gelson Tembo
**Degree Program for training:** Master of Science
**Program Areas or Discipline:** Agricultural Economics
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** N/A
**HC Institution to Benefit from Training:** University of Zambia
**Thesis Title/Research Area:**
**Start Date:**
**Projected Completion Date:**
**Training status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Kabanshi
**Last Name:** Matunga
**Citizenship:** Zambian
**Gender:** Female
**Training institution:** University of Zambia
**Supervising CRSP PI:** Dr. Gelson Tembo
**Degree Program for training:** Bachelors of Science
**Program Areas or Discipline:** Agricultural Economics
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** N/A
**HC Institution to Benefit from Training:** University of Zambia
**Thesis Title/Research Area:**
**Start Date:**
**Projected Completion Date:**
**Training Status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Astridah
**Last Name:** Munsaka
**Citizenship:** Zambian
**Gender:** Female
**Training institution:** University of Zambia
**Supervising CRSP PI:** Dr. Gelson Tembo
**Degree Program for training:** Bachelors of Science
**Program Areas or Discipline:** Agricultural Economics
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** N/A
**HC Institution to Benefit from Training:** University of Zambia
**Thesis Title/Research Area:**
**Start Date:**
**Projected Completion Date:**
**Training Status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Brenda

**Last Name:** Makayi
**Citizenship:** Zambian
**Gender:** Female
**Training institution:** University of Zambia
**Supervising CRSP PI:** Dr. Gelson Tembo
**Degree Program for training:** Bachelors of Science
**Program Areas or Discipline:** Agricultural Economics
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** N/A
**HC Institution to Benefit from Training:** University of Zambia
**Thesis Title/Research Area:**
**Start Date:**
**Projected Completion Date:**
**Training Status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Cynthia
**Last Name:** Chibebe
**Citizenship:** Zambian
**Gender:** Female
**Training institution:** University of Zambia
**Supervising CRSP PI:** Dr. Gelson Tembo
**Degree Program for training:** Bachelors of Science
**Program Areas or Discipline:** Agricultural Economics
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** N/A
**HC Institution to Benefit from Training:** University of Zambia
**Thesis Title/Research Area:**
**Start Date:**
**Projected Completion Date:**
**Training Status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Bwalya
**Last Name:** Mwansa
**Citizenship:** Zambian
**Gender:** Female
**Training institution:** University of Zambia
**Supervising CRSP PI:** Dr. Gelson Tembo
**Degree Program for training:** Bachelors of Science
**Program Areas or Discipline:** Agricultural Economics
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** N/A
**HC Institution to Benefit from Training:** University of Zambia
**Thesis Title/Research Area:**
**Start Date:**
**Projected Completion Date:**

**Training Status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Isaac
**Last Name:** Sikaaswe
**Citizenship:** Zambian
**Gender:** Male
**Training institution:** University of Zambia
**Supervising CRSP PI:** Dr. Gelson Tembo
**Degree Program for training:** Bachelors of Science
**Program Areas or Discipline:** Agricultural Economics
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** N/A
**HC Institution to Benefit from Training:** University of Zambia
**Thesis Title/Research Area:**
**Start Date:**
**Projected Completion Date:**
**Training status:** Active
**Type of Support for training activity:** Partial

**First and Other Given Names:** Winnie
**Last Name:** Pele
**Citizenship:** Zambian
**Gender:** Female
**Training institution:** Kansas State University
**Supervising CRSP PI:** Vincent Amanor-Boadu
**Degree Program for training:** MAB
**Program Areas or Discipline:** Agribusiness
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?**
**HC Institution to Benefit from Training:** University of Zambia
**Thesis Title/Research Area:** Consumption Patterns of Beans in Zambia
**Start Date:** January 5, 2013
**Projected Completion Date:** May 15, 2015
**Training Status:** Active
**Type of Support for training activity:** Full

**First and Other Given Names:** Ednah
**Last Name:** Kasanda
**Citizenship:** Zambian
**Gender:** Female
**Training institution:** Kansas State University
**Supervising CRSP PI:** Vincent Amanor-Boadu
**Degree Program for training:** MAB
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?**
Agribusiness

**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?**
**HC Institution to Benefit from Training:** University of Zambia
**Thesis Title/Research Area:**
**Start Date:** January 2015
**Projected Completion Date:** May 2017
**Training Status:** Active
**Type of Support for training activity:** Full

Two students were enrolled in the Master of Agribusiness (MAB) program at Kansas State University. One student graduated this fiscal year.

## VII. Achievement of Gender Equity Goals

Nothing to report yet.

## VIII. Achievement and Progress Along the Impact Pathway

The Impact Pathway Action Plan is still in effect, and the timeline has been altered for some of the research outputs designated to the host countries' students. Data collected in the DCE survey are expected to be the focus of the students' research projects and Masters thesis. There has been a steep learning curve for the students on the discrete choice experiment approach but it is expected that research outputs will pick up quickly within the first half of FY2016.

## IX. Explanation for Changes

These following activities were delayed until FY2015:

1. Situational Analyses in Zambia
2. Analyses of ranking and factors shaping bean/cowpeas consumption in Zambia; produce report and distribute to local USAID mission, collaborating institutions, policymakers in Zambia, Malawi, Tanzania and SADC
3. Complete draft of policy brief and commence distribution for comment by collaborators and interest parties

**Explanation**

The reports were expected to be compilation of the research studies conducted by the host country PIs and their recruited students with additional assistance from the US PIs. Last year, Zambia encountered challenges with their subcontract, which delayed the recruitment of the students to this project. The challenges with the subcontract have since been addressed, and this year Zambia has aggressively recruited students, including six undergraduate students. It is expected that the situational analyses for Zambia will be completed by the end of the first quarter in FY2016. Since the discrete choice experiment is a relatively new approach for host country PIs and their students, the learning curve has been steeper than originally expected. The US PIs have provided guidance in the research projects and analyses whenever possible as well as provided additional training in specific data analysis on request. To ensure that the reports and policy briefs are completed in a timely manner, the US PIs, host country PIs, and recruitment students will continue to work together in a collaborative approach with the US PIs playing a more active role in the research process.

# X. Self-Evaluation and Lessons Learned

**Lesson Learned**

***Larger Training Facilities***

In each of the six workshops offered, we were forced to close registration and turn people away because of space limitations. We underestimated the demand for training opportunities in each of the focus countries. As we move forward with future training workshops, we need to take this demand into consideration and find locations that can accommodate larger audiences.

***Aligning Project Outcomes and Students' Professional Development***

Whenever possible, work with students whose professional development depends on the success of the project. By positioning these students in leadership roles within the project activities, we are guaranteeing successful completion of the project activities as well as ensuring professional growth for those students.

# XI. Scholarly Accomplishments

Mfikwa, A. In press. Bean Production and Marketing in Tanzania. *Tanzania Journal of Agricultural Science*.

Pele, W. K. 2015. Consumption Patterns of Beans in Zambia. Masters of Agribusiness Thesis

Ross, K.L., V. Amanor-Boadu, and L. Mapemba. *Understanding Consumer Choice for Grain Legumes: Recent Evidence from Malawi*. Paper prepared for presentation at the 90th Annual Conference, Western Economics Association International, June 28–July 2, 2015, Honolulu, Hawaii.

# XII. Data Management

# ANNEXES:

**Annex 1. Tables, Figures and Photos Cited in the Report**

**Annex 2. Literature Cited (List of all literature cited in the body of the technical progress report.)**

# Milestones

**Report on the Achievement of "Milestones of Progress"**
**(For the Period: April 1, 2015 -- September 30, 2015)**

**This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2015**

***Project Title:*** Consumer-Driven Value Enhancement

| | ***Abbreviated name of institutions*** | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | KSU | | | Zambia | | | Malawi | | | Tanzania | | | Institution 5 | | | Institution 6 | | |
| | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | |
| ***Milestones by Objectives*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** |
| | ***(Tick mark the time period for achieving identified milestones by institution)*** | | | | | | | | | | | | | | | | | |
| **Objective 1:** | | | | | | | | | | | | | | | | | | |
| 1.1 Case-based DCE workshop for PIs | | | | | | | | | | | | | | | | | | |
| 1.2 Conduct DCE survey in Zambia | | | | | | | | | | | | | | | | | | |
| 1.3 Analyze Zambian DCE data | x | | x | x | | x | | | | | | | | | | | | |
| 1.4 Produce Zambian DCE results report | x | | x | x | | x | | | | | | | | | | | | |
| 1.5 Conduct DCE survey in Malawi | | | | | | | | | | | | | | | | | | |
| 1.6 Conduct DCE survey in Tanzania | | | | | | | | | | | | | | | | | | |
| 1.7 Analyze DCE data from Malawi and Tanzania | x | | x | | | | x | | x | x | | x | | | | | | |
| 1.8 Produce DCE results report for Malawi and Tanzania | x | | x | | | | x | | x | x | | x | | | | | | |
| **Objective 2:** | | | | | | | | | | | | | | | | | | |
| 2.0 Collecting and organizing secondary data for analyses | | | | x | | x | x | x | | x | x | | | | | | | |
| 2.1 Primary production situation analyses | x | | x | x | | x | x | x | | x | x | | | | | | | |
| 2.2 Primary production situation report | x | | x | x | | x | x | x | | x | x | | | | | | | |
| 2.3 Conduct industry focus group interviews in Zambia | | | | | | | | | | | | | | | | | | |
| 2.4 Conduct industry focus group interviews in Malawi | | | | | | | | | | | | | | | | | | |

## Milestones, continued

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.6 Producer industry focus group interviews report for Zambia | | | | | | | | | | | | | | | | | | |
| 2.7 Producer industry focus group interviews report for Malawi and Tanzania | | | | | | | | | | | | | | | | | | |
| 2.8 Launch Zambia report and conduct industry workshop | | | | | | | | | | | | | | | | | | |
| 2.9 Launch Malawi and Tanzania reports and conduct industry workshops | | | | | | | | | | | | | | | | | | |
| **Objective 3:** | | | | | | | | | | | | | | | | | | |
| 3.1 Industry outreach programs | | | | | | | | | | | | | | | | | | |
| 3.2 MAB Students | x | x | | x | x | | x | x | | x | x | | | | | | | |
| 3.3 MS Students | | | | x | x | | x | x | | x | x | | | | | | | |
| 3.4. Facilitatation of innovative governance mechanisms | | | | | | | | | | | | | | | | | | |
| 3.5 Train the trainer programs | | | | | | | | | | | | | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Name of the PI responsible for reporting on milestones** | Amanor-Boadu | Tembo | Mapemba | Kilima | | |
| **Signature/Initials:** | VAB | GT | LM | FDK | | |
| **Date:** | 16-Nov-15 | 16-Nov-15 | 16-Nov-15 | 16-Nov-15 | | |

# Performance Indicators

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**
**REVISED PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 14, FY 15, FY16, and FY 17**

**Project Name: SO2.2 Grain Legume Value Chain Initiative**

**Summary of all institutions**

| Indic. numbe | Output Indicators | FY 14 Target | FY 14 Revised | FY 14 Actual | FY 15 Target | FY 15 Revised | FY 15 Actual | FY 16 Target | FY 16 Revised | FY 16 Actual | FY 17 Target | FY 17 Revised | FY 17 Actual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (October 1, 2013 - September 30, 2014) | | | (October 1, 2014 - September 30, 2015) | | | (October 1, 2015 - September 30, 2016) | | | (October 1, 2016 - September 30, 2017) | | |
| 1 | 4.5.2(6) Number of individuals who have received USG supported long-term agricultural sector productivity or food security training | 0 | 0 | 0 | 10 | 0 | 3 | 10 | 0 | 0 | 15 | 0 | 0 |
| | Total number by sex | 4 | 0 | 0 | 10 | 0 | 3 | 10 | 0 | 0 | 15 | 0 | 0 |
| | Number of women | 2 | 0 | 0 | 4 | 0 | 2 | 6 | 0 | 0 | 8 | 0 | 0 |
| | Number of men | 2 | 0 | 0 | 6 | 0 | 1 | 4 | 0 | 0 | 7 | 0 | 0 |
| | Total number by New/continuing | 4 | 0 | 0 | 10 | 0 | 3 | 10 | 0 | 0 | 15 | 0 | 0 |
| | Number of New | 4 | 0 | 0 | 10 | 0 | 2 | 8 | 0 | 0 | 6 | 0 | 0 |
| | Number of Continuing | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 9 | 0 | 0 |
| 2 | 4.5.2(7) Number of individuals who have received USG supported short-term agricultural sector productivity or food security training | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total number | 67 | 0 | 0 | 0 | 0 | 242 | 363 | 0 | 0 | 363 | 0 | 0 |
| | Number of women | 27 | 0 | 0 | 0 | 0 | 86 | 129 | 0 | 0 | 129 | 0 | 0 |
| | Number of men | 40 | 0 | 0 | 0 | 0 | 156 | 234 | 0 | 0 | 234 | 0 | 0 |
| | Numbers by Type of individual | | | | | | 242 | 363 | | | 363 | | |
| | Producers | 5 | 0 | 0 | 0 | 0 | 41 | 64 | 0 | 0 | 64 | 0 | 0 |
| | People in government | 30 | 0 | 0 | 0 | 0 | 9 | 20 | 0 | 0 | 20 | 0 | 0 |
| | People in private sector firms | 9 | 0 | 0 | 0 | 0 | 156 | 217 | 0 | 0 | 217 | 0 | 0 |
| | People in civil society | 23 | 0 | 0 | 0 | 0 | 36 | 62 | 0 | 0 | 62 | 0 | 0 |
| 3 | 4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Phase 1: Number of new technologies or management practices under research as a result of USG assistance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Notes:**

These indicators are developed under the Feed the Future Monitoring System. Please provide 'total' numbers and also disaggregate where applicable. Just providing 'totals' will not be approved.

This table corresponds to the Feed the Future Performance Indicators data collection sheet under the FTFMS system. Where an indicator does not apply to the type of work done under the project, leave it blank.

Please follow the indications in the Legume Innovation Lab Indicators Handbook that will be provided to you by the Management Office. Contact Mywish Maredia (maredia@anr.msu.edu) for further information.

# Legumes and Growth (SO3)


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

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


## I. Abstract of Research Achievements and Impacts


In FY 14–15, this project initiated several activities to meet the objectives of evaluating changes in childhood anthropometry, biomarkers of environmental enteropathic dysfunction (EED), and the characteristics of the intestinal microbiome after inclusion of either cowpeas or common beans as an integral component of complementary feeding in two large cohorts of rural Malawian children. In FY13–14, the project obtained IRB approval, conducted acceptability trials to determine the food formulas, and create the operational manual that contains operating procedures that are being utilized for the duration of trail was developed. The operational manual was developed by Chrissie Thakwalakwa, who completed her PhD in Public Health Nutrition utilizing this study to complete her thesis. The local team implementing the clinical trial continues ongoing training in the principles of "Good Clinical Practice." Two Malawian Master level students enrolled at LUANAR and 2 Malawian PhD students enrolled at the University of Malawi–College of Medicine were identified and began work on the project. More than 50% enrollment in Study 1 and full enrollment in Study 2 have been completed.


## II. Project Problem Statement and Justification

Successful interventions to help prevent children from becoming malnourished and achieve their full growth potential remain lacking. EED, a pervasive chronic subclinical gut inflammatory condition, places rural children at high risk for malabsorption, stunting, and acute malnutrition. Minimizing EED is an essential step in improving the survival and growth of at-risk children. EED is characterized by T-cell infiltration of the intestinal mucosa leading to a chronic inflammatory state with increased intestinal permeability, translocation of microbes, nutrient malabsorption, poor weight gain, stunted physical and cognitive development, frequent enteric infections, and decreased response to enteric vaccines. EED often begins to develop shortly after the transition away from exclusive breastfeeding and increases progressively during the first several years of life, a high-risk period marked by mixed feeding with complementary foods to the complete reliance on adult foods for sustenance. In traditional sub-Saharan African societies, complementary foods are dominated by protein-poor and micronutrient-poor starches such as maize, cassava, and sorghum. Alternative, yet culturally acceptable, complementary foods that could provide a better and more palatable balance of nutrients would potentially decrease in EED and improve growth amongst these at risk children. In this study, we are testing two different legume foods as complementary food products, given that their protein content is significantly higher than cereals, and they are rich in dietary fiber, starch, minerals, vitamins, and anti-oxidants. The active engagement of several Malawian graduate students as part of the capacity-building activities is essential to this work, as their local insights and knowledge of food systems and cultural feeding practices will help guide the optimal development and implementation of these bean flours at scale if they prove to be successful in reducing EED and stunting.

# III. Technical Research Progress

**Objective 1: Develop a working Manual of Operations to conduct the research projects in the field.**

The Manual of Operation to conduct the research projects in the field was developed by Chrissie Thakwalakwa with input from the rest of the research team. The study procedure guide describes the mode of operations for all study related participants and community interactions, including clinic operations, patient and participant screening, participant consent, enrollment, and food distribution. The manual also provides guidelines for data collection, giving instructions on surveys, home visits, anthropometric techniques, the collection of biological samples, and event reporting procedures for any unexpected and adverse events. The manual provides the field work directives for the field team.

**Objective 2: Develop and test the acceptability of two sets of 3–4 recipes that include either cow peas or common beans for use infants in the clinical trial.**

The LUANAR graduate students developed food recipes using cowpeas and common beans. The recipes were developed in accordance with WHO specifications and the candidate recipes underwent acceptability testing in Malawian infants with the support of the Malawi College of Medicine. The acceptability data from these studies has been submitted for publication. The preferred flour recipes have been selected and are currently being used in the clinical trials.

**Objective 3: Complete preparations to initiate study aim 1, including staff recruitment, training and community engagement and organization.**

All ethical approvals were obtained from the institutional review boards at the University of Malawi College of Medicine and Washington University in St. Louis. Two Food Science and Technology master level students were recruited and enrolled at LUANAR. Also, two PhD students were recruited at the Malawi College of Medicine. All local staff were recruited and underwent extensive training in Clinical Good Practice techniques and data collection methods to properly conduct all enrollment and data collection. The field teams visited the areas near Masenjere in Nsanje District and Limela in Machinga District to mobilize and engage the district in the research project and started the study in these areas. More than 50% enrollment in Study 1 and full enrollment in Study 2 have been completed. Meetings with local community leaders and health centers continue to take place.

**Objective 4: Increase the capacity, effectiveness and sustainability of agriculture research institutions which serve the bean and cowpea sectors in Malawi.**

The PI and the research team continue to promote sustainable research through relationships with the University of Malawi College of Medicine and with colleagues at LUANAR. In addition to the training of four graduate students, a junior faculty member, Chrissie Thakwalakwa at the College of Medicine, continues to be supported by this project and provide overall supervision of the field studies. The Agriculture Department at LUANAR was engaged in developing the formulations and recipes using cowpeas and common beans, and the Washington University team trained two student LUANAR food scientists on the development processes used in the Washington University food science lab. The LUANAR masters students continue to be engaged in the clinical trial even after having developed the food recipes, supervising bean sourcing, flour production, preparation, and safety monitoring of the intervention foodss.

## IV. Major Achievements

1. Development of the Operational Manual to delineate procedures and guidelines for the conduct of the clinical trials.
2. Chrissie Thakwalakwa received her PhD, supporting the Aim of capacity building.
3. Development and testing of multiple legume recipes and completion of an acceptability study involving more than 100 children to help determine the optimal recipes for usage in the clinical trial.
4. Identification and preparation of the two large clinical trial sites, including education of local village health workers and engagement of community leadership.
5. Submission of the first manuscript from the study to a peer-reviewed journal, describing the study motivation, methods, and progress to date.
6. More than 50% enrollment in Study 1 and 100% enrollment in Study 2, requiring a large amount of effort and resources, including collaboration in the districts where the studies are being conducted. It also required ethics approval to be obtained, all staff to be hired and trained and food formulas to be developed and selected.

## V. Research Capacity Strengthening

The PI and the research team continue to promote sustainable research through relationships with the Malawi College of Medicine and with colleagues at LUANAR. The training provided to the four Malawian graduate students continues and will help to develop them into investigators able to continue research on childhood malnutrition, especially in the use of grain legumes. Chrissie Thakwalakwa of the College of Medicine, with support from Drs. Manary, Trehan and Maleta, developed the study procedures, guidelines and material for the study, and continues to supervise the field team, honing and improving her skills in conducting large collaborative clinical trials aimed at improving the nutritional status of impoverished rural children. The Agriculture Department at LUANAR was engaged in developing the formulations and recipes using cowpeas and common beans, and the Washington University team trained two student LUANAR food scientists on the development processes used in the Washington University food science lab. A freezer was purchased that will be maintained at Washington University and utilized to store samples.

## VI. Human Resource and Institution Capacity Development

**Short-Term Training: Recipe Development**

1. ***Purpose of Training:*** Equip local Malawian institution with the tools needed to initiate and conduct operational health, nutrition, and agriculture studies to improve the health and wellness of its population
2. ***Type of Training:*** Recipe development for dietary interventions
3. **Country Benefitting:** Malawi
4. **Location and Dates of Training:** Malawi, 2014–2015
5. **Number receiving training (by gender):** 2 female
6. **Home Institution(s) (if applicable):** LUANAR
7. **Institution providing training or mechanism:** Washington University in St. Louis

**Short-Term Training: Staff Field Training**

1. ***Purpose of Training:*** Study research nurses, drivers, research assistants and staff received training in study guidelines, anthropometric data collection skills, biological sample collection methods and community engagement. Having a knowledgeable and capable staff is vital to conducting research.
2. ***Type of Training:*** Field training for research activities
3. **Country Benefitting**: Malawi
4. **Location and Dates of Training:** Malawi, 2015
5. ***Number receiving training (by gender):*** 6 female nurses, 4 male drivers, 15 village health workers (11 male, 4 female)
6. ***Home Institution(s) (if applicable):*** Nurses and drivers are from the University of Malawi College of Medicine; village health workers are employed by the Ministry of Health
7. **Institution providing training or mechanism:** University of Malawi College of Medicine

**Degree Training**

**Name of trainee:** Lucy Bollinger
**Country of Citizenship:** United States
**Gender:** Female
**Host Country Institution Benefitting from Training:** United States
**Institution Providing Training:** Washington University in St. Louis
**Supervising CRSP PI:** Mark Manary
**Degree Program:** Masters
**Field or Discipline:** Biological Sciences
**Research Project Title (if applicable):**
**Start Date:** May 2015
**Projected Completion Date:** May 2016
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training status (Active, completed, pending, discontinued or delayed):** Active

**Name of trainee:** Nicole Benzoni
**Country of Citizenship:** United States
**Gender:** Female
**Host Country Institution Benefitting from Training:** United States
**Institution Providing Training:** Washington University in St. Louis
**Supervising CRSP PI:** Mark Manary
***Degree Program:*** Masters in Population Health Sciences
**Field or Discipline:** Medicine
**Research Project Title (if applicable):**
**Start Date:** March 2015
**Projected Completion Date:** May 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training status (Active, completed, pending, discontinued or delayed):** completed

**Name of trainee:** Theresa Ngoma
**Country of Citizenship:** Malawi
**Gender:** Female
***Host Country Institution Benefitting from Training:*** The Lilongwe University of Agriculture and Natural Resources (LUNAR)
**Institution Providing Training:** LUNAR
***Supervising CRSP PI:*** Mark Manary, Indi Trehan, Ken Maleta
**Degree Program:** Masters
**Field or Discipline:** Food Science and Technology
**Research Project Title:** N/A
**Start Date:** January 2015
**Projected Completion Date:** December 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training status (Active, completed, pending, discontinued or delayed):** Active

**Name of trainee:** Ulemu Chimimba
**Country of Citizenship:** Malawi
**Gender:** Female
**Host Country Institution Benefitting from Training:** LUNAR
**Institution Providing Training:** LUNAR
***Supervising CRSP PI:*** Mark Manary, Indi Trehan, Ken Maleta
**Degree Program:** Masters
**Field or Discipline:** Food Science and Technology
**Research Project Title:** N/A
**Start Date:** January 2015
**Projected Completion Date:** December 2015
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training status (Active, completed, pending, discontinued or delayed):** Active

**Name of trainee:** Oscar Divala
**Country of Citizenship:** Malawi
**Gender:** Male
**Host Country Institution Benefitting from Training:** University of Malawi College of Medicine
**Institution Providing Training:** University of Malawi College of Medicine
**Supervising CRSP PI:** Mark Manary, Ken Maleta, Indi Trehan
**Degree Program:** PhD
**Field or Discipline:** Epidemiology
**Research Project Title:** N/A
***Start Date:*** August 2015
**Projected Completion Date:** July 2017
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training status (Active, completed, pending, discontinued or delayed):** Active

**Name of trainee:** Yankho Kaimila

**Country of Citizenship:** Malawi
**Gender:** Female
**Host Country Institution Benefitting from Training:** University of Malawi College of Medicine
**Institution Providing Training:** University of Malawi College of Medicine
**Supervising CRSP PI:** Ken Maleta
**Degree Program:** PhD
**Field or Discipline:** Epidemiology
**Research Project Title:** N/A
**Start Date:** August 2015
**Projected Completion Date:** July 2017
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training status (Active, completed, pending, discontinued or delayed):** Active

**Name of trainee:** Chrissie Thakwalakwa
**Country of Citizenship:** Malawi
**Gender:** Female
**Host Country Institution Benefitting from Training:** University of Malawi College of Medicine
**Institution Providing Training:** Tampere University in Finland
**Supervising CRSP PI:** Ken Maleta
**Degree Program:** PhD
**Field or Discipline:** Community Health
**Research Project Title:** N/A
**Start Date:** August 2015
**Projected Completion Date:** July 2017
**Is trainee a USAID Participant Trainee and registered on TraiNet?** No
**Training status (Active, completed, pending, discontinued or delayed):** Active

## VII. Achievement of Gender Equity Goals

Beneficial findings and knowledge gained from these studies will benefit both women and men in these societies, including parents and children. Farming work is generally carried out by both men and women in this agrarian culture, so this will benefit both genders. Improvements in child health are most likely to benefit women in Malawi, as they have the primary role in childrearing. Health improvements that lead to improved survival and intellectual development of girls will also likely translate into improved school performance and capacity for careers. Demonstrating achievement of such goals is beyond the scope of the current project.

In terms of training future scientists, all but one of our Malawian graduate students is female. Both American graduate students are female. One of our nondegree American students is female.

## VIII. Achievement and Progress Along the Impact Pathway

We remain on track with the Impact Pathway developed during the project planning and work plan stage. Both Goal 1 (capacity building) and Goal 2 (clinical trial decreasing stunting and EED) are being carried out as planned. The measurements of success (Steps 3 and 4) are still several years away from completion, as originally planned.

# IX. Explanation for Changes

We have no significant changes or delays to report.

# X. Self-Evaluation and Lessons Learned

This project has proceeded quite well, beginning with the identification and training of Malawian graduate students. We are optimistic that this will improve host country capacity by improving the talent pool of young scientists who will continue to study innovative agricultural approaches to reducing childhood malnutrition. The development of legume recipes for the clinical trials also proceeded well, led by the LUANAR students. The LUANAR students, in collaboration with Washington University graduate students, conducted an acceptability study for these foods, learning and refining clinical trial methods including consenting, blinding, and data management. The two actual large randomized clinical trials have also begun without much difficulty at both clinical sites, with more than half of the children already enrolled in Study 1 and all of the children already enrolled in Study 2. These children are actively being followed for the duration of the study. The conduct of these trials has been without any unexpected challenges, given our prior clinical trial experience with these types of field studies and the methods involved in studying EED in rural children. The collaboration with LUANAR and the University of Malawi scientists and graduate students has been fruitful, with many shared ideas and insights between all parties as we have all been working side-by-side together in the field.

Our only major challenge has been a logistical one as the government of Malawi has instituted new rules and taxes on imported items for the study, including significant new import duties on vehicles which have made it difficult to complete our work as older and less reliable vehicles have had to be used for the field work. A lesson to be learned here is to have “wiggle room” in the budget for the costs and timeline related to obtaining these large purchases in host countries, as they may change quite rapidly depending on shifting political whims. Proactively obtaining signed agreements with host government ministries may be a wise strategy to take as well, as even prior agreements with USAID may be invalidated by the host government.

# XI. Scholarly Accomplishments

Chrissie Thakwalakwa, Malawi College of Medicine, completed her thesis and received her PhD.

The first manuscript from this project, entitled “Legumes as Complementary Foods to Reduce Environmental Enteric Dysfunction and Stunting in Malawian Children: Study Protocol for Two Randomized Controlled Trials” has been submitted for publication and is currently undergoing peer review.

# XII. Data Management

Please see attached data management plan.

## ANNEXES

**Annex 1. Tables, Figures and Photos Cited in the Report**

**Annex 2. Literature Cited**

# Milestones

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**

**Report on the Achievement of "Milestones of Progress"**

**(For the Period: April 1, 2015 -- September 30, 2015)**

**This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2015**

***Project Title:*** SO3.1 Legumes and growth

| | ***Abbreviated name of institutions*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | WUSM | | | MCM | | | LUANAR | | |
| | Target | Achieved | | Target | Achieved | | Target | Achieved | |
| ***Milestones by Objectives*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** |
| Objective 1 *(Tick mark the Yes or No column for identified milestones by institution)* | | | | | | | | | |
| **1.1 Develop enrollment and consent plan** | **0** | | | **0** | | | **0** | | |
| **1.2 Develop data collection methodology** | **0** | | | **0** | | | **0** | | |
| **1.3 Develop biological sample collection and storage methodology** | **0** | | | **0** | | | **0** | | |
| **1.4 Create unexpected and adverse event plan** | **0** | | | **0** | | | **0** | | |
| **1.5 PI and research team review and finalization of manual** | **1** | **1** | | **0** | | | **0** | | |
| **Objective 2: Recipe Development** | | | | | | | | | |
| **2.1 Development of recipes** | **0** | | | **0** | | | **0** | | |
| **2.2 Examination of orginal recipes and formulations** | **0** | | | **0** | | | **0** | | |
| **2.3 Acceptability trial preparations and approval** | **0** | | | **0** | | | **0** | | |
| **2.4 Conduct field acceptability trial** | **1** | **1** | | **1** | **1** | | **1** | **1** | |
| **2.5 Select and finalize food formulations** | **1** | **1** | | **1** | **1** | | **0** | | |
| | | | | | | | | | |
| **3.1 Staff recruitment** | **0** | | | **0** | | | **0** | | |
| **3.2 Staff training** | **1** | **1** | | **1** | **1** | | **0** | | |
| **3.3 Secure ethics approvals** | **0** | | | **0** | | | **0** | | |
| **3.4 Conduct community engagement programs** | **1** | **1** | | **1** | **1** | | **0** | | |
| | | | | | | | | | |
| **4.1 Chrissie Thakwalakwa develops operations manual** | **1** | **1** | | **0** | | | **0** | | |
| **4.2 Training on the development of food formulations** | **0** | | | **0** | | | **0** | | |
| **4.3 Recruitment of local staff for training positions** | **0** | | | **0** | | | **0** | | |
| **4.4 Training on study methodology and data collection** | **0** | | | **0** | | | **0** | | |
| **4.5 Community engagement activities** | **1** | **1** | | **1** | **1** | | **1** | **1** | |
| | | | | | | | | | |

## Milestones (continued)

| Name of the PI reporting on Milestons by institution | | | |
|---|---|---|---|

Name of the U.S. Lead PI submitting this report to the MO

*  ***Please provide an explanation for not achieving the milestones on a separate sheet.***

Signature

# Performance Indicators

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**
**REVISED PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 14, FY 15, FY16, and FY 17**

**Project Name: SO3.1 Legumes and Growth**

**Summary of all institutions**

| Indic. numbe | Output Indicators | FY 14 Target | FY 14 Revised | FY 14 Actual | FY 15 Target | FY 15 Revised | FY 15 Actual | FY 16 Target | FY 16 Revised | FY 16 Actual | FY 17 Target | FY 17 Revised | FY 17 Actual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (October 1, 2013 - September 30, 2014) | | | (October 1, 2014 - September 30, 2015) | | | (October 1, 2015 - September 30, 2016) | | | (October 1, 2016 - September 30, 2017) | | |
| 1 | 4.5.2(6) Number of individuals who have received USG supported long-term agricultural sector productivity or food security training | 0 | 0 | 0 | 7 | 1 | 7 | 5 | 5 | 0 | 5 | 5 | 0 |
| | Total number by sex | 0 | 0 | 0 | 7 | 1 | 7 | 5 | 5 | 0 | 5 | 5 | 0 |
| | Male | 0 | 0 | 0 | 3 | 0 | 1 | 2 | 1 | 0 | 2 | 2 | 0 |
| | Female | 0 | 0 | 0 | 4 | 1 | 6 | 3 | 4 | 0 | 3 | 3 | 0 |
| | Total number by New/continuing | 0 | 0 | 0 | 7 | 1 | 7 | 5 | 5 | 0 | 5 | 5 | 0 |
| | New | 0 | 0 | 0 | 7 | 1 | 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Continuing | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 5 | 5 | 0 |
| 2 | 4.5.2(7) Number of individuals who have received USG supported short-term agricultural sector productivity or food security training | 0 | 0 | 0 | 12 | 0 | 12 | 12 | 10 | 0 | 12 | 12 | 0 |
| | Total number | 0 | 0 | 0 | 12 | 0 | 12 | 12 | 10 | 0 | 12 | 12 | 0 |
| | Number of men | 0 | 0 | 0 | 6 | 0 | 7 | 6 | 5 | 0 | 6 | 6 | 0 |
| | Number of women | 0 | 0 | 0 | 6 | 0 | 5 | 6 | 5 | 0 | 6 | 6 | 0 |
| | Numbers by Type of individual | | | | | | | | | | | | |
| | Producers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | People in government | 0 | 0 | 0 | 12 | 0 | 12 | 12 | 10 | 0 | 12 | 12 | 0 |
| | People in private sector firms | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | People in civil society | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III) | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 0 |
| | Phase 1: Number of new technologies or management practices under research as a result of USG assistance | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 0 |
| | Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Notes:**

# Impact Assessment of Dry Grain Pulses CRSP investments in research, institutional capacity building and technology dissemination for improved program effectiveness (S04.1)


## Lead U.S. Principal Investigator (PI) and affiliated Lead U.S. University

Mywish Maredia, Professor, International Development, Agricultural, Food and Resource Economics (AFRE), Michigan State University

## Host Country and U.S. Co-PIs and Institutions

Eric Crawford (Co-PI), Robert Shupp (Collaborator), c; Byron Reyes (Collaborator), formerly at MSU, currently at CIAT.
US and HC PIs/collaborators of other Legume Innovation Lab Projects


## I. Abstract of Research Achievements and Impacts


In FY 15, this project worked towards completing or initiating several activities under the three 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 assessment; and 3) build research capacity in the area of impact assessment. A baseline survey in Guatemala was completed in close collaboration with SO1.A1 team. This survey will help us better understand the current status of the climbing bean/maize intercropping production system. Several research studies on the theme of sustainable seed system were initiated in FY 15. This includes a study on 'willingness to pay' for different types of seeds in northern Tanzania and a case study on a farmer association in Burkina Faso involved in cowpea seed production by training member farmers and providing technical oversight to produce quality declared seed for sale to other farmers in the community. Towards the capacity building goal, 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 and East and Southern Africa region.


## II. Project Problem Statement and Justification

Impact assessment is essential for evaluating publicly-funded research programs and planning future research. Organizations that implement these programs should be accountable for showing results, demonstrating impacts, and assessing the cost-effectiveness of their implementation strategies. It is therefore essential to document outputs, outcomes and impacts of public investments in research for development (R4D) activities. Anecdotal data and qualitative information are important in communicating impact to policymakers and the public, but must be augmented with empirical data, and sound and rigorous analysis.

This project is designed to contribute towards evidence-based rigorous ex ante and ex post assessments of outputs, outcomes and impacts with the goal of assisting the Legume Innovation Lab program and its Management Office (MO) to achieve two important goals—accountability and learning. Greater <u>accountability</u> (and strategic validation) is a prerequisite for continued financial support from USAID and better <u>learning</u> is crucial for improving the effectiveness of development projects and ensuring that the lessons from experience – both positive and negative – are heeded. Integrating this culture of 'impact assessment' in publicly funded programs such as the Legume Innovation Lab will ultimately help increase the overall impact of such investments.

# III. Technical Research Progress

**<u>Objective 1. Provide technical leadership in the design, collection and analysis of data for strategic input and impact evaluation</u>**

***1a. Socioeconomic baseline study on the constraints and opportunities for research to contribute to increased productivity of climbing beans in Guatemala:***

This is a joint activity with the SO1.A1 project team (Juan Osorno (NDSU), Julio Martinez (ICTA) under their objective '*Genetic improvement of climbing black beans for the highlands of Central America*.' Byron Reyes, who joined CIAT in November 2014 is also a collaborator in this study. This study is designed to establish a baseline about production of climbing beans in the highlands of Guatemala, and to better understand the current status of the climbing bean/maize intercropping production system.

In FY15, data collection from a total of 548 farm households from five FTF Departments in Guatemala representing the highland bean growing regions was completed. A detailed household level survey instrument was developed in Spanish jointly by the SO4-1 and SO1.A1 team. This was then translated into English and submitted to the NDSU's IRB for approval. In March 2015, team members from the SO4.1 team traveled to Guatemala and trained 13 enumerators and 4 supervisors in data collection and data entry. The survey was conducted from March 9–27 by the trained enumerators as per the sampling plan developed by SO4-1. The survey was designed to get a representative picture of the bean growers in the highlands of the five FTF departments of Guatemala defined as areas above 1500 meters above sea level. Data were collected from an average of 6 randomly selected farm households from 87 villages across the Departments of Chimaltenango, Quiché, Huehuetenango, San Marcos and Quetzaltenango.

Data analysis is currently underway and will be completed in the next few months. The analysis will focus on the current status of the climbing bean/maize intercropping production system (i.e., the *milpa* system) in the highlands of Guatemala. Data concerning cultivated area, production practices, production problems/constraints, seed quality and culinary preferences along with the sociodemographic characteristics of farm households will be analyzed using descriptive and econometric techniques to help establish priorities for the climbing bean breeding program.

***1b. Study on the market potential for biopesticides in Benin:***

This was a collaborative activity with the SO1-B1 project team, specifically with Biaou Agué Eustache and Hinnou C. Léonard from INRAB-Benin, under their objective 3 '*Scaling of solutions.*' This study was designed to serve as a baseline to assess the market potential for biopesticides (e.g., what farmers are willing to pay, what will be the costs to enter the market place for small industries, what are skill sets that need to be developed for womens' groups to potentially make and profit from selling such materials, etc.) and will determine the networks of NGOs and other organizations where the project can pass-off educational approaches (e.g., animations) for scaling.

For this study, the plan was for the Impact Assessment team to provide technical support in the form of human resources and professional expertise in data collection (i.e., sample design, evaluation design, designing data collection instruments, training enumerators, data entry templates, etc.) and analysis. However, due to language constraint, the role of SO4.1 project team in providing this technical assistance has been limited. Field work consisting of the following three phases was mostly completed by INRAB (with support from IITA) in FY15 and the progress report of this Activity is reported in the SO1-B1 Annual Report:

1. Documentation phase: collection of secondary information
2. Exploratory survey in main cowpea production areas mainly through group interviews of major stakeholders in the value chain, but also to collect preliminary data for designing the individual survey questionnaire
3. Detailed survey with individual questionnaires administered to key players in the cowpea value chain particularly targeting producers and consumers, and their willingness to pay for biopesticides and biopesticide-treated cowpea, respectively

**Objective 2. Conduct ex ante and ex post impact assessments**

In FY 15 workplan, two research studies (2a-Assessment of willingness to pay for quality seed) and 2b-impact study in Haiti) were included under this objective. A third activity related to the sustainability of seed system was added during FY 15 upon request from the Management Office. We report the progress of the originally planned study 2a as 2a-i and this additional Activity as 2a-ii under the theme of "Sustainability of legume seed system constraints and opportunities to guide policies and programs."

***2a. Sustainability of legume seed system constraints and opportunities to guide policies and programs:***

*Motivation.* Benefits from plant breeding research can only be transferred to farmers if an 'improved' variety (i.e., a variety that is genetically superior to a local or previously released variety) is released, and good quality seeds of that improved variety are planted by farmers. Thus, gains from investments in plant breeding research depend on both the genetic improvement embodied in the seed as well as on the existence and performance of a seed system that can deliver this improved genetics to farmers in the form of a good quality seed / planting material. Recognizing the importance of the seed system in delivering the benefits of plant breeding research, donors, governments, and research organizations working in development are making significant investments to augment farmers' access to seeds of improved varieties (IVs). Many of these efforts require providing subsidized or free seed to farmers, which may not be sustainable in the long term. Thus, there is a strong interest and need for research in exploring alternative ways of making high-quality low-cost seed locally available to farmers and learning whether a seed market is latent in rural areas of developing countries.

One of the important factors that determine the sustainability of a seed system is the 'effective demand' for seed (i.e., planting material) of improved varieties as reflected in the volume and frequency of purchase of fresh seed by farmers. Even where farmers have adopted improved varieties, the low volume and low frequency of seed demand has been often cited as a major reason for the lack of private sector involvement in the seed system or the development of alternative models of a sustainable seed system. This is especially the case for self-pollinated crops like beans (*Phaseolus vulgaris*), because bean 'seed' of the same variety / type / market class is highly competitive with bean 'grain' as planting material. Since producing and marketing beans as 'seed' involves taking specific and extra measures during seed production and postharvest processing to ensure quality, it is more costly to produce than bean grain. Also, complying with the country's seed regulatory requirements to be able to sell the seeds labeled and packaged as 'certified seed' or 'quality declared seed' (QDS) increases the cost. Keeping the genetics constant (i.e., for the same improved variety), the viability of a seed market will depend on the co-existence of following demand and supply side conditions. On the demand side, it will depend on: 1) whether farmers are able to perceive the 'seed' product as a quality planting material, and 2) given the perceived quality difference, whether they are willing to pay a premium price for seed compared to grain price. On the supply side, it will depend on: 3) whether the price farmers are willing to pay is high enough to recover the cost of producing quality seed; and 3) whether the quantity and frequency of seed demanded at that price is large enough to attract suppliers to produce and sell quality seed. There are no rigorous studies that have examined these demand and supply side dynamics in a systematic manner. The following two activities (2a-i: assessment of the willingness of small holder farmers to pay for quality seed, and 2a-ii: case study on community based seed system) undertaken by this project are attempts to address these demand and supply-side research questions in the context of dry grain legumes—beans and cowpeas.

***2a-i. Assessment of the willingness of small holder farmers to pay for quality seed.***
This study is conducted in close collaboration with Sokoine University of Agriculture (Paul Kusolwa, Fulgence Mishili and Susan Nchimbi-Msolla) and CIAT (i.e., Byron Reyes and J. C. Rubyogo) in northern Tanzania, where four types of seed products are potential options available to farmers as planting materials—certified seeds produced from foundation seed (certified 1), certified seed produced from certified 1 seed (certified 2), quality declared seeds (QDS) and recycled seeds saved from farmers' own harvested grain. These four types of seeds or planting materials differ in seed input (i.e., which generation of seed is used to produce them), the regulatory supervision they receive or not receive, and technical conditions under which they are produced, and thus vary in cost. However, whether the cost differential across these types of seeds makes them qualitatively different products as reflected in their perceived or actual performance of the plant, and whether that translates into differential price that farmers are willing to pay for these seeds is an empirical question rarely addressed in the literature.

This study is based on field experiments (FE) and bidding experimental auctions (BEA) proposed to be conducted in two districts in northern Tanzania to gauge the demand for bean seed of different types, and to collect systematic data from seed consumers (i.e., farmers) to understand the economics of seed system from the demand side. The study is designed to address the following research questions:

1. For a given improved variety, what is the difference in the performance (as measured by yield and other characteristics important to farmers) of bean crop across four seed types – certified 1, certified 2, QDS and farmer saved bean grain when the seeds are planted and managed by farmers under their conditions?
2. How does the observed differential performance of different types of seeds translate into farmers' willingness to pay (WTP) for these seeds?

Due to delays in finalizing the contractual mode for transferring the funds to SUA, the FEs were conducted only in one district in this reporting year. The FEs and BEA auction experiments in the second district will be conducted in the long-rain season in FY 16. The FEs were planted in July

2015 under irrigated conditions and were based on the following methodology.

*Methodology.* To address research questions 1 and 2, a two-step approach was used. First, double-blind field experiments were established in six hamlets across Kawaya, Kikavu chini and Chemka villages in Hai district (in Kilimanjaro region, northern Tanzania). The FE (also called demonstration plots) were used to demonstrate the value of planting certified 1 vs. certified 2 vs. QDS vs. recycled seed of the bean variety, Jesca, so farmers can see firsthand the difference in agronomic performance of the plants, the amount (that could be) harvested and the quality of the beans. Through these experiments farmers were able to learn firsthand how different types/grades of seeds of the same improved variety perform in a location that is close to their farm. Second, once farmers observed how different types of seeds of a particular variety perform, bidding experimental auctions were carried out to extract information about how much they are willing to pay for these seeds based on the perceived / observed differences in their performance.

The FEs were established as a double blind experiment, where neither the farmers nor the agricultural extension officers knew the types of seeds included in the study. Technical staff implementing the FE and farmers knew the variety (i.e., Jesca), and also knew that there are four types of seeds, namely certified 1, certified 2, QDS and recycled seed planted on that plot, and each were randomly labeled A, B, C and D, but they were not told which code is for which seed type. The reason for doing the FE as a double blind experiment is to reduce any systematic bias on the part of the technical staff or the farmer managing the plot towards or against any preconceived higher and lower quality seed type (this is called the Hawthorne effect in the economics literature). The blind experiment reduced any bias farmers as observers may have towards a specific seed type based on their prior personal experience or 'hearsay.' The same seed codes used in the FE were used throughout the study to be able to match all the information collected.

The FEs were planted on a 100 sq. m. (10m x 10m) subplot with a total plot of 400 sq m of land. The amount of seed required for this area was 1 kg (at a planting rate of 40 kg/acre) or 4 kg of seed in total (i.e., 1 kg of each grade). The seeds of different grades were obtained from appropriate seed source prior to the planting.

The field experiments were planted in a farmer's field. Farmers hosting the FE were in charge of planting and managing the FE following their own management practices (i.e., these were not managed as 'experimental trials'). Partners (SUA and agricultural extension officers from selected districts) selected the host farmers, delivered the seed for the FE to selected farmers, and supervised the establishment of the field experiments. During the production cycle, two field days were carried out in the two best performing fields in each village. All farmers living in the village were invited to these field days to see the bean plots and learn about their performance, firsthand. The first field day was conducted around the flowering stage (or soon after) (i.e., first week of September), and the second field day occurred just before or after harvest (i.e., second week of October). Attendees in the first Field Day were given a sheet where they ranked the subplots according to a set of criteria agreed upon by the farmers as a group. During the second field day, the same attendees were asked to rank the best and the worst subplots and the reason for their ranking. The data collected from the FE during the two field days and the yield data from the harvest will be used to estimate the 'per unit gain' from planting different types of seeds under farmer conditions (i.e., certified 1, certified 2, QDS, recycled).

The Bidding Experimental Auctions (BEA) were conducted to determine how much farmers are willing to pay for the different types of seeds (i.e., planting materials, not food grain). These took place during the second field day in October 2015. We followed the Becker-DeGroot-Marschak (BDM, 1964) method, where participants did not bid against other people, but only against themselves. Prior to the seed BDM auction, a 'practice BDM' was conducted with a bar of soap to make sure farmers understood the auction mechanism.

The willingness to pay (WTP) elicitation mechanism was performed using a full bidding method (e.g., Lusk and Shogren 2007, and Alfnes 2009). In this method, farmers were first endowed with TS 4000 (equivalent to about US$2) to make their decisions more realistic (and not be constrained by available cash) and then asked to participate in four auctions by "bidding" their maximum willingness to pay (WTP) for a one kg of seed for each seed type A, B, C and D. Farmers were told that one of the four auctions will be chosen randomly and the bid for that seed would then be compared to a randomly drawn number from a given revealed price range of TS 0 to 3950. If the bid is greater than or equal to the randomly drawn price, then the farmer buys that seed at the randomly drawn price (NOT his/her bid price). The difference in the bids between the four auctions reveals the premium (or discount) due to the different seed type attributes (QDS vs. certified 1 vs. certified 2 vs. recycled). In this method, the farmer is likely to pay less than his/her bid (unless the bid and random price are equal) and thus the auctions are theoretically incentive compatible with regards to eliciting true farmer WTP.

A total of 114 farmers participated in the BEA across the 3 villages. Survey data were collected from each farmer that participated in the auction experiment to capture their socioeconomic household characteristics, and experience with producing beans, varietal use and prior use of different types of seed. Analysis of data is currently ongoing. The results of these auctions will reveal how much farmers would be willing to pay for the different types of seed.

The reason for selecting Tanzania for this study is because it is one of the few countries in the ESA region that officially recognizes quality declared seed (QDS), and it will be interesting to compare the performance of QDS vs. certified seed and then assess farmers' willingness to pay for these two types of seed, which have different cost of production associated with them.

***2a-ii. Case study on community based seed system***

In FY 15, in response to a request from the Management Office, this project initiated a case study of a farmer association in Burkina Faso called *Association Song Koaadba* (ASK), which was established more than 20 years ago with the goal of promoting food self-sufficiency and food security in rural farming communities. It currently has about 7500 members spread over 58 villages in the provinces of Oubritenga, Kourweogo, Kouritenga, Ganzourgou, Sanmatenga, Passore and Sissili. According to the ASK management team, in 2014, a total of about 80 ha of land was devoted to cowpea seed production by about 125 members. ASK members involved in seed production mostly produce QDS seeds of cowpea for sale to other ASK members and nonmember farmers in their communities. Over the past 20 years, ASK has had strong ties with INERA and has received continuous guidance and technical support from them in strengthening their cowpea seed production activities. In turn, ASK has served as an effective organization for INERA to channel new and improved cowpea varieties generated by its cowpea breeding program.

The long-term sustainability of ASK's business model is rare to encounter in a developing country context. This study was thus motivated by the longevity of ASK's involvement in cowpea seed production and sale, and is designed to achieve the following objectives: a) Document the cowpea seed production and distribution model used by ASK; b) Collect and analyze data / information to understand the economics of community based smallholder seed production, and identify strengths and weaknesses of the model used by ASK; and, c) Derive principles of sustainability underlying the model used by ASK for broader applicability within Burkina Faso and other countries. This study was initiated in early 2015 in close collaboration with INERA socioeconomist (Dieudonne Ilboudo) and host country PIs of other Legume Lab projects (Issa Drabo and Clementine Dabire).

*Methodology.* The case study uses a combination of qualitative and quantitative methods to achieve the above objectives. Qualitative method includes conducting key informant interviews (KII) with the management and technical team of ASK and their backward linkage partners, such as the suppliers of foundation seed (i.e., INERA) and forward linkage partners, such as the buyers of the seed produced by ASK. The following KII were completed by the host country collaborators between February to June 2015.

1. KII with ASK management team: Types of information collected from these interviews include, ASK's history, current operation, aspirations for future, and a descriptions of its activities, sources of financial support, organizational and governance structure, seed production and marketing activities, and management teams' perception and opinion on key challenges, strengths and weaknesses.
2. KII with INERA: The cowpea seed program management staff were interviewed to get their perspectives on the demand for foundation seed by ASK, and their perspective on key challenges to meet this demand, and the strengths and weaknesses of the ASK model.
3. KII with SNS (National Seed Service) and UNPS-Union Nationale des Production Semenciers de Burkina. Representatives of these agencies were interviewed to gather information to better understand the formal seed system in Burkina Faso, get an overview of the annual production and sale of certified seeds of cowpea in the country, the certified seed production value chain, seed policy environment, key challenges, strengths and weakness of the formal seed system, and their perspective on the role played by ASK in the seed system.
4. KII with two organizational buyers of seed produced by ASK to gauge their evaluation of the seed quality, ability of ASK to meet their need for cowpea seed, and their perspective on key challenges to meet this demand, and the strengths and weaknesses of the ASK model.

Quantitative method used to achieve the objectives of this study included following types of data collection: secondary data from the Ministry of Agriculture, SNS, UNPS, etc. on cowpea area, production, yield (most recent year by district or lowest administrative unit); historical price data of cowpea grain; historical price data of certified seeds of cowpea; historical data of certified cowpea seed production; and conducting surveys of a sample of cowpea seed producers and seed buyers using structured questionnaires. For this later activity, a list of all the villages where ASK members reside was obtained from ASK with the following information—year in which that village became a member of ASK, number of ASK membership, and number of cowpea seed producers (as of 2014). Twenty five out of 58 villages were randomly selected from the list of seed producing villages (14 villages selected) and nonseed producing villages (11 villages selected). In each village 9 farmers were randomly selected to represent seed producers (in villages where seed producers were located), ASK members and non-ASK cowpea farmers. In total 225 farmers comprised of 54 seed producing farmers, 98 ASK member farmers, and 73 non-ASK member farmers were surveyed in May–June 2015 using a structured questionnaire. A community level questionnaire was also completed for each of the 25 villages visited. The distribution of these 25 village communities surveyed is given in Figure 1. Data entry of the completed survey was completed in September. Analysis of the information obtained through KII and farmer survey is planned over the next few months and a report summarizing the results of this case study will be shared with the management office and USAID in early 2016.

***2b. Impact study in Haiti***

During the past 20 years, with support from USAID, the National Seed Service of the Ministry of Agriculture in Haiti has conducted bean research in collaboration with the University of Puerto Rico, the USDA-ARS and Zamorano. This collaboration resulted in the development and release of bean cultivars such as DPC-40, XRAV-40-4, MEN 2201-64ML and Aifi Wuriti that have greater disease resistance, improved agronomic traits and higher seed yield potential than local landrace varieties of beans. In recent years, the Bean Technology Dissemination (BTD) project in Haiti received funding from USAID to produce and distribute 69 MT of seed of these improved bean cultivars to > 25,000 farmers. Some of the NGO's such as Zanmi Agrikol and Helping Hands that participated in the production of bean seed continue to produce seed of the improved bean cultivars after the BTD project ended.

Despite these recent and long-term investments in bean research and dissemination of improved variety seeds, there is no study conducted by NSS, the Ministry of Agriculture or the National Agricultural Statistics Service in Haiti to assess the adoption of these technologies and its impact. A major reason for this is the lack of capacity within the national system in Haiti to conduct rigorous adoption and impact studies based on farm household surveys. Hence, last year the SO1-A4 team expressed a strong interest in conducting an impact study in Haiti through technical assistance from this project team. As a result, this activity was included in the FY15 workplan of this project. Only partial funding was available at the time of developing the FY 15 workplan, and the plan was to do this study in FY 15 only if funding was secured to meet the total estimated budget. Funding was secured in May 2015 when the proposal jointly submitted by SO1-A4 and SO4.1 to the Legume Innovation Lab in response to the *Call for Proposal to Strengthen Host Country Institutional Capacity* was approved.

Due to elections in Haiti this year, the host country collaborators suggested doing this study in 2016 instead of summer/fall 2015. Thus, no activities were undertaken in FY 15. The plan is to implement the survey next year in the following 5 Departments in areas where the BTD project and NSS have disseminated improved bean varieties—Artibonite, South, Grand Anse, Central Plateau, and Northeast. The plan is to randomly select about 450 beneficiary farmers and 350 nonbeneficiary farmers that share similar characteristics as the beneficiary farmers, and establish a counterfactual using the Propensity Score Matching statistical technique (Cochran and Rubin, 1973; Rosenbaum and Rubin, 1983). In addition to the impact study, there is also a need for a rapid study on grain legume seed systems to understand potential changes in these systems and the opportunities for enhancing seed systems and scaling up these technologies for grain legumes. Thus, rapid reconnaissance of the main stakeholders in Haitian legume seed systems, including NSS, IICA, NGOs, and private sector agents are planned in the second quarter of FY 16.

Field activities for the impact study will be led by the National Agricultural Statistics Service with technical support and guidance from MSU. All other activities will be a joint collaboration between SO4.1 and the host country partners.

**Objective 3. Build institutional capacity and develop human resources in the area of impact assessment research**

This project addressed the objective of institutional capacity building and human resource development through the following activities implemented in FY 15:

1. Research studies conducted in Guatemala, Burkina Faso and Tanzania under objectives 1 and 2 (described above) involved host country PIs/collaborators/students in the planning and execution of field data collection. Host country collaborators from Legume Innovation Lab projects participated in the rapid appraisal visits, development of research design, and training enumerators and field staff in data collection, data entry and analysis.
2. Activities planned under this project involved graduate students in the planning and conduct of field research and write-up of research results. These students were recruited from within the Department of Agricultural, Food and Resource Economics at MSU (see the details on trainees in the Training section).
3. Short courses on impact assessment. Two short-term training workshops (one funded by LIL and the other funded through external funds) to build capacity of local partners were implemented in collaboration with CIAT and other NARS partners as described in the Training section. These training workshops focused on teaching theoretical concepts and demonstrating practical applications of these concepts to rigorously assess the impact of agricultural projects and programs. The topics included current theory and methods on impact evaluation, sampling methods, data collection instrument design, data collection using computer assisted personal interviewing software and paper questionnaires, and the use of statistical software for data cleaning and analysis.

# IV. Major Achievements

We would like to highlight the following emerging 'messages' about factors contributing to the sustainability of community seed banks based on the thesis research completed in FY 15.

- Factors positively contributing to the sustainability of community based seed production include the importance of training (seed marketing and business skills), ownership of productive asset (especially silos), experience of leadership, cost recovery, quality and quantity of seed produced, and operational formality in the form of conducting meetings and documenting decisions made at meetings.

- Community based seed bank models provided a production and delivery model that lasted longer than individual banks. The policy implication of these results is that CSBs present a more sustainable dissemination channel of improved variety seed to farmers than small scale contract-based seed production by individual farmers.

# V. Research Capacity Strengthening

Unlike other Legume Innovation Lab projects, this project does not have a country-specific collaborating HC institution. We serve as the cross-cutting project that works towards building the institutional capacity and human resources in the area of impact assessment across all the projects of the Legume Innovation Lab. In FY 15, an intensive one week short term training workshop was implemented towards this broader goal of capacity strengthening in the area of monitoring and impact evaluation. This was funded through Supplemental Institutional Capacity Strengthening funds provided to ZARI. Researchers and economists from IIAM, LUANR, ZARI, SUA, Makere University and EIAR were invited to attend this training workshop that took place in Lusaka, Zambia in September 2015. This course was be led by Legume Innovation PI and economists from CIAT. Additional details are provided in Section VI.

# VI. Human Resource and Institution Capacity Development

<u>**Short-Term Training**</u>

***Training 1***

**Purpose of Training:** to strengthen the capacity of research and development organizations to document the results and impacts related to the development of agricultural technologies

**Type of Training:** Training workshop

**Country Benefitting:** Uruguay, Argentina, Brazil

**Location and Dates of Training:** Montevideo, May 18–22 2015

**Number receiving training (by gender):** 10 males; 9 females

**Home institution(s) (if applicable):**

**Institution providing training or mechanism:** CIAT (with technical input from MSU)

***Training 2***

**Purpose of Training:** to strengthen the capacity of research and development organizations to document the results and impacts related to the development of agricultural technologies

**Type of Training:** Training workshop

**Country Benefitting:** Zambia, Mozambique, Malawi, Tanzania, Uganda and Ethiopia

**Location and Dates of Training:** Lusaka, September 21–25 2015

**Number receiving training (by gender):** 12 males; 4 females

**Home Institution(s) (if applicable):** ZARI

**Institution providing training or mechanism:** MSU and CIAT

<u>**Degree Training**</u>

**First and Other Given Names:** David

**Last Name:** DeYoung

**Citizenship:** USA

**Gender:** Male

**Host Country Institution Benefitting from Training:** None directly

**Training institution:** Michigan State University

**Supervising CRSP PI:** Mywish Maredia
**Degree Program for training:** M.S.
**Program Areas or Discipline:** Agricultural Economics
**Thesis Title/Research Area:** Determinants of sustainability of community seed banks in Nicaragua: A duration analysis approach
**Start Date:** Fall 2011
**Projected Completion Date:** Fall 2015 (thesis defense exam completed in August 2015)
**If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?** No
**Training status (Active, completed, pending, discontinued or delayed):** Completed

## VII. Achievement of Gender Equity Goals

This project is designed to assess how the technologies and knowledge generated by the Legume Innovation Lab (and its predecessor CRSP) benefits both men and women farmers, entrepreneurs and consumers. Thus, where applicable, gender equity is used as one of the metrics in evaluating the impact of Legume Innovation Lab research. Survey instruments are designed to collect gender disaggregated data on beneficiaries. Where applicable, results of analysis based on primary data are reported by gender to assess the impact on women farmers and other potential beneficiaries of Legume research.

## VIII. Achievement and Progress Along the Impact Pathway

For this project we have identified two project outputs to be achieved over the life of the project that will contribute towards developing an impact oriented research program that features: 1) Greater awareness among researchers of the importance of achieving developmental outcomes; and 2) Better design of research programs that incorporate strategies and partnerships to transfer research outputs into outcomes and impacts; and 3) Continued and increased support for investments in agricultural research in general, and on legume crops in particular. Towards the impact pathway of achieving this 'vision of success', the following was achieved (cumulatively) as of the end of FY 2015 for each output:

**Output 1. development of impact pathway analytical tools and guidelines:**
***Transfer of analytical tools to project PIs and research teams:*** Completed as planned (in FY 14)

***Input and feedback to research teams on their impact pathway: completed as planned in FY 14***
Monitor the progress towards projected outputs and strategies to achieving the vision of success as laid down in the impact pathways: Ongoing

**Output 2: Evidence based assessments of potential and realized impacts of investments in agricultural research:**
Publication of results of the assessments in technical reports and peer reviewed venues: Three technical reports, one thesis, and two manuscripts for peer reviewed venue have been completed.

# IX. Explanation for Changes

The following outputs targeted to be achieved by the end of FY 2015 have been delayed:

1. One manuscript for journal submission. We had set a target of one manuscript for journal submission and/or presentation at professional meetings. Two Abstracts based on research results of this project were submitted for the AAEA professional meeting in 2015, but were not accepted. A manuscript or a professional meeting presentation based on the recently completed MS thesis paper by David DeYoung is planned by early 2016.
2. Impact Briefs. We had planned to develop two Impact briefs in FY 2014 and one in FY 2015. To date these outputs have not been achieved. We are waiting for the research studies to be published in peer reviewed venue before developing the Impact Briefs. We plan to do this soon after the manuscripts are published.
3. Haiti impact study. As indicated before, due to elections in Haiti, the host country collaborators proposed doing this study in 2016 instead of 2015.
4. Tanzania study on willingness to pay. Due to delays in finding a suitable mode of transferring the funds to SUA, the field activities could not take place as planned in the Long-rainy season. Only one set of field experiments has been completed in FY 15. The other set is planned to be completed in FY 16.
5. One of the short-term training courses anticipated to be conducted <u>through external funding</u> in Mozambique did not take place as planned. With the departure of B. Reyes (collaborator on this project) and R. Benfica (a faculty member in AFRE who was going to be the collaborator in organizing the training workshop in Mozambique) from MSU early FY 2015, this workshop never materialized.

# X. Self-Evaluation and Lessons Learned

**<u>Challenges</u>**

Our project is a collaborative project cutting across all the other projects funded by the Legume Innovation Lab. We depend on the support and collaboration of the lead US and HC PIs in implementing our workplan. In some cases, we have to rely on the existing contractual agreements between the US and HC institutions of other LIL projects to channel the funds for field research. As such delays in the contract amendments between these institutional partners (which is not in our control) impacts our workplan.

In the case of the Benin study, the lack of French language skills on our part was also a challenge in engaging with the HC collaborator in planning this activity and contributing to this study as we had planned.

In November 2014, a key collaborator at MSU on this project (B. Reyes) joined CIAT. His departure from MSU has had an impact on available human resources for this project, and contributed to some of the delays in completing the workplan.

**Failures.** Although, there are no ‘failures’ in doing research, we do consider the ‘delays’ in implementing the workplan or ‘incomplete’ activities reported in this Annual Report as a failure on our part to properly manage time and available resources to meet the outputs set for this project.

**Successes/Strengths.** The support and collaboration we have received from other project teams in the implementation of research and capacity building activities is greatly appreciated. This spirit of cross-disciplinary collaboration evident in the activities reported in this project's annual report is a strength of this program.

## XI. Scholarly Accomplishments

### Publications and Manuscripts

Maredia, M., Reyes, B., D. DeYoung. 2014. Farmer perspective on the use of and demand for seeds of improved bean varieties: Results of beneficiary surveys in Guatemala, Honduras and Nicaragua. Staff Paper 2014–04. Department of Agricultural, Food and Resource Economics, Michigan State University, East Lansing. http://ageconsearch.umn.edu/bitstream/196540/2/MSU%20AFRE%20Staff%20Paper%202014-04%20BTD%20Report%20Beneficiary%20Survey_final.pdf

Reyes, B., D. DeYoung and M. Maredia. 2014. Effectiveness of the bean seed dissemination models implemented under the Bean Technology Dissemination (BTD) Project: Results of key informant interviews in Guatemala, Honduras and Nicaragua. Staff Paper 2014–03. Department of Agricultural, Food and Resource Economics, Michigan State University, East Lansing. http://ageconsearch.umn.edu/bitstream/196539/2/MSU%20AFRE%20Staff%20Paper%202014-03%20BTD%20Report%20KII_final.pdf

Maredia, M. K., Reyes, B. A., Ba, M., C. Dabire, Pittendrigh, B., & Bello-Bravo, J. Effectiveness of animation videos in inducing technology adoption: A field experiment in Burkina Faso. (Revise and resubmit to *Journal of Agricultural Economics*)

### Thesis

DeYoung, David. 2015. Determinants of sustainability of community seed banks in Nicaragua: A duration analysis approach. Thesis for partial fulfillment of MS degree in Agricultural, Food and Resource Economics, Michigan State University (to be submitted in December 2015).

### Presentations

Maredia, M., Reyes, B. A., Ba, M., Dabire, C., Pittendrigh, B., Bello-Bravo, J. 2014. *Are Animation Videos Effective in Inducing Technology Adoption? A Field Experiment in Burkina Faso*. presented at Department of Economics Research Seminar, Western Michigan University, Kalamazoo, Michigan (November)

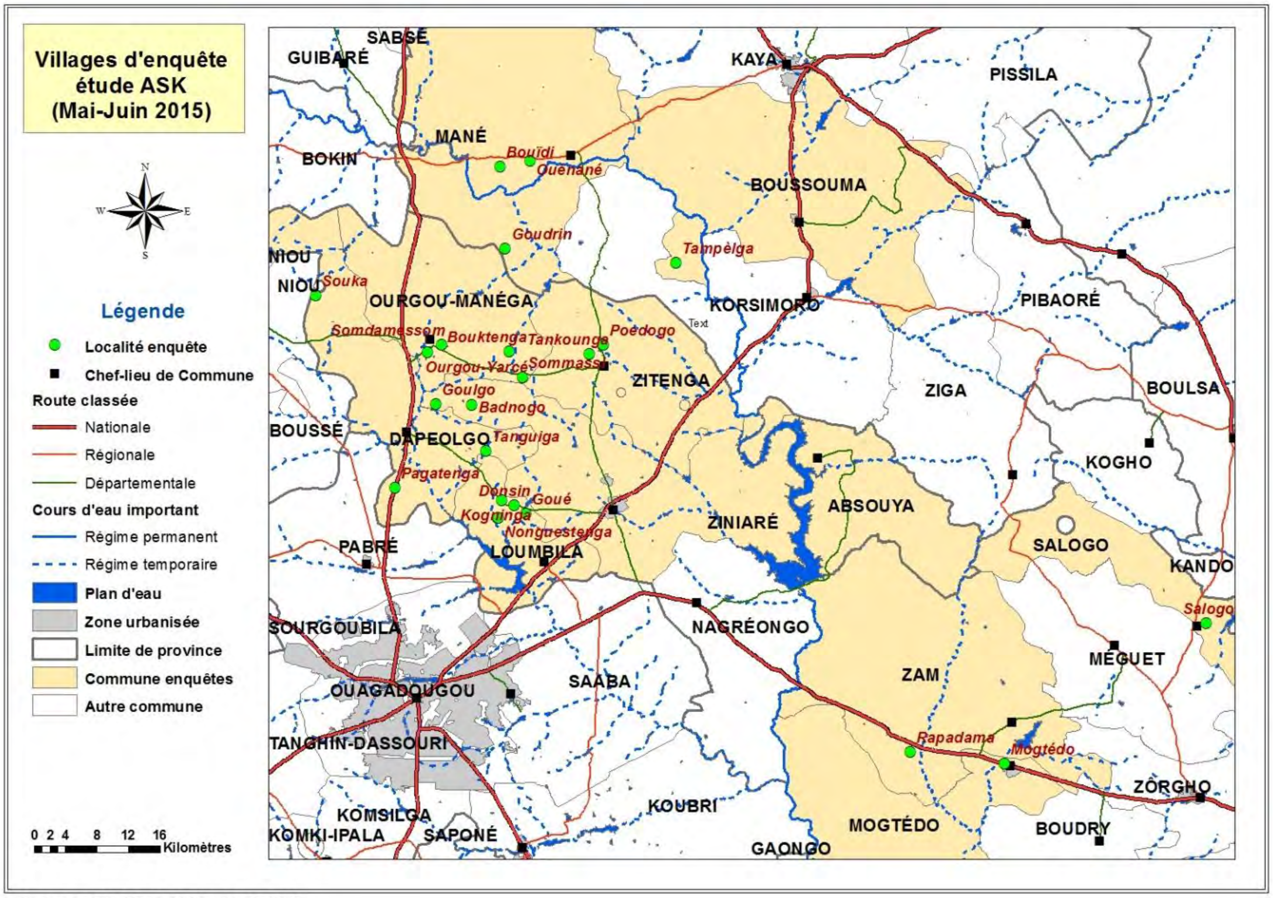
## XII. Data Management

A data management plan was submitted to LIL Management Office in July 2014 which outlined the plan for making 8 datasets generated by this project public over the next 3 years. No datasets have been submitted to publically accessible data bases in this reporting period (FY2015).

**ANNEXES**

**Annex 1. Tables, Figures and Photos Cited in the Report**

Figure 1. Location of villages selected for ASK seed producer and member surveys in Burkina Faso (villages are indicated by green dots)




Sources : BNDT_MajBGB, projet ASK

**Annex 2. Literature Cited**


Alfnes, F. 2009. Valuing Product Attributes in Vickrey Auctions when Market Substitutes are Available, *European Review of Agricultural Economics*, 36, 133–149.

Becker G.M., DeGroot M.H., Marschak J. 1964. "Measuring utility by a single-response sequential method". *Behav Sci* **9** (3): 226–32. *doi*:*10.1002/bs.3830090304*

Cochran, W. and Rubin, D.B. 1973. "Controlling Bias in Observational Studies", *Sankyha*, 35, 417–446.

Lusk, J.L. and J. Shogren. 2007. Experimental Auctions: Methods and Applications in Economic and Marketing Research. Cambridge: Cambridge University Press.

Rosenbaum, P.R. and Rubin, D.B. 1983. "The Central Role of the Propensity Score in Observational Studies for Causal Effects", *Biometrika*, 70, 1, 41–55.

# Milestones

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**

**Report on the Achievement of "Milestones of Progress"**
**(For the Period: April 1, 2015 -- September 30, 2015)**

**This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2015**

***Project Title:*** **technology dissemination for improved program effectiveness**

| | ***Abbreviated name of institutions*** | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MSU | | | Institution 2 | | | Institution 3 | | | Institution 4 | | | Institution 5 | | | Institution 6 | | |
| | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | | Target | Achieved | |
| ***Milestones by Objectives*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** | **10/1/15** | **Y** | **N*** |
| | ***(Tick mark the Yes or No column for identified milestones by institution)*** | | | | | | | | | | | | | | | | | |
| **Objective 1** | **Provide technical leadership in the design, collection and analysis of data for strategic input and impact evaluation** | | | | | | | | | | | | | | | | | |
| 1.1 Finalize the study design/pr | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 1.2. contribute towards complet | **X** | **X** | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 1.3 Finalize the study design, s | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 1.4 Complete data collection in | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 1.5 Contribute to completing the | **X** | | **X** | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| **Objective 2:** | **Conduct ex ante and ex post impact assessments** | | | | | | | | | | | | | | | | | |
| 2.1 Finalize the study design fo | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 2.2 Complete field experiments | **X** | **X** | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 2.3 Finalize the study design fo | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 2.4 complete data collection an | **X** | | **X** | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 2.5 Complete one Impact Brief | **X** | | **X** | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |

## Milestones, continued

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Objective 3:** | **Build institutional capacity and develop human resources in the area of impact assessment research** | | | | | | | | | | | | | | | | | |
| 3.1 Organize at least one short- | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |
| 3.2 Organize two more short-te | **X** | X | | **0** | | | **0** | | | **0** | | | **0** | | | **0** | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Name of the PI reporting on milestones by institution** | M Maredia | PI name | PI name | PI name | PI name | PI name |

| | |
|---|---|
| **Name of the U.S. Lead PI submitting this report to the MO** | M Maredia |

Mywish Maredia

**Signature**

Nov 11 2015

**Date**

# Performance Indicators

**Feed the Future Innovation Lab for Collaborative Research on Grain Legumes**
**REVISED PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 14, FY 15, FY16, and FY 17**

**Project Name: SO4.1 Impact Assessment of Dry Grain Pulses CRSP investments in research, institutional capacity building and technology dissemination for improved program effectiveness**

**Institution 1 Name (one sheet per institition): Michigan State University**

| Indic. numbe | Output Indicators | FY 14 Target | FY 14 Revised | FY 14 Actual | FY 15 Target | FY 15 Revised | FY 15 Actual | FY 16 Target | FY 16 Revised | FY 16 Actual | FY 17 Target | FY 17 Revised | FY 17 Actual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (October 1, 2013 - September 30, 2014) | | | (October 1, 2014 - September 30, 2015) | | | (October 1, 2015 - September 30, 2016) | | | (October 1, 2016 - September 30, 2017) | | |
| 1 | 4.5.2(6) Degree Training: Number of individuals who have received degree training | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | Total number by sex | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | Number of women | | | | | | | 1 | | | | | |
| | Number of men | | | | | | | | | | | | |
| | Total number by New/continuing | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | New | | | | | | | 1 | | | | | |
| | Continuing | | | | | | | | | | | | |
| 2 | 4.5.2(7) Short-term Training: Number of individuals who have received short-term training | | | | | | | | | | | | |
| | Total number by sex | 0 | 0 | 0 | 0 | 0 | 16 | 15 | 0 | 0 | 0 | 0 | 0 |
| | Number of women | | | | | | 4 | 5 | | | | | |
| | Number of men | | | | | | 12 | 10 | | | | | |
| | Numbers by Type of individual | | | | | | | | | | | | |
| | Producers | | | | | | | | | | | | |
| | People in government | | | | | | 16 | 15 | | | | | |
| | People in private sector firms | | | | | | | | | | | | |
| | People in civil society | | | | | | | | | | | | |
| 3 | 4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Phase 1: Number of new technologies or management practices under research as a result of USG assistance | | | | | | | | | | | | |
| | Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance | | | | | | | | | | | | |
| | Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance | | | | | | | | | | | | |

**Notes:**

These indicators are developed under the Feed the Future Monitoring System. Please provide 'total' numbers and also disaggregate where applicable. Just providing 'totals' will not be approved.

This table corresponds to the Feed the Future Performance Indicators data collection sheet under the FTFMS system. Where an indicator does not apply to the type of work done under the project, leave it blank.

Please follow the indications in the Legume Innovation Lab Indicators Handbook that will be provided to you by the Management Office. Contact Mywish Maredia (maredia@anr.msu.edu) for further information.

There is additional guidance on the USAID/Microlinks website: http://agrilinks.org/sites/default/files/resource/files/FY14%20FTFMS%20Guidance_2.pdf