FY 2016 TECHNICAL PROGRESS REPORTS

October 1, 2015–September 30, 2016

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

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

Legume Innovation Lab

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- 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)
- Honduras (SO1.A4)

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- USDA/ARS, Tropical Agriculture Research Station, Mayaguez, 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)
  Savanna Agricultural 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)
  Centro de Comunicación para el Desarrollo (CECODE)
- **Haiti** National Seed Service (NSS), Ministry of Agriculture
- **Honduras** Escuela Agrícola Panamericana–Zamorano (EAP–Zamorano) and
  Dirección de Ciencia y Tecnología (DICTA)
- **Malawi** Lilongwe University of Agriculture and Natural Resources (LUANAR)
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- **Mozambique** Instituto de Investigação Agrária de Moçambique (IIAM)
- **Nicaragua** Instituto Nicaragüense de Tecnologías Agrícolas (INTA)
- **Niger** Institut National de la Recherche Agronomique du Niger (INRAN)
- **Senegal** Institut Sénégalais de Recherches Agricoles (ISRA)
- **Tanzania** Sokoine University of Agriculture (SUA)
- **Uganda** Makerere University
  National Agricultural Research Laboratories (NARL)
  National Crops Resources Research Institute (NaCRRI)
- **Zambia** 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 for Agricultural Research and Development Program
BNF	Biological Nitrogen Fixation
Bt	*Bacillus thuringiensis*
CA	Central America (Includes Guatemala, Honduras, El Salvador, Nicaragua and Costa Rica)
CCARDESA	Centre for Coordination of Agricultural Research and Development for Southern Africa
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture)
CRI	Crops Research Institute (Kumasi, Ghana)
CRP	Consortium Research Program
CRSP	Collaborative Research Support Program
CSB	Community Seed Bank
CSD	Community Seed Depot (MASFRIJOL)- equivalent to CSB
CSIR	Council for Scientific and Industrial Research (Ghana)
DDL	Development Data Library
DEC	Development Experience Clearinghouse
DEPI	Dynamic Environmental Phenotyping Imager
EAP	Escuela Agrícola Panamericana–Zamorano (Honduras)
EET	USAID commissioned External Evaluation Team
FAO	Food and Agriculture Organization
FTF	Feed the Future
GWAS	Genome-Wide Association Study
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)
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)
IYP	International Year of Pulses
KSU	Kansas State University
LIL	Feed the Future Innovation Lab for Collaborative Research on Grain Legumes
LSP	Legume Scholars Program
LUANAR	Lilongwe University of Agriculture and Natural Resources
MAS	Marker-Assisted Selection
ME	Management Entity for the Feed the Future Legume Innovation Lab (Michigan State University)
MO	Management Office of the Feed the Future Legume Innovation Lab
MSU	Michigan State University
MSPAS	Ministerio de Salud Pública 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)
PABRA	Pan-African Bean Research Alliance
PCCMCA	Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos y Animales
PI	Principal Investigator
QDS	Quality Declared Seed
QTL	Quantitative trait loci
RIL	Recombinant Inbred Lines
RMC	Research Management Committee
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 (Morogoro, Tanzania)
TMAC	Technical Management Advisory Committee
UCR	University of California- Riverside
UNZA	University of Zambia
UNL	University of Nebraska- Lincoln
UPR	University of Puerto Rico
USDA	United States Department of Agriculture
ZARI	Zambian Agriculture Research Institute (Zambia)

Executive Summary

The Feed the Future 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 multi-institutional, multi-country and multidisciplinary projects are subcontracted to Lead U.S. universities that sub-subcontract to 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 solutions (e.g., improved climate-resilient and disease resistance bean and cowpea varieties; sustainable integrated pest management practices using biologicals to control insect pests in cowpea; communications tools for low education farmers) and new knowledge (e.g., factors influencing farmer soil fertility management decision making, attributes of sustainable of seed systems for legumes, nutritional and health benefits of grain legumes in diets of young children, function of grain legume value chains) that can benefit stakeholders of grain legume value chains in developing countries.

The Management Office of LIL also administered one associate award in FY 2016: 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.

LIL Program Activities and Highlights

FY 2016 was the fourth and next-to-last year of the extension phase (April 1, 2013 – September 29, 2017) of the Feed the Future Innovation Lab for Collaborative Research Program on Grain Legumes (Legume Innovation Lab) administered by Michigan State University (AID-EDH-A-00-07-00005). The Management Office (MO) is pleased to report that FY 2016 was a highly productive and successful year. All ten subcontracted research and institutional strengthening/training projects have made acceptable technical gains toward achieving project output objectives as outlined in FY 16 workplans.

The LIL was afforded a unique opportunity in 2016 to promote grain legumes for increasing productivity and sustainability of cropping systems and for enhancing the nutritional quality of diets of the rural poor by partnering with the international pulse community to celebrate the International Year of Pulses, as declared by the FAO of the United Nations. To this end, the LIL MO collaborated with the Global Pulse Confederation and Emergingag.inc to organize a symposium at The Sackler Institute for Nutritional Science on “Realizing the Potential of Pulses to Meet Today’s Global Health Challenges” (11-19-2015), to prepare science-based messages on sustainability and human nutrition for distribution globally, and to develop a “10-year Research Strategy for Pulse Crops.”

A highlight of FY 2016 was the joint Pan-African Grain Legume and World Cowpea Conference held in Livingstone, Zambia (28 February – 4 March 2016), co-hosted by the Feed the Future Legume Innovation Lab and IITA in partnership with CIAT, the Zambia Ministry of Agriculture and CCARDESA. The conference provided a forum for grain legume scientists in a broad range of disciplines conducting research on diverse edible grain legume species (i.e., cowpea, common bean, pigeon pea, chickpea, etc.) from throughout Africa to share research advances, to network and to discuss the importance of grain legumes in the African continent. Thematic sessions and poster sessions addressed strategic issues relative to grain legumes in Africa (i.e., climate resilience, genomics, human nutrition and health, gender and youth, seed systems, BNF, orphan legume crops, etc.). The conference was attended by 550 persons from 46 countries, including 80 PIs from LIL. Scholarships were provided to 75 young African scientists and graduate students. A post-conference survey revealed that host country scientists networked with peers, learned about research advances in other disciplines, and established new collaborative research relationships.

The MO awarded $159,138.00 to support thirteen Institutional Capacity Strengthening activities at LIL partner HC institutions in FY 2016. These funds were used to procure research equipment for phenotyping, seed testing and storage, insect rearing for pest resistance screening, disease screening, plus for the development of apps to share integrated crop management (ICM) information with low education farmers, and for the short-term training of technicians and graduate students.

The MO strengthened partnerships with CIAT, IITA and ICRISAT in FY 2016, opening doors for new research collaborations on grain legumes with LIL scientists and partner U.S. and HC institutions.

The MASFRIJOL project, an associate award, established 36 community bean seed depots, distributed quality seed of improved bean varieties to 33,000 farmers, and provided nutrition education to >12,000 families in the FTF region of Guatemala in FY 2016.

The LIL MO facilitated a program performance assessment of LIL by the USAID commissioned EET. The EET reviewed technical research, training and financial reports and interviewed all U.S. and HC PIs. The final LIL evaluation report with an MSU response was posted on the DEC web site.

LIL Key Accomplishments

SO1.A1. Three lines of climbing bean (*Texel, Utatlan* and *Labor Ovalle*) have been validated in field trails and genetically pure foundation seed prepared for multiplication in 2017 for distribution to farmers in the highlands. Molecular characterization of the Guatemalan highland climbing bean collection with >150K SNP markers and phenotyping have revealed broad genetic diversity for important agronomic traits.

SO1.A2. A cutting edge phenotyping center for grain legumes was established at UNZA, based on the open access PhotosynQ plant phenotyping platform. MultispeQ instruments and training were used to collect high-throughput photosynthesis data in the field. In a major achievement, UNZA produced a complete proof-of-concept GWAS mapping for photosynthetic responses of common beans to drought.

SO1.A3. New resistance genes to anthracnose, common bacterial blight, and rust and tolerance to drought were identified in Uganda and Zambia. Three SSR markers associated with rust resistance and one InDel marker associated with anthracnose resistance were identified. Three genomic regions controlling traits for enhanced biological N-fixation were identified on chromosomes Pv03, Pv07 and Pv09. Twenty-three Andean bean lines were chosen by the farmer groups in Uganda based on cooking time and superior nutritional profiles.

SO1.A4. New improved bean varieties have been released in Central America and Haiti including: small black bean varieties *Sankara* and MEN-2201-64ML; the first bruchid resistant line- AO-1012-29-3-3A; the first yellow bean line with multiple virus and leafhopper resistances- PR1146-138; and the drought tolerant small red *INTA Rojo Jinotega*. Progress has been in increasing seed size, improving agronomic traits and enhancing disease resistance (BCMNV, rust, common blight) in Tepary lines.

SO1.A5. A differential cowpea panel was used to identify several aphid resistance sources effective against both U.S. and West African aphid populations. Three aphid resistance loci were genetically mapped to three different cowpea chromosomes. Advanced backcross progenies were developed by adding aphid resistance QTLs into elite recurrent parent varieties for African and US cowpea production.

SO1.B1. Over 67,000 parasitoids were released into Western Benin and Southern Burkina Faso for control of legume pod borer in cowpea. Research indicates that animated cell-phone based IPM information for low-education farmers is effective for scaling up IPM educational programs.

SO2.1. Two multi-stakeholder bean Innovation Platforms (IPs) organized in Uganda (10+ value chain member organizations and 400+ farmers) have validated improved management practices and technologies achieving increased bean yields: (1) soil testing; (2) quality seed; (3) increased plant density; (4) three weedings; and (5) the use of chicken manure in combination with inorganic fertilizers.

SO3.1. Data collection in the two nutrition studies in Malawi will be completed by December 2016. Malawian graduate students and district health professionals and local community leaders were vital to the success of the study. Insights into cultural feeding practices will guide the scale up of bean flours.

SO4.1. A study based of 8,000 small rural farm households in Zambia indicate positive effects of cereal-legume rotation and other legume technologies on net crop income, calorie and protein production, and months of adequate household food provisioning. A study on farmer willingness to pay for quality seed in Tanzania (for beans) and Ghana (for cowpeas) found that seed quality matters; certified seed out-performs QDS and QDS outperforms farmer recycled seed. Farmers are also willing to pay a premium for quality seed—but are influenced by their perception of seed quality differences.

LIL Research Program Overview and Structure

The Feed the Future 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 agro-ecologies 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 agro-ecological regions where legumes are commonly grown in Africa and Latin America
- **SO1.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 decisions

In 2016, Michigan State University administered a portfolio of ten subcontracted multi-institutional collaborative research and capacity strengthening projects and one associate award (MASFRIJOL). A lead PI at a subcontracted U.S. university is responsible for the development of annual workplans and budgets, project implementation, monitoring of technical progress, and annual reporting.

The Feed the Future 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 advanced HC research institutions, and coordination with CGIAR legume scientists through the CG's 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 scientists;
- Enhancing the capacity of strategic national and international agriculture research institutions to address critical 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 Feed the Future 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

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Fernando Aldana, ICTA-Guatemala – Retired July 2015.

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. Results from framer field trials during the 2016 growing season 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, Labor Ovalle, and Utatlan continued during FY 2016 in order to ensure adaptation and acceptability by growers. Genetic purification of Bolonillo-Texel is at its last stages in order to guarantee a homogeneous variety released. Even though this is not a big issue for growers, this will facilitate seed production of this variety in the future. The climbing bean collection was finally received at NDSU and genotyping of the collection has been done as planned. Approximately 150k SNP markers were used to characterize a non-duplicated subset 420 accessions from this germplasm collection. Preliminary results show that this population is structured as an admixture of genotypes with no clear separation into subgroups. Genetic relationships with other races, gene pools, and species are currently under study. Approximately 95% of the seed samples obtained from the grower survey were successfully increased at the ICTA greenhouses and are now increased and characterized in the field during the 2016 growing season. 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. Preliminary results from the growers survey allowed a better understanding if the current situation of climbing bean production and consumption in this region. The 3 students (2 female, 1 male) recruited to do their M.S. training in plant breeding and genomics at NDSU continue to make progress and programs should be completed by FY2017. This will ensure the next generation of bean scientists for Guatemala. Personnel from ICTA and Zamorano had the opportunity to do a site visit to NDSU dry bean breeding program during July 2016. In addition, new collaborations have been established with project SO4-1 and MASFRIJOL to augment the success of the breeding efforts of this project.

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 mid-altitude 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 Feed the Future Legume Innovation Lab has been involved in collaborative bean breeding research targeting lowland agro-ecologies 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.

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, Angela Miranda, Jessica Moscoso, Edgardo Carrillo.

1.1. Farmer's 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 (Dr. Aldana just retired from ICTA in July 2015 after more than 40 years of service). 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 ICTA-Chimaltenango. Results from these trials from last year (FY2015) are available as Appendix 1. In addition, an evaluation for natural infestation of *Asphondylia* sp. was also made at ICTA-Chimaltenango and results are shown in Appendix 3. In general, all genotypes were affected by this insect; however Texel was the least affected and the highest yielding genotypes, confirming its yield and agronomic potential already seen across years and locations.

1.2. Breeding pipeline

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 day length (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 in order to save time. By doing this, we successfully obtained 36 F1 populations (Appendix 1) instead of having to wait an extra year for a second attempt. All the F1 seed was then planted in the field at ICTA-Quetzaltenango during the 2016 growing season for evaluation and generation advancement. Additional 71 crosses (Appendix 1) were also made during the 2016 growing season at ICTA-Chimaltenango and are currently being harvested at the time of this report in order to have a continuous breeding pipeline for the future (see objective 1.2).

1.3. 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 have been made within the breeding lines since the 2013 growing season. An initial set of 101 F7 and 29 F5 individual plant selections have been 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 (2015-2016) 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, 97 individual plants from different F8 lines as well as 19 F6 lines were selected and sent to ICTA-Quetzaltenango for evaluations during the 2016 growing season. All these lines have been selected based on the characteristics mentioned above and harvest of this material is almost complete at the time of this report.

1.4. Field evaluation of the 3 most promising genotypes (Bolonillo-TEXEL, Utatlan, and Labor Ovalle (ICTA)

Validation plots were also made at farmer's fields for the 3 genotypes that have shown the best potential to be released as new improved cultivars: Bolonillo-Texel, Utatlan, and Labor Ovalle. These validation plots are a side-by-side comparison of one of these genotypes against the local landrace normally grown by the farmer. Plot size is usually a "cuerda" (~410 m^2) for each variety grown in a milpa system using the local maize variety as well. Each genotype was tested across 15 locations distributed in 3 departments (Quetzaltenango, San Marcos, and Totonicapan). Combined across locations, the highest difference between the improved genotype and the local check was for Labor Ovalle (table1), followed by Texel. There were no significant differences between Utatlan and the local check. However, this was somewhat expected because the interesting attribute of Utatlan is not its high seed yield but its early maturity compared with the rest of genotypes. Many farmers have said this would be highly preferred. All detailed information about these trials can be found in Appendix 2. Once results from the 2016 growing season are available (last year of field testing), final decisions will be made within ICTA in order to decide which genotypes will be officially released as new climbing bean varieties for the Guatemalan highlands.

Table 1. Seed yield of 3 improved genotypes of the ICTA-climbing bean project across 15 locations during the 2015 growing season

Genotype	Seed Yield (Kg/Ha)	Seed Yield of Local Check (Kg/Ha)	Yield Difference (Kg/Ha)
Utatlan	262	221	41^{NS}
Labor Ovalle	407	235	172*
Texel	506	359	148*
Mean – All Genotypes	391	271	120*

*Significant differences (P<0.05) based on paired t-test.

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 Eng. Elmer Estrada) and crop extension personnel from the Ministry of Agriculture have been crucial for finding these growers and locations. Results from 2016 will allow the collection of enough data across years and locations for the validation group to present this as official release at ICTA.

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.

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, Jessica Moscoso, Angela Miranda and Maria G. Tobar-Piñon.

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

Finally after several difficulties in obtaining seed of good quality and the proper phytosanitary permits to import the seeds to the U.S. (see previous reports for details), we were able to start working on this objective with very promising results so far. This is the main research topic of one of our trainees (Maria Gabriela Tobar-Piñon). The original Guatemalan climbing bean collection has 594 accessions. After selecting the accessions with seeds with uniform color, uniform shape and uniform size, the number of accessions was reduced to 377. This step was important because accessions very different within them can represent segregation and the results will not be consistent in the population structure analysis and the association mapping study. The intra-accession diversity of the collection will be evaluated in a different step of this study (Objective 2.2).

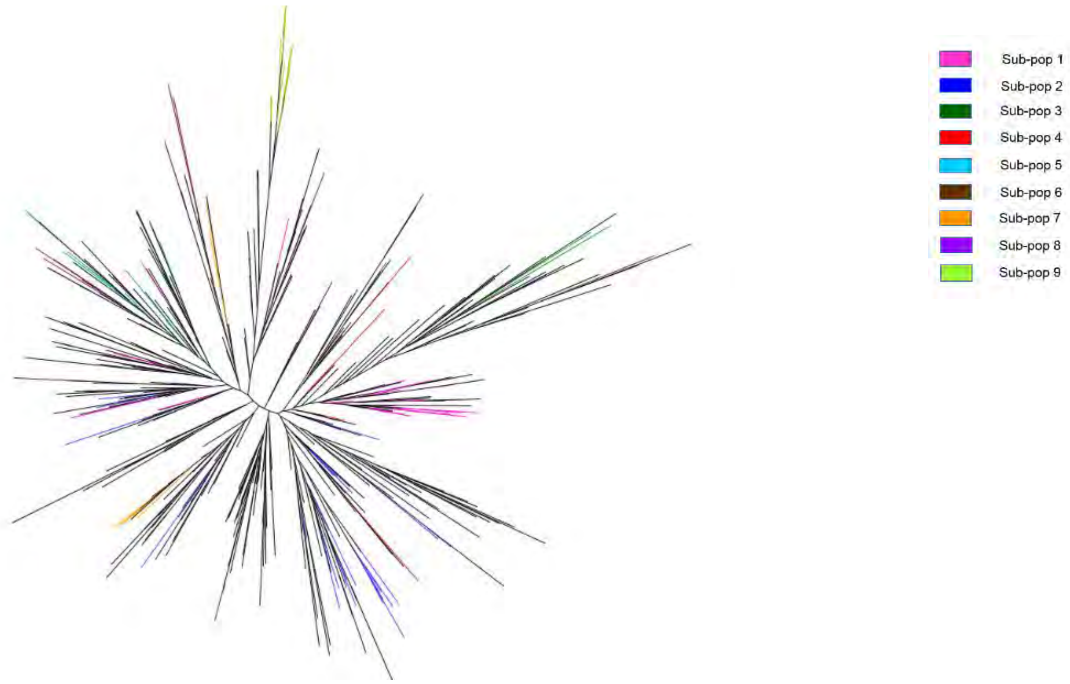
Methods

- 377 accessions of *P. vulgaris* collected in the highlands of Guatemala 50 years ago were analyzed.
- Two seeds of each landrace were planted; tissue was collected 15 days after planting.
- DNA extraction was made using the Genomic DNA Mini Kit (Plant), from IBI SCIENTIFIC.
- The libraries were created using Genotype by Sequencing and then sequenced using Illumina platform.
- Reads were mapped to the Version 2 of the G19833 reference genome sequence using BWA-MEM.
- SNPs were called using the Genome Analysis toolkit – GATK.
- A total of 102,822 SNPs were obtained.
- Using the markers, a maximum-likelihood tree was developed using SNPhylo. Markers were selected by using a Linkage Disequilibrium (LD) cut-off value of 0.1.
- Population structure was analysed using fastSTRUCTURE, with K=1 to 10. The best K was determined using the model complexity that maximizes marginal likelihood and Distruct was used to generate the plots.
- For association mapping SNPs markers with minor allele frequency ≥ 5% (78,754 SNPs) were used and Principal Component Analysis (PCA) was used to control for population structure.

    - Two PCs cumulatively explain 12% of the variation.
- A kinship matrix, generated by EMMA algorithm (Kang et al., 2008) was used to control for individual relatedness.
- The traits evaluated for GWAS were 26, using the morphological characterization performed to this collection with GAPIT (Lipka et al., 2012). Multiple models were tested for each trait: ***Naive*** model, ***Linear*** model with fixed effect (account for population structure), ***Mixed linear*** model (Yu et al., 2006) to control for relatedness or both relatedness and population structure.
- The best model was determined using the Mean Square Differences (MSD) (Mamidi et al., 2011) and markers with a bootstrapped (1000 replications) p-value falling in the top 0.01 percentile were considered as significant levels.

Preliminary Results

The estimated number of sub-populations was nine based on the model complexity that maximizes marginal likelihood. Figure 2 shows the individuals distribution for each population. However, based on the ML tree (figure 1) and the PCA analysis (figure 3) the population structure is low. A total of 101 accessions had a value of membership higher than 0.8 in the nine populations. The analysis also shows a high percentage of admixture in the accessions. It was concluded that the high number of markers used for this analysis allowed a false determination of K using STRUCTURE. It is suggested that Guatemalan climbing beans belong to race Guatemala, and for this reason the accessions are very similar between them. A comparison with accessions of Mesoamerican and Andean races will allow the confirmation of this hypothesis and will be our next step in this study. Additionally, a comparison with a new set of Guatemalan climbing bean accessions (500) collected in 2015 will be compared to this group to determine their geographical location.



1. **Figure 1.** Maximum-likelihood tree of 369 climbing bean accessions based on 2,732 SNPs (LD=0.1). Color in the branches shows the sub-population where they belong based on the Structure analysis.

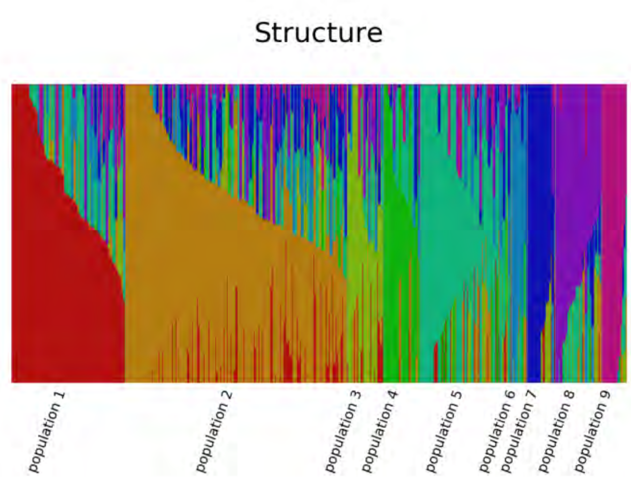


Figure 2. Hierarchical organization of the 369 climbing bean accessions based on 2732 SNPs (LD=0.1) for

K=9.

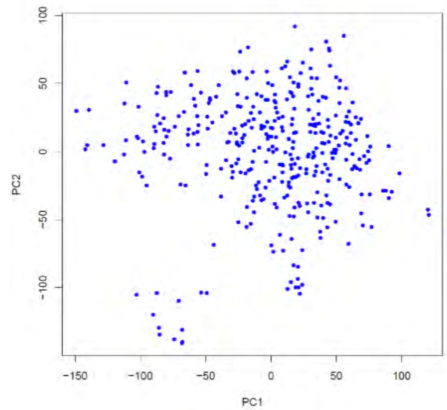


Figure 3. Principal Component Analysis (PCA) of the SNPs diversity for the Guatemalan climbing bean accessions.

A GWAS analysis was performed for multiple traits (agronomic and natural disease pressure) using phenotypic data previously recorded under field conditions at ICTA-Chimaltenango. Since disease resistance is one of the main objectives of this project, here is an example of how genomic information could help towards the development of good resistant cultivars in the future: For the trait of Rust (*Uromyces appendiculatus*) resistance, a significant peak in chromosome 2 (Figure 4) was found. This SNP is inside a gene encoding a leucine-rich repeat transmembrane protein kinase. This type of gene is generally associated with plant resistance to diseases. For the trait of downy mildew (*Phytophthora nicotianae* var. *parasitica*) resistance there is a strong peak found in chromosome 6. This marker is inside a gene encoding an ubiquitin ligase binding protein. Other studies also relate this kind of gene with some resistance to necrotrophic pathogens. These results are promising for the use of this collection as a source of alleles in common bean breeding.

Rust

Phytophthora

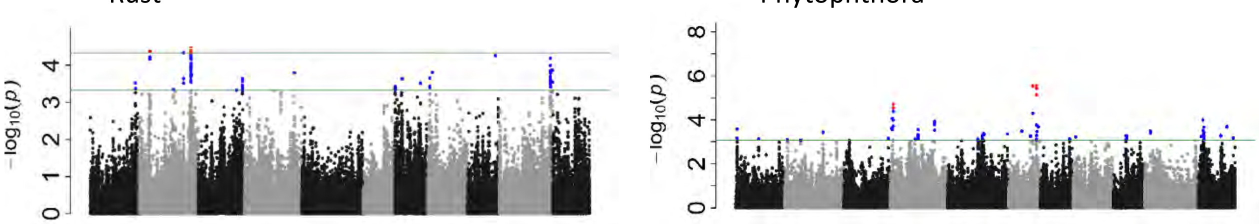


Figure 4. Manhattan plots of the best models for Rust and Phytophthora resistance. The green lines are the cut-off values to call a peak significant. The SNPs that pass the 0.01 percentile are highlighted in red, while those that pass the 0.1 percentile are highlighted in blue.

Two additional M.S. students at NDSU (ICTA trainees) are also using this germplasm collection as part of their thesis. Luz de Maria Montejo is focused on the identification of resistant accessions to bean rust, while Carlos Maldonado is evaluating the collection to find new sources of resistance to Anthracnose.

Bean rust bean samples were taken from bean producing fields at Guatemalan Highlands and two highly frequent rust races have been identified, in collaboration with Dr. Jim Steadman from the Plant Pathology Department at University of Lincoln, Nebraska. Rust races were identified as a 63-1 and 31-1. Samples were taken from the following departments at Guatemala during the end of the 2015 growing season: Chimaltenango, Quetzaltenango, and San Marcos. Both races were found within each department and preliminary results suggest that they affect mainly Andean-origin rust genes. In addition, the entire climbing collection was screened for those two Guatemalan rust races and with race 20-3, the newest and most frequent race in North Dakota. Preliminary results are showing that 39% of the climbing bean accessions showed resistance to the 63-1 rust race and 58% showed resistance to the 31-1 rust race. The 20-3 ND race is currently being evaluated at NDSU greenhouse and final data is going to be reported soon.

In the case of Anthracnose, the climbing bean collection was evaluated with race 73 which is the most commonly found race in North Dakota. Preliminary results suggest that almost a 10% of the climbing bean germplasm accessions are resistant with no visible symptoms in the plants (disease score 1) to race 73. Same as with rust, anthracnose sampling was made at different locations from the Guatemalan highlands during the 2015 and 2016 growing seasons. Samples of climbing beans from small scale farmers from Totonicapan, Quetzaltenango, San Marcos, and Huehuetenango departments were taken from leaves, pods, or stems that showed symptoms of anthracnose. Samples will be sent to Dr. Talo Pastor-Corrales at USDA-ARS in Beltsville-MD for further race typing and characterization.

All phenotypic data collected from disease reaction to both rust and anthracnose will be used to identify genomic regions associated with genetic resistance using the same GWAS approach reported above. Results will be useful not only for Guatemala but also to find new potential sources of resistance to local races found In North Dakota, the largest producer on dry bean in the U.S. Once genomic regions can be located with accuracy, new diagnostic markers can be designed that could be used in a Marker Assisted Selection (MAS) scheme.

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. This activity is currently underway and result will be reported in the next cycle.

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 FY2015 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 1.2). 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 FY 2016. These selected accessions were used for the first set of crosses described in objective 1.2.

Objective 3. A better understanding of the current socio-economic 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. A total of 548 farms were surveyed covering the 5 most important bean producing departments in the western highlands (details about survey protocol can be found in previous reports or in the IRB document). 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. Gustavo Mejia, social economist from ICTA-Quetzaltenango was also of key importance for the success of this activity.

Collected data has been entered into a digital format (Excel) by ICTA personnel and was revised and filtered of errors at MSU. Data was then analyzed using the proper statistical tools and preliminary results were presented at the Pan-African Grain Legume and World Cowpea Conference at Zambia in March 2016. Results of this survey will be also shared not only within the project but with other projects currently working in Guatemala (e.g. Masfrijol) and government agencies interested.

Major findings are summarized below.

Bean Consumption

- Majority of farmers (80%) do not sell beans; only 6% sold more than 50% of their harvest.
- Own production covered less than half of annual bean consumption for 23% of farmers; for another 33% of farmers, own production covered between 50-75% of annual consumption. Once own produced beans were consumed, 50% of farmers purchased beans at least weekly.
- On average, a household cooked beans 2.5 times and consumed a total of 5 cups of (uncooked) beans in the week prior to the survey.
- Households with children (under 14) on average served beans to the children 3 days in the week preceding the interview. On days that children ate beans, more households served beans at breakfast (75%) and dinner (79%) than at lunch (53%).

- Beans are consumed throughout the year; it is highest at or after the harvest – from November to March, and lowest in July and August.
- Dietary diversity, culinary preferences and farmers' perceived nutritional value of beans.
- On average a household consumed 6 out of 12 diverse food groups in the day prior to the survey; More than 85% reported consuming beans the previous day.
- Frijol negro, vulgaris and bolonillo were among the most preferred bean variety/type for consumption named by farmers.
- Respondents indicated that flavor (76%) was what they like most about a bean variety followed by thickness of bean broth (32%), cooking time (3.2%), expansion of size (1.5%) and color retention during cooking (0.7%).
- On a scale of 0-10, farmers rated beans 8.9 in terms of nutritional value, which was just below the score for maize (9.4), but higher than the perceived nutritional value of rice (8.1), potatoes (7.8), meat (6.9), chayote (5.9) and Coca Cola (1.4).

Bean Productivity and Production Practices

- An average household owns 0.73 ha (median=0.27 ha) and devotes 1.3 parcels of land on the simultaneous planting of milpa (direct planting) system, with an average plot size of 0.29 ha (median=0.18 ha). The average bean yield on the simultaneous planting milpa plots is 318 kg/ha (median=208 kg/ha).
- Farmers use the Milpa intercropping system with low crop rotation. The majority of farmers' plots were planted with maize in the year of the survey (94%) and also in the previous year (92%). Climbing beans were also planted on the same plot in the previous year (91%).
- Simultaneous Milpa(direct planting) was a more common practice (73%) than waiting several weeks to plant beans (relay) (21%); only 2.3% of plots surveyed had beans planted alone in rows or intercropped with other crops (2.0%).
- Most plots were planted with one bean variety (74%) while 18% had two varieties, and 6% had three varieties.
- Desired characteristics of a bean variety as cited by percentage of farmers are yield (49%), seed size (36%), seed color (32%), fast cooking time (32%), taste (31%), resistance to field pests (27%), resistance to lodging/weighing down maize (23%), early maturity (21%), and resistance to diseases (21%).
- Farmers are willing to pay on average $6.6 Guatemalan Quetzals per pound (US$ 0.80) for improved variety seeds that have the characteristics they desire and indicated that they would initially purchase on average 6.8 pounds of seed.

The study is one of the first representative farm surveys of climbing bean growers in the region. The analysis of this data has helped gain a better understanding of farmer characteristics, bean production practices in the *Milpa* system, and the role of beans in household food consumption. The analysis contributes towards establishing priorities for the climbing bean breeding program targeted for increasing the productivity of the *Milpa* system.

3.2. Seed increase of samples collected during the survey (ICTA/NDSU)

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 ~460 (out 540 surveys) climbing bean germplasm accessions that virtually represents what climbing bean growers are using in their farms currently. Within this group, there is a set of ~100 accessions that were collected by the ICTA genetic resources unit during 2015 and were shared with us as well. Since seed amounts were limited, 4 seeds per sample were planted in the greenhouse in 2015 for increase and future evaluation during FY 2016. Harvested seed from the greenhouse was then planted in the field for a second round of increase and evaluation at ICTA-Chimaltenango during the 2016 growing season and it is being harvested at the time of this report. This provided 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). As a matter of fact, a group of 24 accessions from this new group have been selected in the field at ICTA-Chimaltenango for future testing and crosses.

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 across time could be detected. Seed samples have been received at NDSU and DNA extraction us currently underway. 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, try to pinpoint 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 in the future (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.

4.1. Graduate Students

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. The three students are currently living in Fargo, ND and making progress towards their M.S. degree by taking classes and doing research at NDSU. Research topics are directly related to the research objectives described above. The graduate students are provided with 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.

4.2. Site visit/workshop at NDSU for ICTA personnel

As described in the technical project description, a site visit/workshop has been proposed for the third year of this project. A total of 6 host country collaborators (3 from ICTA-Guatemala and 3 from Zamorano-Honduras) spent 7 days during July 2016 at NDSU. The goal of this training/workshop was to show the visiting group how bean production is made in North Dakota (the largest producer in the U.S.) and also to receive training on modern techniques in plant breeding, plant pathology, molecular markers, and other genomic tools that could help in the breeding process. Activities included field tours to breeding nurseries, commercial farming operations, and bean industries in the region. Visitors also received talks about molecular techniques, plant pathology, and seed production/systems, among others. Many visitors said this opportunity was an “eye opener” for them regarding how different and efficient productions systems can be and how many things could be implemented back into their countries. One of the outcomes of this sit visit was the writing of a medium and long-term plan for breeding of climbing beans in Guatemala that could be used for planning purposes if additional funding is available to continue this project in the future.

Major Achievements

1- On farm field testing and validation across 15 locations of 9 breeding lines with potential to be released in the near future.
2- On-farm testing and validation of Bolonillo-Texel, Utatlan, and Labor Ovalle across 15 locations.
3- Establishment of a breeding pipeline and second set of crosses.
4- Genetic purification of promising lines.
5- Initial molecular characterization (DNA extraction) of climbing bean collection.
6- Completion of grower survey and data tabulation of ~500 questionnaires.
7- Completion of statistical analyses of grower survey and presenting/distributing preliminary results to interested audiences.
8- Collection of seed samples from surveyed growers and seed increases in the greenhouses.
9- Selection of new genotypes from grower survey with breeding potential.
10- Recruitment of 2 female students and 1 male student for formal training (M.S. in Plant Sciences) at NDSU.
11- Site visit/workshop at NDSU made by 6 host country scientists during July 2016.
12- New collaborations established with project SO4-1 and MASFRIJOL will augment the success of the breeding efforts of this project.

Research Capacity Strengthening

During FY 2016, 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 held at San Jose, Costa Rica during April 2016. The meeting attracted approximately 400 participants from the region. The funds were used to support travel of ICTA personnel to this important event.

Human Resource and Institution Capacity Development

Short-Term Training

Site visit/workshop to NDSU at Fargo, ND

Purpose of Training: To train a group 6 host country scientists in modern plant breeding techniques and bean productions systems in the U.S.
Type of training: 7-day visit/workshop.
Country Benefiting: Guatemala and Honduras.
Location and dates of training: NDSU, Fargo-ND, July 17-24 2016.
Location and dates of training: 3 female, 3 male.
Home institution(s): ICTA-Guatemala and Zamorano-Honduras
Institution providing training or mechanism: NDSU (Juan M. Osorno, Phil McClean, and other NDSU personnel).

Field Days – Agricultural Technology Showcase at ICTA-Quetzaltenango:

Purpose of Training: Area farmers are invited to the station for a day to learn about different aspects of crop production, including bean and maize.
Type of training: 1-day visit/workshop.
Country Benefiting: Guatemala.
Location and dates of training: ICTA-Quetzaltenango, October 6-28, a different group each day (see table 2).
Location and dates of training: 335 female, 533 male.
Home institution(s): ICTA-Guatemala
Institution providing training or mechanism: ICTA-Quetzaltenango (Jessica Moscoso and Karen Agreda).

Table 2. Field Days at ICTA-Quetzaltenango.

	Date	Male	Female	Total
1	10/6/2016	40	10	50
2	10/12/2016	11	5	16
3	10/13/2016	129	73	202
4	10/18/2016	52	65	117
5	10/19/2016	47	76	123
6	10/21/2016	36	4	40
7	10/23/2016	31	3	34
9	10/25/2016	123	82	205
10	10/28/2016	64	17	81
	Total	533	335	868

Degree Training

First and Other Given Names: Maria Gabriela
Last Name: Tobar Piñon
Citizenship: Guatemalan
Gender: Female
Training Institution: NDSU
Supervising Innovation Lab 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 LIL Support (full, partial or indirect) for training activity: Full

First and Other Given Names: Luz de Maria
Last Name: Montejo
Citizenship: Guatemalan

Gender: Female
Training Institution: NDSU
Supervising Innovation Lab 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 LIL Support (full, partial or indirect) for training activity: Full

First and Other Given Names: Carlos
Last Name: Maldonado-Mota
Citizenship: Guatemalan
Gender: Male
Training Institution: NDSU
Supervising Innovation Lab 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: Anthracnose 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 LIL Support (full, partial or indirect) for training activity: Full

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.

Explanation for Changes

No changes to report.

Self-Evaluation and Lessons-Learned

After 3 years working in this partnership between NDSU and ICTA-Guatemala, the project has been able to make a lot of progress, considering this is a brand new project within the Feed the Future Legume Innovation Lab research portfolio. 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-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 Feed the Future Legume Innovation Lab for bush type beans for the lowlands along with the University of Puerto Rico. With the results from farmer field trials from the 2016 growing season, there should be enough data across years and locations (environments) to make final decisions regarding cultivar releases. It is important to note that final decisions regarding cultivar releases are made by another group within ICTA called the validation group. We are intensively communicating with the group leader (Mr. Julio Franco) to ensure they understand the importance of releasing genetic material and the end of the cycle of this project. This is where politics gets in the middle of science but we are trying our best to ensure this will happen. The good thing is that we have total support from ICTA director (Dr. Elias Raymundo).

We are very pleased to be able to report on the molecular characterization of the germplasm collection. Because of multiple reasons, this activity was delayed but we are happy to report we are back on track and results are being generated. In the same way, the results from the grower survey will allow a better understanding of the needs for this region as well as many bean consumption habits that were not completely clear based on previous information. In addition, we are very excited about the induction of “new” germplasm collected from this survey. This newer collection opens multiple opportunities for future research that will benefit the region directly.

After many difficulties, we were able to recruit 3 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.

Scholarly Accomplishments

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.

DeYoung D., Reyes B., Villatoro J.C., Montejo L.M., Moscoso-Alfaro J., Osorno J.M., and Maredia M. 2016. The Role of Beans in the Milpa Production and Dietary Systems of Guatemalan Highlands: Results of a Farm Household Survey. Pan-African Grain Legume and World Cowpea Conference. Livingstone, Zambia. Feb. 28th to March 4th.

Moghaddam S.M., Mamidi S., Osorno J.M., Lee R. Brick M., Kelly J., Miklas P., Urrea C., Song Q., Cregan P., Grimwood J., Schmutz J., McClean P. 2016. Genome-wide Association Study Identifies Candidate Loci Underlying Agronomic Traits in a Middle American Diversity Panel of Common Bean (Phaseolus vulgaris L.). Plant Genome. doi: 10.3835/plantgenome2016.02.0012; Date posted: July 25, 2016

Montejo L.M., Dardon, D., Villatoro J.C., Aldana L.F., Osorno J.M. 2016. Phenotypic Characterization of Bean Rust Isolates from Common Bean in the Guatemalan Highlands. Pan-African Grain Legume and World Cowpea Conference. Livingstone, Zambia. Feb. 28th to March 4th.

Osorno J.M., McClean P., Villatoro J.C., Aldana L.F., Moscoso-Alfaro J., Montejo L.M., Maldonado C., Tobar M.G. 2016 Breeding Efforts for the Improvement of Climbing Beans for the Guatemala Highlands. Pan-African Grain Legume and World Cowpea Conference. Livingstone, Zambia. Feb. 28th to March 4th.

Osorno J.M., Villatoro J.C., Miranda A., Moscoso-Alfaro J. 2016. Climbing Beans Affected by Ascochyta spp. in the Guatemala Highlands. IV International Ascochyta Workshop. Troia, Portugal. Oct 10-11.

Soltani A., Bello M., Mndolwa E., Schroder S., Moghaddam S.M., Osorno J.M., Miklas P., McClean P.E. 2016. Targeted Analysis of Dry Bean Growth Habit: Interrelationship Among Architectural, Phenological, and Yield Components. Crop Sci.

doi: 10.2135/cropsci2016.02.0119

Tobar-Piñon M.G., Moghaddam S.M., Lee R., Villatoro J.C., Osorno J.M., McClean P. 2016. Genetic diversity of the Guatemalan climbing bean collection. II International Legume Society Conference. Troia, Portugal. Oct. 12-14.

Villatoro J.C., Moscoso-Alfaro J., Agreda K.A., Osorno J.M., McClean P., Montejo L.M. 2016. Preliminary Study of the Presence, Damage Level and Population Dynamics of Mexican Pod Weevil (Apion godmani) in Bean Genotypes (Phaseolus vulgaris L.), in the Highlands of Guatemala. Pan-African Grain Legume and World Cowpea Conference. Livingstone, Zambia. Feb. 28th to March 4th.

Villatoro, J.C., Moscoso-Alfaro J., Agreda K.A., Monzon F., Osorno J.M., McClean P., Montejo L.M. 2016. Nivel de daño y dinámica poblacional de Apion godmani en frijol (Phaseolus vulgaris L.). Annu. Meet. PCCMCA. San Jose, Costa Rica. May 5-8.

Villatoro J.C., Beaver J., Porch, Rosas J.C., Miranda A., Carrillo E.E., Moscoso-Alfaro J. 2016. Evaluación de líneas de frijol para determinar resistencia al daño del gorgojo Acanthoscelides obtectus. Annu. Meet. PCCMCA. San Jose, Costa Rica. May 5-8.

Villatoro, J.C., Moscoso-Alfaro J., Agreda K.A., Monzon F., Osorno J.M., McClean P., Montejo L.M. 2016. Evaluación de rendimiento en 10 genotipos de frijol voluble y nivel de daño por Asphondylia spp. Annu. Meet. PCCMCA. San Jose, Costa Rica. May 5-8.

Villatoro, J.C., Osorno J.M., McClean P., Aldana L.F., Moscoso-Alfaro J., Miranda, A., Agreda K.A., 2016. Evaluación de genotipos de frijol voluble, densidades, y su efecto sobre el maíz. Annu. Meet. PCCMCA. San Jose, Costa Rica. May 5-8.

Professional Recognitions

Juan M. Osorno received the Distinguished Achievement Award given by the Bean Improvement Cooperative during their biennial meeting in November, 2015 in Niagara Falls, Ontario, Canada. The award is presented to a scientist who has worked in bean improvement fewer than 15 years and recognizes outstanding scientific accomplishments relating to bean improvement and education.

Progress in Implementing Impact Pathway Action Plan

After three years of this new project, we are confident that our activities have been in accordance with our impact pathway plan. There are no major delays to report and all the previous delays/problems reported before have been solved. Please refer to the Impact Pathway Plan document for more details.

Data Management

A revised data management plan was submitted to the Feed the Future Legume Innovation Laboratory Management Office. Scientists interested in using a data set generated with support from the Feed the Future 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 deposit the information in the USAID Development Data Library (DDL).

Milestones

October 1, 2015 – March 31, 2016

Feed the Future Innovation Lab for Collaborative Researchon Grain Legumes

Report on the Achievement of "Milestones of Progress"

(For the Period: October 1, 2015-- March 31, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by April 1, 2016

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	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**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 Farmer's field testing of 12 lines	**0**			**0**			**0**			**0**			**0**			**0**		
1.2 Breeding pipeline	**0**			**X**	**X**		**0**			**0**			**0**			**0**		
1.3 Genetic purification of selected material	**0**			**X**	**X**		**0**			**0**			**0**			**0**		
1.4 Field evaluation of Bolonillo-TEXEL	**0**			**0**			**0**			**0**			**0**			**0**		
1.5 Second crossing block	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 2:	**Characterization of the genetic diversity of this unique set of germplasm.**																	
2.1 Genotypic evaluation (6k SNP chip)	**0**			**0**			**0**			**0**			**0**			**0**		
2.2 Assessment of the intra-accession variab.	**0**			**0**			**0**			**0**			**0**			**0**		
2.3 Field evaluation of the ICTA collection (2nd year)	**0**			**X**	**X**		**0**			**0**			**0**			**0**		
2.4	**0**			**0**			**0**			**0**			**0**			**0**		
2.5	**0**			**0**			**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 systems in the regi**																	
3.1 Tabulation of grower's survey data and statistical analyse	**0**			**0**			**0**			**0**			**0**			**0**		
3.2 3.2. Seed increase of survey samples	**0**			**X**	**X**		**0**			**0**			**0**			**0**		
3.3	**0**			**0**			**0**			**0**			**0**			**0**		
3.4	**0**			**0**			**0**			**0**			**0**			**0**		
3.5	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 4:	**Capacity building.**																	
4.1 Graduate Students	**X**	**X**		**0**			**0**			**0**			**0**			**0**		
4.2 Bean workshop at NDSU	**0**			**0**			**0**			**0**			**0**			**0**		
4.3	**0**			**0**			**0**			**0**			**0**			**0**		
4.4	**0**			**0**			**0**			**0**			**0**			**0**		
4.5	**0**			**0**			**0**			**0**			**0**			**0**		
Name of the PI reporting on milestones by institution	PI name			PI name			PI name			PI name			PI name			PI name		

Name of the U.S. Lead PI submitting this Report to the MO: PI name

Signature **Date**

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

April 1, 2016 – September 30, 2016

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: April 1, 2016 -- September 30, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2016

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	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**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 Farmer's field testing of 12 lines	**0**			**X**	**X**		**0**			**0**			**0**			**0**		
1.2 Breeding pipeline	**0**			**X**	**X**		**0**			**0**			**0**			**0**		
1.3 Genetic purification of selected material	**0**			**X**	**X**		**0**			**0**			**0**			**0**		
1.4 Field evaluation of Bolonillo-TEXEL	**0**			**X**	**X**		**0**			**0**			**0**			**0**		
1.5 Second crossing block	**0**			**X**	**X**		**0**			**0**			**0**			**0**		
Objective 2:	**Characterization of the genetic diversity of this unique set of germplasm.**																	
2.1 Genotypic evaluation (6k SNP chip)	**X**	**X**		**0**			**0**			**0**			**0**			**0**		
2.2 Assessment of the intra-accession variab.	**X**		**X**	**0**			**0**			**0**			**0**			**0**		
2.3 Field evaluation of the ICTA collection (2nd year)	**0**			**0**			**0**			**0**			**0**			**0**		
2.4	**0**			**0**			**0**			**0**			**0**			**0**		
2.5	**0**			**0**			**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 systems in the re**																	
3.1 Tabulation of grower's survey data and statistical ar	**X**	**X**		**X**	**X**		**0**			**0**			**0**			**0**		
3.2 3.2. Seed increase of survey samples	**0**			**0**			**0**			**0**			**0**			**0**		
3.3	**0**			**0**			**0**			**0**			**0**			**0**		
3.4	**0**			**0**			**0**			**0**			**0**			**0**		
3.5	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 4:	**Capacity building.**																	
4.1 Graduate Students	**X**	**X**		**0**			**0**			**0**			**0**			**0**		
4.2 Bean workshop at NDSU	**X**	**X**		**0**			**0**			**0**			**0**			**0**		
4.3	**0**			**0**			**0**			**0**			**0**			**0**		
4.4	**0**			**0**			**0**			**0**			**0**			**0**		
4.5	**0**			**0**			**0**			**0**			**0**			**0**		
Name of the PI reporting on milestones by institution	Juan M. Osorno			Julio Cesar 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

Indicators overall

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. number	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	3	3	3	3	3	0
	Total number by sex	0	0	0	2	3	2	3	3	3	3	3	0
	Number of women	0	0	0	2	2	1	2	2	2	2	2	0
	Number of men	0	0	0	0	1	1	1	1	1	1	1	0
	Total number by New/continuing	0	0	0	2	3	2	3	3	3	3	3	0
	New	0	0	0	2	3	2	0	0	0	0	0	0
	Number of women							0	0	0	0	0	0
	Number of men							0	0	0	0	0	0
	Continuing	0	0	0	0	0	0	3	3	3	3	3	0
	Number of women							2	2	2	2	2	0
	Number of men							1	1	1	1	1	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	897	825	825	0
	Total number	20	14	75	65	140	135	78	78	897	825	825	0
	Number of women	5	4	55	20	95	110	27	27	348	310	310	0
	Number of men	15	10	20	45	45	25	51	51	549	515	515	0
	Numbers by Type of individual	20	14	75	65	140	135	28	178	897	825	825	0
	Producers	15	10	9	40	130	125	0	150	868	800	800	0
	Number of women							0	50	335	300	300	0
	Number of men							0	100	533	500	500	0
	People in government	5	4	7	20	10	10	28	28	29	25	25	0
	Number of women							0	0	13	10	10	0
	Number of men							0	0	16	15	15	0
	People in private sector firms	0	0	50	5	0	0	0	0	0	0	0	0
	Number of women							0	0	0	0	0	0
	Number of men							0	0	0	0	0	0
	People in civil society	0	0	9	0	0	0	0	0	0	0	0	0
	Number of women							0	0	0	0	0	0
	Number of men							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	20	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	10	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	10	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. 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, leave it blank.
There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

NDSU

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:

Institution 1 Name (one sheet per instittition):

Indic. number	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	2	3	2	3	3	3	3	3	0
	Total number by sex	0	0	0	2	3	2	3	3	3	3	3	0
	Number of women				2	2	1	2	2	2	2	2	
	Number of men				0	1	1	1	1	1	1	1	
	Total number by New/continuing	0	0	0	2	3	2	3	3	3	3	3	0
	New				2	3	2	0	0	0	0	0	
	Number of women												
	Number of men												
	Continuing				0	0		3	3	3	3	3	
	Number of women							2	2	2	2	2	
	Number of men							1	1	1	1	1	
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	0	8	8	9	0	0	0
	Number of women							2	2	5			
	Number of men							6	6	4			
	Numbers by Type of individual							8	8	9	0	0	0
	Producers												
	Number of women												
	Number of men												
	People in government							8	8	9			
	Number of women									5			
	Number of men									4			
	People in private sector firms												
	Number of women												
	Number of men												
	People in civil society												
	Number of women												
	Number of men												
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. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

ICTA

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:

Institution 2 Name (one sheet per institition):

Indic. number	Output Indicators	FY 14 Target	FY 16 Revised	FY 16 Actual	FY 17 Target	FY 17 Revised	FY 17 Actual
		2013 - Septemb	tober 1, 2015 - September 30, 20		(October 1, 2016 - September 30, 2017)		
1	4.5.2(6) Degree Training: Number of individuals who have received degree tr	0	0	0	0	0	0
	Numbers by Sex	0	0	0	0	0	0
	Number of women						
	Number of men						
	Numbers by New/Continuing		0	0	0	0	0
	New						
	Number of women						
	Number of men						
	Continuing						
	Number of women						
	Number of men						
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training						
	Numbers by Sex	20	70	888	825	825	0
	Number of women	5	25	343	310	310	
	Number of men	15	45	545	515	515	
	Numbers by Type of individual	20	170	888	825	825	0
	Producers	15	150	868	800	800	
	Number of women		50	335	300	300	
	Number of men		100	533	500	500	
	People in government	5	20	20	25	25	
	Number of women			8	10	10	
	Number of men			12	15	15	
	People in private sector firms			0		0	
	Number of women						
	Number of men						
	People in civil society			0		0	
	Number of women						
	Number of men						

cont.

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	20	20	23	23	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance		10	10	10	10	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance		10	10	10	10	
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance				3	3	

Notes:

These indicators are developed under the Feed the Future Monitoring System. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

Improving Photosynthesis in Grain Legumes with New Plant Phenotyping Technologies (SO1.A2)

Lead U.S. Principal Investigator and University
David M. Kramer, Michigan State University

Collaborating Host Country and U.S. 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,

I. Abstract of Research and Capacity Strengthening Achievements
In FY 2016 we made substantial progress on all our aims. A key component of this effort is the development, dissemination and application of phenotyping technologies with our partners to identify target processes and genes for improvement of photosynthetic responses in beans and cowpeas. There are two major components to the project: bringing the lab to the world, through an open access science platform we developed called PhotosynQ that brings cutting edge phenotyping and analytics technologies to field researchers around the world.

A publication describing the development, characterization and initial use of the MultispeQ has just been published. We delivered 6 MultispeQ beta devices to the University of Zambia (UNZA), and are following up with a set of the newly-released version of the device. We also trained seven undergraduate students at UNZA, and two research technicians at Zambia Agricultural Research Institute (ZARI), who collected quality field measurements of common bean GWAS lines for QTL mapping. Based on initial results from our collaboration with UNZA we have revised the MultispeQ, developed new protocols and procedures to improve the statistical sampling of phenotype data and developed analytical methods to process complex interactions among photosynthetic and environmental parameters. In a major achievement, UNZA has produced a complete proof-of-concept GWAS mapping for photosynthetic responses of common beans to drought using the PhotosynQ platform.

Project Problem Statement and Justification
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 on-line communication and analysis tools.

Technical Research Progress

(Describe the research activities (research methods, studies conducted, analyses completed, and significant findings) completed under each objective during the FY 2016 reporting period. Present sufficient detail so that the reviewers will understand and have confidence that the research was carried out in a manner that meets high scientific standards. Briefly discuss primary results, findings, and/or technological achievements that give evidence of technical progress toward objectives. Please be reminded to highlight significant outputs that have potential for impact.)

If certain research activities described in the FY 2016 Workplan were not completed, they must be identified and an acceptable explanation provided in the field (VIII) “Explanation for Changes.”

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

During the past year, our primary focus towards this objective was to build high-throughput methodologies for QTL mapping using the DEPI platform. To accomplish this objective we tested a range of developmental times of common bean GWAS genotypes. Using the growth populations that we established for QTL mapping, Dr. Kamfwa and his undergraduate students successfully collected robust field measurements of photosynthesis that were used for QTL mapping.

At MSU, we have successfully mapped key QTL’s using controlled conditions at MSU using the DEPI chambers, and demonstrated the approach for distinguishing genetic variation in the responses of photosynthesis to both low and high temperatures. From these results, we have determined which conditions and MAGIC populations are best suited for QTL mapping for photosynthetic responses to temperature, and the experimental protocols are in the process of being performed and analyzed.

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.

In FY 2016 we made major strides towards achieving this objective. In December, 2015 Kelvin Kamfwa completed his doctorate training at MSU and moved to the University of Zambia. At the same time we distributed 6 MultispeQ instruments and 6 android mobile devices to the University of Zambia. Dr. Kamfwa trained six undergraduate students on the MultispeQ and the PhotosynQ platform, and students began collecting PhotosynQ data. Furthermore, in March 2016 David Kramer and Dan TerAvest visited UNZA and trained undergraduates on data collection methodologies and the plant physiological parameters measured by the MultispeQ instrument. The result of these combined trainings are that students at UNZA have collected over 4,000 MultispeQ measurements on the common bean Andean Diversity Panel.

At the same time, another graduate student, Isaac Dramadri (from Uganda) continued to use PhotosynQ to probe the photosynthetic responses of RIL and GWAS lines at MSU. At the end of FY 2016, Isaac returned to Makerere University in Uganda, where he will train faculty and staff on the PhotosynQ platform.

Objective 3. Development of Data Management Plan
As a part of the development process, we will modify the PhotosynQ platform to meet the needs of project collaborators while concurrently meeting the requirements of USAID's open data policy. We are currently in the process of working with USAID staff to ensure that the PhotosynQ platform conforms to USAID policies.

Major Achievements

1. Dissemination and publication of the PhotosynQ beta instrument (Kuhlgert et al., 2016)
2. Development of the Version 1.0 device
3. First proofs-of-concept for the complete QTL mapping process for photosynthetic properties in common beans using PhotosynQ at the University of Zambia.
4. Training of several graduate students at both UNZA and MSU.
5. Development of a new PhotosynQ-guided experimental protocols.

Research Capacity Strengthening

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

First, Several LIL participants are currently using the PhotosynQ platform as a part of their LIL-supported work, including Kelvin Kamfwa at the University of Zambia, Isaac Dramadri (at MSU with James Kelly), Isaac Osei-Bonsu (in the Kramer lab at MSU) as well as several students working with collaborators Tim Close (U.C. Riverside), Phillip Roberts (U.C. Riverside) and Phil McLean (NDSU).

Second, we are actively working towards setting up cutting edge phenotyping centers at the University of Zambia and Makerere University in Uganda. At UNZA, faculty and staff now have access to 6 MultispeQ and are actively involving the UNZA team in the redesign, validation and implementation of the new version 1.0 devices as well as the new online analytical capacity, which will both lead to publications and help nucleate a phenotyping center at UNZA. In addition, seven undergraduate and one master's students at UNZA, and two research technicians from Zambia Agricultural Research Institute (ZARI) in the Ministry of Agriculture have received training on PhotosynQ. The six undergraduate students include five males and two female who are pursuing Bachelor of Science degree in crop science at UNZA. The two technicians from ZARI include one male and one female who work for the National Bean Breeding Program. Similarly, there are currently 3 MultispeQ instruments available for faculty and staff to use at Makerere University resulting in the initiation of four separate research projects in which nearly 7,000 measurements have been made on cowpea, groundnuts, and maize.

The irrigation system at research station at UNZA is currently being renovated and up-graded using supplemental Institutional Capacity Strengthening funds. Purchase of irrigation equipment and renovation works are underway. Once the renovations are completed the research capacity UNZA to conduct drought experiments in FY17 will be enhanced.

Finally, it is important to emphasize that all of the research accomplishments are purposely and directly connected to capacity strengthening. For example, the development of the instrumentation and

PhotosynQ-guided experimental protocols were guided by the research goal of identifying the genetic bases of photosynthetic responses, but are also incorporated in the PhotosynQ platform to enable future work.

Human Resource and Institution Capacity Development

Short-Term Training

Degree Training

Name of trainee: Kelvin Kamfwa
Country of Citizenship: Zambian
Gender: Male
Host Country Institution Benefitting from Training: University of Zambia
Institution providing training: MSU
Supervising Legume Innovation Lab PI: James D. Kelly
Degree Program: Doctorate
Field 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
Training Status: Active
Is trainee a USAID Participant Trainee and registered on TraiNet? Yes
Type of Legume Innovation Lab Support (full, partial or indirect): Full

Name of trainee: Isaac Dramadri
Citizenship: Uganda
Gender: Male
Host Country Institution Benefitting from Training: Makerere University
Training Institution: MSU
Supervising Legume Innovation Lab PI: James D. Kelly and Wayne Loescher
Degree Program: 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
Projected Completion Date: September 2017
Is trainee a USAID Participant Trainee and registered on TraiNet? Yes
Training Status: Active

Name of trainee: Isaac Osei-Bonsu
Citizenship: Ghana
Gender: Male
Host Country Institution to Benefit from Training: CSIR-Crops Research Institute
Training Institution: Michigan State University
Supervising Innovation Lab PI: Dr. David Kramer
Degree Program for training: Doctorate
Field or Discipline: Plant Physiology

Thesis Title/Research Area: Heat Stress Effects On Photosynthesis in Legumes
Start Date: August, 2015
Projected Completion Date: 2019
Training status (Active, completed, pending, discontinued or delayed): Active, indirect support

Achievement of Gender Equity Goals

A critical component of accomplishing our gender equality goals is to ensure that PhotosynQ technologies are equally accessible to women and men. In FY 2016 we have made progress towards that goal by 1) training two female undergraduate students at UNZA and 2) identifying a female graduate student who will pursue a Master's Degree in plant breeding and seed systems at UNZA using the PhotosynQ platform starting in FY 2017, with Dr. Kamfwa as her PI.

Explanation for Changes
(Identify and justify all project changes or inability to complete research and training activities during the FY 2016 project period, as outlined in the workplan. If specific activities have been delayed, indicate when they will be carried out in the future and confirm that sufficient funds have been encumbered to support these activities at that time. Please remember that delayed activities will need to be reported in future annual project technical progress reports.)

During FY 2016 we were not able to complete the data management plan to ensure that PhotosynQ's data policies conform to USAID's open data policy. Scheduling conflicts made it impossible to travel to Washington D.C. to consult with USAID regarding the data management plan. We have included completing the data management plan in the FY 2017 workplan and will complete this objective prior to September 30, 2017.

Self-Evaluation and Lessons-Learned

Prior to FY 2016, most of the collaborative research was undertaken in the United States (at MSU, UC-Riverside, and NDSU). This made communication between collaborators very easy. In FY 2016, Kelvin Kamfwa relocated to the University of Zambia, making communication more challenging. In addition to direct communication between collaborators, we now need to provide educational and training modules to collaborators with poor internet access and speed in Zambia and Uganda. Currently, many of our training modules are in the form of short tutorial videos. However, these videos are often not appropriate for those with slow internet connections. Therefore, the PhotosynQ team will need to re-evaluate how we deliver training and educational materials to LIL partners.

Scholarly Accomplishments

Kuhlgert S et al. 2016. MultispeQ Beta: a tool for large-scale plant phenotyping connected to the open PhotosynQ network. R. Soc. open sci. 3: 160592. http://dx.doi.org/10.1098/rsos.160592

Hoh D, Osei-Bonsu I, Cruz J, Savage L, Hall D, Kramer DM. 2016. The effects of temperature on photosynthetic parameters of cowpea (Vigna unguiculata (L.) Walp.) genotypes and relation of photosynthetic parameters and seed yields on cowpea. Poster, PhotosynQ workshop, East Lansing, MI.

TerAvest D, Yohane E, Mnthambala F, Kramer DM. 2016. Deploying PhotosynQ to enhance local pigeonpea breeding programs in Malawi. Poster, Pan-African Grain Legume & World Cowpea Conference. Livingstone, Zambia

Osie-Bonsu I, Hoh D, Cruz J, Savage L, Kuhlgert S, TerAvest D, Austic, Zegarac R, Kramer DM, 2016. Variation in chlorophyll fluorescence-derived photosynthetic parameters and SPAD of cowpea genotypes subjected to drought and flooding stress at the pod filling stage. Poster, Pan-African Grain Legume & World Cowpea Conference. Livingstone, Zambia

Progress in Implementing Impact Pathway Action Plan

Outputs

Output #1. 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 FY 2016, we provided 6 MultispeQ devices to project partners at the University of Zambia so that they can perform cutting edge research. In the first year of having MultispeQ instruments, multiple undergraduate students have received training on the PhotosynQ platform and these same students have collected over 4,000 MultispeQ measurements.

Output #2. Capacity building through advanced phenotype-driven identification of QTLs for improving the efficiency and resilience of photosynthesis in grain legumes.

We have successfully identified phenotype-driven QTL's using both controlled conditions in DEPI chambers and using MultispeQ under true field conditions.

Output #4. Capacity building through education. Another essential component of the project is to enable researchers in HC to take possession of both the technology and the educational efforts required to use it effectively. To achieve this, we plan to engage students in the process of developing and disseminating the educational materials, giving them ultimate control of the platform and process.

We have made progress towards this output goal through the following of activities: 1) training of undergraduate and graduate students at Michigan State University and the University of Zambia and 2) developing training videos and educational modules that are available on www.photosynq.org so any user on the platform can learn how to use the PhotosynQ platform to answer research questions.

Milestones

October 1, 2015 – March 31, 2016

Feed the Future Innovation Lab for Collaborative Researchon Grain Legumes

Report on the Achievement of "Milestones of Progress"

(For the Period: October 1, 2015-- March 31, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by April 1, 2016

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

	Abbreviated name of institutions																	
	Michigan State University			University of Zambia			Institution 3			Institution 4			Institution 5			Institution 6		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Milestones by Objectives	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***
	(Tick mark the Yes or No column for identified milestones by institution)																	
Objective 1	**Probing photosynthetic responses in RIL and GWAS lines.**																	
1.1 Test a range of developmental times to determine the sm	x	x		0			0			0			0			0		
1.2 Extend these assays to common bean GWAS genotypes	x	x		0			0			0			0			0		
1.3 Test selected lines to determine the feasibility of QTL ma	0			0			0			0			0			0		
1.4 Establish growth populations for initial QTL analyses in Z	0			x	x		0			0			0			0		
1.5	0			0			0			0			0			0		
Objective 2:	**Increase the capacity, effectiveness and sustainability of agriculture research institutions which serve the bean and cowpea sectors in the target FTI**																	
2.1 Transferring 15 PhotosynQ MultispeQ units to Zambia ar	0			x	x		0			0			0			0		
2.2 Training of four students in Zambia in the use of Photosy	0			x	x		0			0			0			0		
2.3 Testing of field measurement protocols in Zambia	0			x	x		0			0			0			0		
2.4 Development of rapid cowpea and common bean pheno	x	x		0			0			0			0			0		
2.5 Initial feasibility study of cowpea lines for QTL mapping	x	x		0			0			0			0			0		
Objective 3:	**Development of Data Managnent Plan**																	
3.1 Develop privacy layers for PhotosynQ platform and infor	x		x	0			0			0			0			0		
3.2 Further development and refinement of data managemer	0			0			0			0			0			0		
3.3	0			0			0			0			0			0		
3.4	0			0			0			0			0			0		
3.5	0			0			0			0			0			0		

cont.

Objective 4:	**write objective here**					
4.1	**0**	**0**	**0**	**0**	**0**	**0**
4.2	**0**	**0**	**0**	**0**	**0**	**0**
4.3	**0**	**0**	**0**	**0**	**0**	**0**
4.4	**0**	**0**	**0**	**0**	**0**	**0**
4.5	**0**	**0**	**0**	**0**	**0**	**0**
Name of the PI reporting on milestones by institution	PI name Kramer	PI name Kramer	PI name Kramer	PI name Kramer	PI name Kramer	PI name Kramer

Name of the U.S. Lead PI submitting this Report to the MO	David Kramer

Signature Oct. 31, 2016
Date

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

April 1, 2016 – September 31, 2016

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: April 1, 2016 -- September 30, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2016

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

	Abbreviated name of institutions																	
	ichigan State Universit			University of Zambia			Institution 3			Institution 4			Institution 5			Institution 6		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Milestones by Objectives	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***
	(Tick mark the Yes or No column for identified milestones by institution)																	
Objective 1	**Probing photosynthetic responses in RIL and GWAS lines.**																	
1.1 Test a range of developmental times to determine t	**0**			**0**			**0**			**0**			**0**			**0**		
1.2 Extend these assays to common bean GWAS gen	**0**			**0**			**0**			**0**			**0**			**0**		
1.3 Test selected lines to determine the feasibility of Q	**x**	**x**		**0**			**0**			**0**			**0**			**0**		
1.4 Establish growth populations for initial QTL analyse	**0**			**0**			**0**			**0**			**0**			**0**		
1.5	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 2:	**Increase the capacity, effectiveness and sustainability of agriculture research institutions which serve the bean and cowpea sectors in the tar**																	
2.1 Transferring 15 PhotosynQ MultispeQ units to Zam	**0**			**0**			**0**			**0**			**0**			**0**		
2.2 Training of four students in Zambia in the use of P	**0**			**0**			**0**			**0**			**0**			**0**		
2.3 Testing of field measurement protocols in Zambia	**0**			**0**			**0**			**0**			**0**			**0**		
2.4 Development of rapid cowpea and common bean	**0**			**0**			**0**			**0**			**0**			**0**		
2.5 Initial feasibility study of cowpea lines for QTL map	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 3:	**Development of Data Managnent Plan**																	
3.1 Develop privacy layers for PhotosynQ platform and	**0**			**0**			**0**			**0**			**0**			**0**		
3.2 Further development and refinement of data mana	**x**		x	**0**			**0**			**0**			**0**			**0**		
3.3	**0**			**0**			**0**			**0**			**0**			**0**		
3.4	**0**			**0**			**0**			**0**			**0**			**0**		
3.5	**0**			**0**			**0**			**0**			**0**			**0**		

cont.

Objective 4:	**write objective here**																	
4.1	**0**			**0**			**0**			**0**			**0**			**0**		
4.2	**0**			**0**			**0**			**0**			**0**			**0**		
4.3	**0**			**0**			**0**			**0**			**0**			**0**		
4.4	**0**			**0**			**0**			**0**			**0**			**0**		
4.5	**0**			**0**			**0**			**0**			**0**			**0**		
Name of the PI reporting on milestones by institution	PI name			PI name Kramer			PI name Kramer			PI name Kramer			PI name Kramer			PI name Kramer		
Name of the U.S. Lead PI submitting this report to the MO	David Kramer																	

Oct. 31, 2016

Signature **Date**

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

Performance Indicators

Indicators Overall

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. number	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	3	2	2	0
	Total number by sex	0	0	0	2	0	2	2	2	3	2	2	0
	Number of women	0	0	0	0	0	0	2	2	1	2	1	0
	Number of men	0	0	0	2	0	2	0	0	2	0	1	0
	Total number by New/continuing	0	0	0	2	0	2	2	2	3	0	2	0
	New	0	0	0	2	0	2	2	2	1	0	0	0
	Number of women	0	0	0	0	0	0	0	0	2	2	2	0
	Number of men	0	0	0	0	0	0	0	0	0	0	0	0
	Continuing	0	0	0	0	0	0	0	0	2	0	2	0
	Number of women	0	0	0	10	10	10	10	10	0	10	1	0
	Number of men	0	0	0	6	6	6	6	6	2	6	1	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	0	0	0	10	10	10	10	10	9	10	5	0
	Number of women	0	0	0	6	6	6	6	6	3	6	2	0
	Number of men	0	0	0	4	4	4	4	4	6	4	3	0
	Numbers by Type of individual	0	0	0	10	10	10	10	10	9	10	5	0
	Producers	0	0	0	0	0	0	0	0	0	0	0	0
	Number of women	0	0	0	0	0	0	0	0	0	0	0	0
	Number of men	0	0	0	0	0	0	0	0	0	0	0	0
	People in government	0	0	0	10	10	10	10	10	9	10	5	0
	Number of women	0	0	0	0	0	0	6	6	3	0	2	0
	Number of men	0	0	0	0	0	0	4	4	6	0	3	0
	People in private sector firms	0	0	0	0	0	0	0	0	0	0	0	0
	Number of women	0	0	0	0	0	0	0	0	0	0	0	0
	Number of men	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
	Number of women	0	0	0	0	0	0	0	0	0	0	0	0
	Number of men	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	3	0	3	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	2	0	2	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	1	0	1	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. 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, leave it blank.
There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

MSU

REVISED PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 14, FY 15, FY16, and FY 17

Project Name:

Institution 1 Name (one sheet per instititon):

Indic. number	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	2	0	2	0	0	2	0	1	0
	Total number by sex	0	0	0	2	0	2	0	0	2	0	1	0
	Number of women												
	Number of men				2		2			2		1	
	Total number by New/continuing	0	0	0	2	0	2	0	0	2	0	1	0
	New				2		2						
	Number of women												
	Number of men												
	Continuing									2		1	
	Number of women												
	Number of men									2		1	
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	0	0	0	0	0	0	0
	Number of women												
	Number of men												
	Numbers by Type of individual							0	0	0	0	0	0
	Producers												
	Number of women												
	Number of men												
	People in government												
	Number of women												
	Number of men												
	People in private sector firms												
	Number of women												
	Number of men												
	People in civil society												
	Number of women												
	Number of men												
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	2	0	2	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance				1		1			1		1	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance				1		1			1		1	
	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. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

University of Zambia

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:

Institution 2 Name (one sheet per instititION):

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 tr	0	0	0	0	0	0	2	2	1	2	1	0
	Numbers by Sex	0	0	0	0	0	0	2	2	1	2	1	0
	Number of women							2	2	1	2	1	
	Number of men												
	Numbers by New/Continuing							2	2	1	2	1	0
	New							2	2	1			
	Number of women									1			
	Number of men												
	Continuing							0	0		2	1	
	Number of women											1	
	Number of men												
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Numbers by Sex	0	0	0	10	10	10	10	10	9	10	5	0
	Number of women				6	6	6	6	6	3	6	2	
	Number of men				4	4	4	4	4	6	4	3	
	Numbers by Type of individual	0						10	10	9	10	5	0
	Producers												
	Number of women												
	Number of men												
	People in government				10	10	10	10	10	9	10	5	
	Number of women							6	6	3		2	
	Number of men							4	4	6		3	
	People in private sector firms												
	Number of women												
	Number of men												
	People in civil society												
	Number of women												
	Number of men												
7	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	1	0	1	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance									1		1	
	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:

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

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Abstract of Research and Capacity Strengthening Achievements

Common bean (*Phaseolus vulgaris*) is the most important grain legume consumed in Uganda and Zambia. The project has successfully identified local lines that are quicker cooking and these are being tested in on-farm trials with local producers in Uganda. Breeding programs in both countries continue to identify sources of disease resistance to many of the more serious pathogens that attack beans and are using these lines as parental material to further improve local varieties. Changes in climate are leading to less predictable rainfall patterns and the project has identified Andean breeding lines that perform better than local varieties under these conditions. Novel methodologies are being developed to screen more efficiently for cooking time and modern molecular tools have been deployed to map genomic regions that control anthracnose resistance. Genomic mapping with SNP markers and RNA sequencing has been used to pinpoint genomic regions that control anthracnose resistance, and enhanced symbiotic nitrogen fixation and candidate genes underlying these basis functions have been identified. The potential to enhance N-fixation in beans grown under low fertility conditions typical of subsistence farmers is now within the reach of local breeders. Training of future bean researchers continues to be a major objective by providing the environment to develop both scientific and leadership skills.

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 BNF and faster cooking time.

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 2016, the program in Uganda continued to assemble and utilize different nurseries which included the following;

- A set of 50 lines (50 seeds each) for common bacterial blight (CBB) acquired from the University of Nebraska
- A drought nursery comprising of 60 entries (500 seeds each) from the University of Nebraska.
- A set of 10 lines for Rust acquired from Uyole, Tanzania
- A drought Nursery comprising of 96 Andean (DAB)-lines from CIAT

These nurseries have been evaluated this year and those showing resistant potential have already been utilized in breeding program for introgression of specific resistances into the Ugandan farmer preferred and yet susceptible germplasm. The specifics of the some of the acquired germplasm have been appended at Annex 2.

1.2 Evaluation of Integrated Nursery in Zambia

In Zambia a traditional or conventional approach to combine resistances for ALS and CBB into preferred seed types was undertaken at Misamfu. The resulting lines were evaluated in other sites within the country where bean production is important. After a number of selection cycles, 50 lines were selected based on their performance over time and were planted at 3 sites within the country. Out of the 50 lines planted; 28 lines were selected at Misamfu, 23 in Kabwe and 21 at Msekera and eleven were common at all three sites. These same lines have been earmarked for on-farm testing. Most of the lines selected were medium to large seeded sizes as these are the preferred types among the small-holder farmers of Zambia. Average disease score of 2.0 and 2.5 for ALS and CBB respectively indicated that the lines were also resistance to these important diseases.

1.3 Identification of resistance sources in Uganda

A disease nursery was screened against different pathogens, rust, ANT, and ALS in a screenhouse and under field conditions in Uganda. Using either field condition for prevailing diseases and/or screenhouse conditions with inoculum from different pathogens, a number of nurseries and/or germplasm sets were screened using different pathotypes for different pathogens. From these we were able to establish the reaction of different germplasm to the different pathogens and also identify some resistant genotypes which are currently being using to introgress resistances to susceptible but preferred market class varieties for Uganda. Data from some of the different nurseries that have been screened to date has been either reported in drafted journal papers, poster papers and/or student dissertations.

A germplasm collection of 138 lines comprising of 30 landraces, 20 released varieties in Uganda and 93 introduced lines including the 12 rust differentials were screened for rust in both in the screenhouse and field conditions. A second germplasm collection 64 lines inclusive of both ANT and ALS differentials was set out for field screening in the 2016A season. Unfortunately, we had a very severe drought so we lost most the germplasm and no data was taken for diseases incidences. A third germplasm collection of 132 common bean accessions were screened in both screenhouse and field for reaction to CBB. In screenhouse, genotypes were inoculated with a local isolate “Kawempe 1” in screenhouse while natural infestation was used in field. We noted variation of the different genotypes to Kawempe 1 and identified also resistant genotypes that have been utilized in crosses to introgress resistance to Uganda susceptible market class varieties. Another assembled germplasm collection of 80 lines from CIAT and local germplasm was screened for resistance to BCMV using a mixture of inoculum obtained from diseased leaved obtained from Hioma, Kawanda and Namulonge. Presence or absence of either BCMV or BCMNV in all inoculated and screened lines was detected using the Double Antibody Sandwich (DAS) ELISA. Lines selected for resistance to rust include Mexico 309, CNC, P1181996, Mexico 235, Redlands Pioneer, Ouro Negro and Aurora; Selected resistant lines that are resistant to CBB include; NE2-14-8, NE17-14-29, NE14-09-78 and VAX3; Selected resistant lines that are resistant to BCMV include; SCR 48, SCN 9 and SCN 6.

1.4. Cross sources of resistance for ANT, ALS, CBB rust and drought tolerance into large seeded lines with contrasting colors in Uganda

The project has continued to introgress different resistance genes into the backgrounds of some of the most preferred Andean bean varieties in Uganda. For all the resistant genotypes that have been identified for the various pathogens, crosses have been initiated with Uganda market class and consumer preferred varieties to introgress resistant genes for respective traits. We have also started generating population for the new crosses these include, populations for rust, CBB resistance and BCMV resistance. Some genetic studies for resistance to the different stresses in relation to the Andean Ugandan market class genotypes have been undertaken. Below are some of the different crosses that have been initiated and /or on-going. Genotypes Mexico 309, CNC, P1181996, Mexico 235, Redland pioneer, Ouro Negro and Aurora identified for resistance to rust have been crossed 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. The progenies are under evaluation. Four CBB resistant genotypes i.e. NE2-14-8, NE17-14-29, NE14-09-78 and VAX3 have already been utilized in crosses with four Ugandan Andean susceptible market class varieties, NABE 15, NABE 16, NABE 17 and NABE 19 to try and introgress CBB resistance. Genetic studies have also been undertaken to determine the mode and nature of inheritance for this resistance. Three identified BCMV resistant genotypes namely SCR 48, SCN 9 and SCN 6 were crossed with four Ugandan Andean susceptible market class varieties, K132, NABE 15 NABE 17, NABE 18 to introgress BCMV resistance also in this case, genetic studies have also been undertaken to determine the mode and nature of inheritance for BCMV resistance in these genotypes. 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 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 genotypes that have been identified from the ADP panel. A few selected climbers in each country will be crossed to sources for ALS, ANT, CBB, and rust resistance. This activity is yet to be undertaken but will be initiated in the coming season.

1.5. Cross lines with superior disease resistance to those with shorter cooking time and high mineral bioavailability

The initial 23 ADP lines that were selected for shorter cooking time were tested for adaptability, preference and fast cooking time with 9 farmer groups composed of 326 farmers (96 men and 230 women) in three agroecologies in Uganda. From these only seven lines namely ADP 0512, ADP 0009, ADP 0001, ADP 0468, ADP 0521, ADP 0098, and ADP 0522 have been identified as suitable and with fairly shorter cooking time. These will be advanced for further evaluation and also crossed with other Andean Uganda market class varieties in the coming season.

1.6. Drought tolerance

Mr. Dramadri also 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 non-irrigated), 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. This work will continue at two field locations in Uganda in fall 2016 as part of Mr. Dramadri dissertation research.

1.6.1. Screen the drought nursery in Uganda to intermittent drought stress

A nursery of 60 bean lines that was obtained from Dr. Urrea, UNL was screened under terminal drought protocol during off-season period and irrigation employed. The yield obtained from replicated trail in both the irrigation and non-irrigated trials is attached in Annex 2. From these preliminary results lines ADP-102, ADP-41, ADP-47, ADP-61, ADP-617, ADP-660 and ADP-678 were noted to perform fairly well in drought conditions. These could be suitable varieties for utilization in drought prone and the semi-arid regions of Uganda and could potentially be good sources of resistance for drought tolerant genes for breeding purposes.

1.6.2. Other drought tolerance screening trials

A second preliminary yield trail was conducted for 169 lines that had been obtained from CIAT. This trial was to confirm data obtained in the first yield trial. In addition, there was need to also increase on the amount of seed available to enable multilocation yield trials. Results obtained and shown in Annex 2 are indicative of yield variation with a range of 3625kg. The large variation in yield between the different genotypes will be exploited to select and utilize best adapted and highest yielders for future release and/or utilization in our breeding program. Further selections made in the next evaluation trials will depend on resistance to diseases and farmer preferred traits. Selected lines from these two trials will undergo multilocation trials to evaluate their reaction in the different agroecologies.

1.6.3.

In another germplasm evaluation trial, 421 individual plants that were selected from 35 segregating drought large seeded bean populations obtained from South Africa. These were then established in trials as 421 single row families and evaluated. From these trials a total a total of 416 lines were selected (Annex 2) and only 5 lines are so far deselected this was mainly because of the superior performance exhibited by the families. Also the other purpose of the trial was to increase seed available to enable establishment of replicated trials in future evaluations. So far selections made were mainly based on the early maturity and market trait characteristics. We intend to do further selection in the coming season basing on yield, disease resistance and drought tolerance. We still consider these set of materials unique due that fact that they are the first large seeded drought tolerant genotypes being evaluated in the country. We further anticipate that we will be able to obtain some fast track material for utilization in drought prone areas within this region and also materials that will be utilized in the drought breeding program for the larges seeded varieties.

1.6.4.

A 25-entry uniform drought nursery was grown in Michigan in 2016. Weather conditions were favorable for the development of drought in the first 45-days following nursery establishment and the local check varieties outyielded most of the drought tolerant lines, underscoring the importance of local adaptation. The nursery was coordinated by Drs. Urrea and Porch.

1.7. Nebraska

The common bacterial blight nursery dispatched to Uganda and Zambia was screened for CBB reaction at the West Central Research and Extension Center, North Platte, NE, in an augmented replicated field trial. The plot size consisted of 1 row 3 m long spaced 0.56 m. The resistant XAN 159; the moderately resistant Neb 1 Sel. #27, and ABC-Weihing; and the susceptible Orion lines were used as reference checks. At flowering, plants were sprayed with a bacterial solution of 3 x 107 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. Data is being analyzed. In 2016 the ADP lines were tested for response to terminal drought (irrigation was stopped at flowering stage). Data is being processed. Harvest was finished few days ago. The drought tolerant lines (ADP) dispatched to Uganda and Zambia were tested at both locations under normal and drought conditions in 2016. The ADP panel grown under normal and drought stress will be cooked. Seeds will be soaked overnight (16 hours) then, placed in the Mattson Bean Cooker, and beans will be cooked when 80% of the weighted plungers drop. Based on data collected in Nebraska from 2013 (common bacterial blight, experiments on drought, and cooking time), 36 F1 combinations initiated in 2015 were advanced to F3 by bulking one pod per plant. The F3 generation will be planted in Puerto Rico for generation advancement and seed will be available to be distributed to Zambia and Uganda in 2017.

1.8 Farmer Evaluation of the Nutritionally Superior Bean Genotypes in Three Agro-ecological Zones in Uganda

A subset of the ADP comprised of 23 genotypes was screened on-farm across three districts in Uganda in 2015. The genotypes represented various market classes and were selected for faster cooking times and superior nutritional quality profiles. A participatory variety selection approach was implemented where the farmers belonging to nine farmer groups participated in the collection of both qualitative data (preference scores) and quantitative data (disease reactions, plant architecture, and seed yield). Farmers also rated seed quality preferences after harvest. In general, farmers preferred high yielding early maturing lines that exhibited tolerance to too little and/or too much water. A small seeded red mottled variety (Chijar) from Puerto Rico was consistently the most productive across all the agro-ecological zones used in the study with an average yield of 1,000 kg ha^{-1}.

In the 2016 growing season, the genotypes were planted in March to evaluate their performance during the short rainy season across the nine locations. The genotypes were further refined and based on yield data from the 2015 season only 15 experimental entries were planted along with the local check. The growers participated in collecting data on disease stress as well as agronomic data during harvest for all the 16 accessions. Farmers also rated the genotypes at harvest based on yield and seed quality. The most preferred genotypes were also evaluated for sensory quality in the communities. The seeds of genotypes from all accessions are being evaluated for cooking time, mineral profiles, and iron bioavailability to determine the stability of these traits and identify good germplasm for breeding to improve common bean for nutritional quality traits.

1.9 Crossing resistance sources in Zambia

A common bacterial blight nursery consisting of 50 lines was planted and evaluated at two sites (Misamfu and Mpika) in Zambia. More than 66% of the lines showed some level of resistance to CBB. The lines were also evaluated for ANT and ALS and a number of lines showed combined resistance to all three diseases. In addition to the research to introgress CBB into local preferred lines Dr. Kamfwa at UNZA, has expanded that effort by crossing the light red kidney variety Badillo, which is resistant to CBB, high yielding and is well adapted to Zambia with the local landrace Kabulangeti, which is susceptible to CBB. The F4 population of the cross was planted in the field in 2016 growing season for seed multiplication and evaluation will be conducted during the 2016/17 season.

1.10 Evaluation of lines for BNF

In the 2016 growing season, 211 RILs of the Sowezi x AO-1012-29-3A, a light red kidney from University of Puerto Rico with resistance to seed weevils, (SA) population was planted at Misanfu Research Station, in Kasama and at University of Zambia Farm in Lusaka to evaluate for nitrogen fixation. Due to poor nodulation at both locations, no data on nitrogen fixation was collected in 2016. The SA population will be planted next year at Misanfu, using seed inoculated with rhizobium and evaluated for N-fixation. This represents a continuation of work initiated at MSU as part of Dr. Kamfwa's doctoral dissertation research.

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

In the period 2015-2016, advances in cooking time prediction have been made in the development and optimization of Vis/NIRS chemometric models using dry bean seeds of Phaseolus vulgaris with broad genetic diversity and planted in different years and locations. In addition, a hyperspectral imaging (HYPERS) technique, that combines the main features of imaging and spectroscopy to acquire spectral and spatial information from products simultaneously, was implemented and tested for evaluating cooking time in similar accessions of dry seeds tested by Vis/NIRS. The HYPERS technique involved the development of image preprocessing and image segmentation methods of bean seed from spectral images in the wavelength range of 400-1,000 nm. Also, due to the large data set generated by both Vis/NIRS and HYPERS techniques and in order to avoid over-fitted models, a wavelength selection procedure was implemented to select the best spectral or image properties for further prediction analyses. A goal of this experiment was to evaluate and compare the predictive power of Vis/NIRS (400-2,498 nm) and HYPERS (400-1,000 nm) techniques for predicting cooking time on independent and combined sets of dry bean samples. Various spectral/image preprocessing methods were tested for improving the prediction accuracy. The evaluated accessions were

1. 446 bean samples of the ADP grown in 2013 at the Montcalm Research Farm, Michigan with wide variations in cooking time ranging from 17.7 to 96.4 min. The ADP collection included accessions from Africa, Europe, Asia, Central America, Caribbean, North America, and South America which were planted in Michigan;
2. 140 bean samples from four different market classes of agricultural importance to Eastern Africa, Southern Africa, the Caribbean and North America. The seed types were yellow; cranberry, light red kidney, red mottled and brown. They were planted in 2014 over 5 locations in two contrasting geographical regions. Two field locations were located in Northwestern United States (USDA-ARS; Othello, WA). The other three locations were located in Tanzania: Arusha (Selian Agricultural Institute), Mbeya (Uyole Research Station) and Morongo (Sokoine University of Agriculture). This subset of germplasm combined three bean accessions with wide variations in cooking time ranging from 19.9 to 160.1 min;
3. 52 bean samples of the previous subset which were stored and grown in 2015 at Washington, and with cooking times ranging from 17.1 to 61.9 min.
4. 113 bean samples obtained from Washington and Tanzania and grown at the Montcalm Research Farm in 2015. The cooking time of these samples ranged between 18.2 to 113.1 min.

In the model building process, we found that the combination of two preprocessing methods (i.e., continues wavelength transform followed by the two-wavelength ratio approach) give most consistent and reproducible predictions for cooking time, as compared with the best single preprocessing methods. Results showed that using independent sets of samples the prediction accuracy for Vis/NIRS models was of 66.9% (error = 9.4 min) for set (i) and 68.1% (error = 10.4 min) for set (iv). For HYPERS models the accuracy was of 65.6% (error = 11 min) for set (i), 75.6% (error = 10.5 min) for set (ii), 83.0% (error = 7.1 min) for set (iii), and 73.8% (error=9.3) for set (iv). On the other hand, even though the large diversity of the samples, predictions for the combination of these accessions also showed pretty decent results. The models were very consistent given prediction accuracies for Vis/NIRS of 63.8% (error = 9.3 min) combining sets (i)+(iv); and for HYPERS of 88.5% (error = 10.8 min) combining sets (ii)+(iii), and 75.4% (error = 8.3 min) combining the four data sets ((i)+(ii)+(iii)+(iv)). In this study, the models were built using partial least square regression methods that is the most common multivariate approach used for prediction and classification tests; however, applications or other more powerful approaches such as artificial neural networks and support vector machine may further improve the prediction performance and robustness of the models. We concluded that in spite of the large genetic diversity, source and planting years of bean samples, Vis/NIRS and HYPERS have great potential for predicting cooking time over a wide range of measurements; however, the robustness of sensing models seems to be affected by the genotypic diversity, planting year and distribution of the cooking time data used for model building, and hence, chemometric models should be constantly maintained and updated with new data.

The development of a procedure for model updating and cross-year predictions using different genotypes is needed and it will be considered in our next studies.

1.12 Seed multiplication
In Uganda bean lines received for the different nurseries, for maintenance and seed multiplication purposes, a few seed were planted in the screen house and the rest planted in the field. The field also enabled us to evaluate for adaptability to local conditions and also make a quick assessment on susceptibility to diseases. In addition to the nurseries introduced into Zambia discussed above, five varieties, Zorro black, Eldorado pinto, Bunsi navy, Bellagio and Etna cranberry from the MSU program have since been integrated into the breeding program in Zambia and seed has been increased to have the varieties ready for further testing and crossing.

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.

2.1 ANT and ALS characterization and screening in Uganda
Continue with the collection of isolates of ANT, ALS, CBB, and Rust in different production regions of Uganda. Collections for different disease sample for different pathogens were collected and these included, 136 rust, 54 anthracnose, 24 BCMV and 60 ALS samples collected from different bean growing agroecologies within Uganda. These were later isolated for further characterization.

2.2
Increase seed of the differentials for ANT, ALS and rust in Uganda. Differentials for rust, ANT and ALS were obtained and multiplied in the field to increase the amount of seed availed. Unfortunately, some genotypes for ALS and anthracnose did not germinate and a few others did not put on as much seed as needed. There is still need to continue with seed multiplication for these differentials and also to obtain the genotypes that did not produce enough seed.

2.3
Initiate race characterization of Rust, CBB, BCMV, ANT and ALS in Uganda. A number of isolates were obtained from collected diseases samples for different pathogens and these were further characterized into different pathoypes using various techniques and indicated below.

2.3.1. Rust
A field survey was conducted in 15 Ugandan districts that represented the areas of high bean production. High incidence of bean rust and severity was observed in the low altitudes and in the Western Highlands of Uganda. Hoima district had the highest rust disease incidence of 70 to 76% and average severity of 6. Also there was high rust disease incidence and severity in the bean-maize–groundnut cropping system and fields cultivated with commercial cultivars or landraces. The mobile nursery protocol was used to determine the effectiveness of specific rust resistance genes in genotypes in Uganda. The mobile nursery did not work out as had been expected in Uganda and thus other molecular based techniques were thus sought for identification of resistant rust genes.

2.3.2.
A total of 23 single rust isolates were obtained from the collected diseases samples collected in Uganda and inoculated on 11 bean rust differentials and Ouro Negro (Ur-14 gene) cultivar. From these isolates,

six rust pathotypes including 2-0, 4-0, 50-0, 5-1, 4-33 and 63-19 were identified. The identification of rust resistant sources was conducted using both phenotypic and genetic characterization and the following bean lines including Mexico 309, CNC, P1181996, Mexico 235, Redland pioneer, Ouro Negro and Aurora were identified to have good levels of resistance to rust pathotypes existing in Uganda. These have been utilized in crosses to introgress rust resistance into Ugandan germplasm. A study was conducted to identify sources of broad-spectrum rust resistance in common bean germplasm including landraces, commercial cultivars and introduced genotypes in Uganda using a combination of phenotypic and genotypic screening with 22 simple sequence repeat (SSR) markers located on chromosome Pv04. A total of 138 genotypes were field screened from 2014 and 2015 using an alpha lattice design. Resistance of each genotype was compared to the presence and absence of amplified SSR markers. There were highly significant differences ($P < 0.001$) among the genotypes for disease incidence, AUDPC and total grain yield and a strong correlation ($P < 0.001$) between disease incidence and AUDPC in both years. The SSR markers, BARC_PV_SSR04725, bean_ssr_0778 and bean_ssr_2892 were associated ($P \leq 0.05$) with rust resistance. Fifteen genotypes which included the landraces Nabufumbo, and Kapchorwa white, and the commercial cultivar NABE 2 were identified as new sources of rust resistance that would be useful in future bean breeding programs in Uganda.

2.3.3. Rust samples were sent and analyzed at the University of Nebraska by Dr. James Steadman. The first analysis of resistance gene patterns relating to binary races: 63-1, 31-1, 23-1 and 29-1. This indicated that GN 1140 (Ur-7 gene) was susceptible, but all other Middle American differentials were resistant (Ur-3, Ur-5, Ur-3+, CNC, and Ur-11 genes). Also it was noted that all Andean gene sources with the exception of PI 260418 and in a few instances PC 50 and Redlands Pioneer were susceptible. These are still preliminary findings that need to be confirmed. Rust samples from Kampala sent earlier this fall, with a proper APHIS permit was diverted to the United Arab Emirates. Thus, it was delayed 3.5 weeks in transit. Very few rust pustules had any viable spores. Nine urediniospores were isolated and binary races 23-1, 29-1, 63-1 and 31-1 were identified. Race 31-1 was found in six field samples while 63-1 was found in two field samples and 29-1 and 23-1 were only in one sample each. There is a concern that the surviving rust urediniospores may not be representative of all the spores originally sampled. Researchers from NE will travel to Uganda in Oct 2016 to collect more bean leaves with rust to send back to UNL in a 3-4 day period. Previous information on Zambia bean rust from 2015 revealed race 31-1 to be the primary race with 31-3 and 63-1 present in low numbers. We plan to evaluate rust again this year.

2.3.4. CBB. We obtained and utilized an already available pathotype “Kawempe 1” of CBB which we used to screen the available nursery and germplasm collection for resistant genotypes. We managed to obtain four CBB resistant genotypes namely NE2-14-8, NE17-14-29, NE14-09-78 and VAX3.

2.3.5. BCMV. Eighty samples were screened using inoculum obtained from the disease plants in the field. From these three genotypes including SCR 48, SCN 9 and SCN 6 were identified as resistant, and fortunately these same genotypes have also been known to be tolerant to drought condition.

2.4

Leverage the NIFA nurseries and collect information on foliar pathogens on the ADP and UNL drought tolerant germplasm nurseries for reaction to different foliar pathogens on surviving lines and Uganda. This has been undertaken especially for the UNL drought tolerant germplasm nursery for which we have already had the first drought evaluation trial, the preliminary results of which have been indicated in this report. We are now choosing the most relevant races of ANT, ALS and rust and strains of CBB for screening breeding nurseries in Uganda. The specific races/stains have been selected for Rust, CBB and BCMV and have been utilized in the screening process to identify resistant genotypes. These same races will be utilized for the screening of progenies from the crosses that have been initiated.

2.5. Anthracnose race characterization, screening in Zambia
Progress on incorporating ANT resistance is underway using the variety Werna which is resistant to anthracnose and CBB. The F4 population of the cross between Kabulangeti and Werna was also planted in the field in the 2016 growing season for seed multiplication and will be evaluated for resistance at Misamfu and UNZA in 2016/17 season.

2.6. Root rot characterization in Zambia
Six bean lines from the initial 405 entries from the ADP and NE trials previously screened in Zambia were found to have resistant to root and crown rots (RCR) and other foliar diseases and were adapted to Zambia. The primary pathogens associated with dry bean root and crown rots were identified and characterized from samples collected in survival nursery trials evaluated in the period under review. A total of 405 fungi and oomycetes were recovered from the tissue samples. Classical isolation and molecular techniques were used in the identification and characterization of the primary RCR pathogens. The primary RCR pathogens were identified as Fusarium sp. with the predominant pathogens being *F. oxysporum* followed by *F. solani* and *F. equiseti*. This data is a critical starting point in breeding for resistance to the different RCR pathogens present in the bean production regions of Zambia.

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.
Fast cooking lines with high mineral bioavailability will be grown in on farm trials and will be evaluated for farmer acceptability based on agronomic and cooking characteristics. This year the initial 23 ADP short cooking bean lines were reduced to 16 and these were re-evaluated with the same groups of farmers. From the second on-farm participatory evaluation trials, lines were reduced to seven and these were the ones that were eventually taken through for sensory test. Results of the on-farm trials will be reported by Mr. Dennis Katuuramu, a PhD student, Michigan State University.

3.2.
Conduct sensory evaluation of lines with superior cooking time and mineral bioavailability in Michigan, Uganda. Sensory evaluation tests were conducted with 9 famer groups in Uganda in the regions of Hoima, Rakai and Kamuli for the seven ADP lines short cooking lines that had been selected by the famers in the participatory variety selection trials. The sensory evaluation results will be reported by the PhD student, Mr. Dennis Katuuramu.

3.3. 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. 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. Prior work identified a major QTL linked to the Co-1 locus on Pv01 and a breeder friendly InDel marker was developed (50.2Mb) that was linked to four alleles at the Co-1 locus. Work continues to develop Indel and SSR markers at the other genomic positions on Pv02, Pv04, Pv08 and Pv11 where resistance genes were identified. A comprehensive transcriptome analysis was also conducted using Illumina sequencing of two near isogenic lines (NILs)

differing for the presence of the Co-1 gene on Pv01 during a time course following infection with race 73 of *C. lindemuthianum*. From this, we identified 3,250 significantly differentially expressed genes (DEGs) within and between the NILs over the time course of infection. During the biotrophic phase the majority of DEGs were up regulated in the susceptible NIL, whereas more DEGs were up-regulated in the resistant NIL during the necrotrophic phase. Various defense related genes, such as those encoding PR proteins, peroxidases, lipoxygenases were up regulated in the resistant NIL. Conversely, genes encoding sugar transporters were up-regulated in the susceptible NIL during the later stages of infection. Additionally, numerous transcription factors (TFs) and candidate genes within the vicinity of the Co-1 locus were differentially expressed, suggesting a global reprogramming of gene expression in and around the Co-1 locus. Through this analysis, we reduced the previous number of candidate genes reported at the Co-1 locus from eight to three. These results suggest the dynamic nature of *P. vulgaris* – *C. lindemuthianum* interaction at the transcriptomic level and reflect the role of both pathogen and effector triggered immunity on changes in plant gene expression.

3.4. Mapping resistance genes for bruchid resistance

The same SA population was sent to Dr. Beaver's Lab at University of Puerto Rico for evaluation for bruchid resistance. The evaluation has been completed and QTL analysis for bruchid resistance is currently being conducted in Zambia.

<u>Objective 4. Develop phenometric approaches to improving the efficiencies of breeding for abiotic stress tolerance, especially drought</u>

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 support these efforts, research was conducted on the physiology of drought and heat stress in a selection of bean genotypes with varying degrees of stress tolerance including tepary bean. The response of different metabolites to drought stress was a major focus. Beans exposed to drought stress had no differences in free proline concentration in their leaves, either between treatments or among genotypes. For soluble carbohydrates, no differences among genotypes were found under control conditions, but the concentration of malic acid, glucose, fructose, inositol, and raffinose all increased in the leaf tissues of plants exposed to drought stress. Glucose, fructose, and inositol were all found in higher concentrations in more tolerant genotypes, so it is likely that their accumulation is correlated with drought tolerance. These compounds accumulated in sufficient quantities to osmotically adjust bean leaf tissues, and leaf water potential measurements revealed that those genotypes that accumulated more soluble carbohydrates under drought stress also had lower leaf water potentials while no differences among genotypes existed for leaf water potentials under control conditions. Abscisic acid was responsive to drought stress in beans, but what differences existed in its concentration among genotypes did not seem directly related to drought tolerance. Grafting experiments revealed that it is shoot identity that controls the concentration of ABA in root tissues under drought stress. Drought stress also affects a number of photosynthesis related traits in beans. Photosynthesis vs. intercellular CO2 concentration curves revealed that none of the photosynthetic parameters derived were related to drought tolerance, but the maximum carboxylation rate of rubisco and the rate of electron transport could be related to general productivity. Based on measurements of gas exchange on control and drought stressed beans, lower stomatal conductances are associated with drought tolerant genotypes regardless of water treatment. Lower stomatal conductances would allow a plant to conserve more water during periods of drought stress. Grafting experiments showed that stomatal conductance is controlled mainly by factors located in the shoot tissue and not the root tissue. However, these factors are unrelated to leaf density or the density of stomata on leaf surfaces. Bean plants exposed to temperatures of 45 °C for two days showed measurable signs of heat stress. Measures of gas exchange, chlorophyll fluorescence, and oxidative stress were for the most part only affected by this high temperature and not by any temperatures below it. These measures also correlated well with visual signs of damage on leaf tissue caused by heat stress. The method was useful for screening a large group of germplasm for heat tolerance, but this heat tolerance only partially related to drought tolerance observed in the field. Plant breeders can utilize some of these methods to supplement field data and further characterize the stress tolerance of later generation bean lines.

Objective 5. Institutional Capacity Building and Training

Institutional Capacity Building and Training continues at MSU for two doctoral students, Isaac Dramadri, and Dennis Katuuramu from Uganda. Two doctoral students graduated in FY16 (fall 2015); Kelvin Kamfwa from Zambia, and Jesse Traub, and one MS student Grady Zuiderveen student from the US all in Plant Breeding, Genetics and Biotechnology at MSU. Thesis title listed in Annex 1. In Uganda, three postgraduate students have been engaged and trained under the project. The students are at different levels of their research as indicated below;

Ms. Blessing Odogwu; is a PhD student at Makerere University undertaking studies under the research topic “Genetic diversity study of common bean rust in Uganda”. Blessing is currently completing her thesis write up and will submit by the end of 2016.

Mr. Alladassi Mahulé Elysé Boris is an MSc. Student at Makerere University, Uganda, and has conducted research on the “Genetics of resistance to Common Bacterial Blight disease of Common Bean (Phaseolus vulgaris L.) in Uganda”. He has already completed his research work and submitted his thesis for examination.

Mr. Basil Evarist Kavishe is also an MSc. Student at Makerere University, Uganda who is conducting research on the “Resistance to bean common mosaic poty-viruses (BCMV and BCMNV) and its inheritance in selected Ugandan bean genotypes” Evarist is still conducting his research work and hopefully will completed by end of 2016.

- In addition to graduate student training in Uganda, we were able to train five (5) technicians and four (4) research assistants on the drought screening and capture of data using the irrigation and non-irrigation technique. Also five (5) technicians together with 326 farmers and three (3) personnel were taught on bean disease identification and possible control measures.
- In Zambia, the training of Seed Growers (farmers) in clean seed production and integrated pest and disease management for improved dry bean production and productivity. Seed growers were trained on best practices for seed and dry bean production by the staff from the Bean improvement program. A total of 118 males and 99 females attended the trainings. The trainings were conducted through workshops and seminars and farmer learning centers. The trainings were conducted in >11 Districts from Muchinga and Northern Province. These training were attended by members from Shangila seed grower association, Chinchi Wa babili seed grower association, Kabulamwiko seed grower association and others with a membership of 40 males 37 females, 69 males 87 females and 54 males and 50 females, respectively. These seed grower associations help multiply and supply clean reliable seed for over 230,000 households growing beans in the major bean growing areas in Zambia.

- Training of students on identification of root rots in the field and integrated pest and disease control measures. The station received students on industrial attachments where the NIFA RCR project was based receive students on attachment every year and they get to have an opportunity to learn and participate in the projects and activities on the station. A total of 66 students from 6 local Agriculture training institutions/colleges have been trained and made aware of RCR of dry beans and the methods of evaluation and sampling of plants for pathogen identification and integrated management of diseases and pests in dry bean in the period under review.

One hectare (1.0ha) irrigation facility has been installed in Misamfu using LIL Sub-project funding which will benefit the breeding program, as field research can continue even in the off- season as opposed to waiting for the rainy season.

Major Achievements

The project 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, in country USAID Field Mission, USAID Feed the Future monitoring and evaluation teams, 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. We have also had engagements with postgraduate students, farmers, NGOs and Community Based Organization (CBOs) in bean growing agroecologies in Uganda. The research achievements so far 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 two sets of drought nurseries and two sets of differentials (Rust and ALS) from collaborating partners.
- To date we have been able to collect and evaluate a germplasm collection of slightly over 750 germplasm for different traits.
- We have identified 6, 5, 3, 7, and 7 tentative resistance bean sources for rust, CBB, BCMV, drought and short cooking time respectively.
- Made over 86 different crosses to introgress different diseases resistances and drought tolerance into the susceptible Uganda market class bean varieties.
- We have determined the incidences and severities of the different bean folia pathogen within major bean growing regions of Uganda.
- We have undertaken inheritance studies to determine modes of inheritance of rust and CBB and BCMV resistance for through preferred Andean bean genotypes in Uganda.
- Seed of different nurseries acquired were increased to obtain enough seed for screening purposes within Uganda.
- Several isolates of rust, CBB, BCMV, anthracnose, and angular leaf spot were obtained from bean diseases samples obtained from different bean production regions of Uganda. Some of these have been characterized.

- The project has continued screening of progenies obtained from crosses made to introgress resistances for drought, rust, CBB, BCMV and anthracnose into the preferred Andean market class bean varieties for Uganda.
- Preliminary and advanced yield trials conducted for promising drought tolerant line.
- We have built capacity for 4 Research Assistant and 5 Technicians drought screening, isolation and inoculation techniques for rust, anthracnose, CBB and BCMV, data collection and foliar disease management for beans and in addition trained and mentored 6 students (3 PhD and 3 MScs) in breeding methodologies and skills.
- We have engaged and trained 326 farmers, three (3) extension personnel on bean foliar disease management, on-farm trials management in Uganda while evaluating and making selections for the utilization of fast cooking bean varieties.
- New sources of resistance to ANT, ALS, CBB and rust have been identified in Uganda and Zambia.
- Several sources of drought tolerance were identified. A drought trial of 60 entries is being tested in 2016 at Uganda and Zambia under normal and drought stress conditions.
- Based on previous, 36 F1 hybrid combinations were initiated to combine multiple disease resistance and drought tolerance into African elite germplasm. Segregating populations will be distributed in 2017 for local selections in Uganda and Zambia
- Ur-3, Ur-5, Ur-3+, CNC and Ur-11 would be genes from the Middle American cultivars that would confer resistance in Uganda and except for one rust isolate that caused a susceptible reaction on Ur-3 can be used in Zambia for breeding.
- Breeder-friendly marker developed for anthracnose resistance
- Identified genomic regions controlling BNF and anthracnose resistance.
- 15 refereed publications in print or press.

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 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.

Human Resource and Institution Capacity Development

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. student is looking at breeding for resistance to CBB while the second student is conducting research on the 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 Innovation Lab PI: Prof. James 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
Gender: 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 Innovation Lab 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
Gender: 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 Innovation Lab 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
Completion Date: December 2015
Is trainee a USAID Participant Trainee and registered on TraiNet? Yes
Training Status: graduated

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
Completion Date: September 2015
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: graduated

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
Completion Date: January 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: graduated.

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.

Student 8
Name of trainee (First and Last Name): Dennis Katuuramu.
Citizenship: Uganda
Gender: M
Host Country Institution to Benefit from Training: Makerere University
Training Institution: MSU
Supervising Legume Innovation Lab PI: Karen Cichy and James Kelly
Degree Program for training: Doctorate
Field or Discipline: Plant Breeding, Genetics and Biotechnology
Thesis Title/ Research Area: Iron and Zinc Bioavailability in Andean Beans
Start Date: August 2012
Projected Completion Date: September 2017
Is trainee a USAID Participant Trainee and registered on TraiNet? NO
Training Status: Active, Partial, USDA-ARS funding.

Achievement of Gender Equity Goals

We have continued to undertake all project activities in consideration of gender equity in Uganda. For this to happen, we have ensured that both women and men are equitably represented and /or involved in executing project activities. This has been shown in all our project 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 Uganda. In Zambia we have identified NGO's 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 includ 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.

Explanation for Changes

There are no changes to set out activities but a few delays due to changes in the weather pattern, in many locations planting has been delayed to delays in on-set of rains. Other 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.

Self-Evaluation and Lessons-Learned

Due to the delays in the rains and the reduction in the amounts received in Uganda, we need to think seriously of investing in a heavy duty irrigation facility as an institute. Also due to the large number of experiments that we are running currently we need to invest into electronic data capture and ease on the amount of work. Additionally, we need to invest in dereferencing all our farmers' trial sites. 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 trials 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.

Scholarly Accomplishments – See Annex 1

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 FY17. The achievements outlined above have encountered challenges mainly due to the severe drought that was experienced during the first season 2016 (March-July 2016), where we lost quite a significant number of experiments in Uganda. To solve the problem and save some of the seed, we invested in on-spot irrigation with improvised pumps and this save us some of our precious seed.

ANNEXES

Annex 1.Scholarly Accomplishments- Refereed Publications

Isaacs, K.B., S.S. Snapp, J.D. Kelly and K. R. Chung. 2016. Farmer knowledge identifies competitive bean ideotype for maize-bean intercrop systems in Rwanda. Agriculture & Food Security 5:15. doi 10.1186/s40066-016-0062-8

Kelly, J.D., G.V. Varner, S. Hooper, K.A. Cichy, and E.M. Wright. 2016. Registration of 'Samurai' otebo bean. J. Plant Registrations 10:109-114. doi:10.3198/jpr2015.09.0051crc.

Mendoza, F.A, J. D. Kelly, and K. A. Cichy. 2016. Automated prediction of sensory scores for color and appearance in canned black beans (*Phaseolus vulgaris* L.) using machine vision. International Journal of Food Properties, doi:10.1080/10942912.2015.1136939.

Moghaddam, S.M., S. Mamidi, J. M. Osorno, R. Lee, M. Brick, J. Kelly, P. Miklas, C. Urrea, Q. Song, P. Cregan, J. Grimwood, J. Schmutz, and P. E. McClean. 2016. Genome-wide association study identifies candidate loci underlying agronomic traits in a Middle American diversity panel of common bean. The Plant Genome 9: doi: 10.3835/plantgenome2016.02.0012

Hoyos-Villegas, V., E. M. Wright and J.D. Kelly. 2016. GGE biplot analysis of yield associations with root traits in a Mesoamerican bean diversity panel. Crop Sci. 56:1081-1094. doi:10.2135/cropsci2015.10.0609

Zuiderveen, G.H., B. A. Padder, K. Kamfwa, Q. Song and J. D. Kelly. 2016. Genome-wide association study of anthracnose resistance in Andean beans. PLoS ONE 11(6): e0156391. doi:10.1371/journal.pone.0156391

Ai, Y., K A. Cichy, J. B. Harte, J. D. Kelly, and P. K.W. Ng. 2016. Effects of extrusion cooking on the chemical composition and functional properties of dry bean powders. Food Chemistry 211:538–545. doi:10.1016/j.foodchem.2016.05.095

Hoyos-Villegas, V., Q. Song, J.D. Kelly. 2016. Genomewide association analysis for drought tolerance and associated traits in common bean. The Plant Genome 9: doi:10.3835/plantgenome2015.12.0122

Hoyos-Villegas, V., Q. Song, E.M. Wright, S. E. Beebe and J.D. Kelly. 2016. Joint linkage QTL mapping for yield and agronomic traits in a composite map of three common bean RIL populations. Crop Sci. 56: doi:10.2135/cropsci2016.01.0063.

Heilig, J.A. J. S. Beaver, E. M. Wright, Q. Song, and J. D. Kelly. 2016. QTL analysis of symbiotic nitrogen fixation in a black bean RIL population. Crop Sci. 56: doi.

Nakedde, T., F. J. Ibarra-Perez, C. Mukankusi, J. G. Waines, and J. D. Kelly. 2016. Mapping of QTL associated with Fusarium root rot resistance and root architecture traits in black beans. Euphytica 212: 53-61. doi: 10.1007/s10681-016-1755-6

Padder, B.A., K. Kamfwa, H.E. Awale and J. D. Kelly. 2016. Transcriptome profiling of the *Phaseolus vulgaris - Colletotrichum lindemuthianum* pathosystem. PLoS ONE 11: e0165823. doi:10.1371/journal.pone.0165823.

Kelly, J.D. 2016. Developing improved high-yielding varieties of common bean. Ch.18. In: Achieving sustainable cultivation of grain legumes (ed. Sivasankar et al) Burleigh Dodds Science Publishing (in press).

Odogwu, B.A., S. T. Nkalubo, C. Mukankusi, T. Odong, H. E. Awale, P. Rubaihayo, and J. D. Kelly. 2016. Phenotypic and genotypic screening for sources of rust resistance in common bean germplasm in Uganda. Euphytica (in print).

Odogwu, B.A., S. T. Nkalubo, C. Mukankusi, P. Paparu, P. Rubaihayo, J. D. Kelly, and J. Steadman. 2016. Assessment of the common bean rust prevalence and variability in Uganda. African J. Plant Res. (in review).

Presentations, Dissertations, Patents and Awards

Poster paper presentations

Alladassi M.E.B, S.T Nkalubo, C Mukankusi, J Kelly, and Urrea C. 2016. Identification of Common Bacterial Blight Resistant Sources for the Bean Breeding Program in Uganda. Poster Presented during the Pan African Grain Legume and World Cowpea Conference 28 February – 4 March 2016, Livingstone, Zambia

Berry, M., Wiesinger, J., Nchimbi-Msolla, S., Miklas, P., Porch, T., Fourie, D., and Cichy, K.A. (2016). Breeding for a Fast Cooking Bean: Study of Genotypes across Environments to Determine Phenotypic Stability in Phaseolus vulgaris. Poster Presentation, Pan African Grain Legumes Research Conference, Livingstone, Zambia March 3.

Cichy, K.A., Wiesinger, J., Mendoza, F., Hooper, S., Grusak, M.A., Glahn, R., and Kelly, J. (2016). A Nutritional Profile of Fast Cooking Bean Germplasm. Poster Presentation, Pan African Grain Legumes Research Conference, Livingstone, Zambia March 4.

Cichy, K.A. and Rueda, J.A. (2016). Beans as Ingredients in "Better for You" Foods at the Michigan Agri-Business Association Winter Conference, Michigan Bean Shippers.

Dramadri, I. and J. D. Kelly. 2016. Genome wide association analysis for drought tolerance responses in Andean common beans. Poster presented National Association Plant Breeders- NAPB conference, North Carolina State Univ. Raleigh NC.

Katuuramu, D.N., Kelly, J.D., Glahn, R.P., and Cichy, K.A. (2016). Field Evaluation of Nutritionally Superior Common Bean Genotypes with Farmers in Three Agro-ecological Zones in Uganda. Oral Presentation, Pan African Grain Legumes Research Conference, Livingstone, Zambia Feb 29.

Kelly, J.D. (2016). Genome-Wide Association Analysis of Traits Associated with Drought Tolerance in Common Bean. Oral Presentation, Pan African Grain Legumes Research Conference, Livingstone, Zambia Feb 29.

Odogwu A. B, Nkalubo S. T, Paparu P, Mukankusi C, Rubaihayo P, Steadman J and Kelly J. D. (2016). Yield loss Associated with Common Bean Rust on Germplasm Evaluation in Uganda. Poster Presented during the Pan African Grain Legume and World Cowpea Conference 28 February – 4 March 2016, Livingstone, Zambia;

Odogwu A. B., S.T. Nkalubo, C. Mukankusi, P. Rubaihayo, C. A. Urrea, J. Steadman and J. D. Kelly. (2016). New Sources of Resistance to Bean Rust Established with SSR Markers in Uganda. Poster Presented

during the Pan African Grain Legume and World Cowpea Conference 28 February – 4 March 2016, Livingstone, Zambia

Wang, W, Cichy, KA, Kelly, JD, Mukankushi, CM. (2015). QTL Analysis for Fusarium Root Rot Resistance in Common Bean (Phaseolus vulgaris). Biennial Bean Improvement Cooperative Meeting, Niagara Falls, Canada. November 1-4, 2015

- Three scientific articles drafted and submitted/pending to scientific Journals for publication and these include (i) Occurrence of *Uromyces appendiculatus* and response of selected common bean cultivars to the different races of the pathogen collected from Uganda (drafted but pending submission)
- MSc. Thesis by Mr. Alladassi Mahulé Elysé Boris entitled, "*Genetics of resistance to Common Bacterial Blight disease of Common Bean* (*Phaseolus vulgaris L.) in Uganda*" submitted to postgraduate school Makerere University Uganda for examination.

Non-refereed Publications

Acosta-Gallegos, J.A., Y. Jiménez Hernández, V. Montero Tavera1, M. A. Martínez Gamiño, M. D. Herrera, J. L. Anaya López, and J.D. Kelly. 2016. Release of pinto Raramuri dry bean for the semi-arid highlands of Central Mexico. Bean Improvement Cooperative Annual Report 59:253.

Berry, M., Wiesinger, J, Nchimbi-Msolla, S, Miklas, P, Porch, T, Fourie, D, and Cichy, K. 2016. Breeding for a fast cooking bean: a study of genotypes across environments to determine stability of the cooking time trait in Phaseolus vulgaris. Bean Improvement Cooperative Annual Report 59:33-34

Chilvers, M.I., J.L. Jacobs, A.M. Byrne, and J.D. Kelly. 2016. Screening Andean dry bean germplasm for root rot resistance. Bean Improvement Cooperative Annual Report 59:105-106.

Cichy, K.A. and F. Mendoza. 2016. Color retention in canned black beans. Bean Improvement Cooperative Annual Report 59:25-26.

Zuiderveen, G.H., B. Padder, K. Kamfwa and J. D. Kelly. 2016. Mapping the Co-1 locus conditioning anthracnose resistance in common bean. Bean Improvement Cooperative Annual Report 59:17-18.

Patents

Plant Variety Protection Certificate 201500009 was issued for Snowdon White Kidney Bean on 2/26/2016.

Plant Variety Protection No. 201500008 was issued for Eldorado pinto bean on 7/6/2016.

Plant Variety Protection No 201500385 was issued for Powderhorn great northern bean on 6/3/2016

Theses and Dissertations

Al Dossary, O. (2016). Color retention and anthocyanin concentration in canned black beans. M.S. Thesis, Michigan State University.

Heilig, J.A. (2015). QTL mapping of symbiotic nitrogen fixation in dry bean; Dry bean performance under organic production systems. Doctoral Dissertation, Michigan State University, East Lansing MI. 153pp.

Hoyos-Villegas, V. (2015). Identification of genomic regions and development of breeding resources associated with drought tolerance in common bean (Phaseolus vulgaris L.). Doctoral Dissertation, Michigan State University, East Lansing MI. 132pp.

Nakedde, T. (2015). Identification and mapping of QTL associated with Fusarium root rot resistance and root architecture traits in black beans (Phaseolus vulgaris L.). Master's Thesis, Michigan State University, East Lansing. MI. 119pp.

Traub, J.R. (2015). Physiological characteristics leading to differences in drought tolerance in Phaseolus vulgaris and P. acutifolius. Doctoral Dissertation, Michigan State University, East Lansing MI. 148pp.

Wang, W. (2016). QTL analysis and candidate genes identification associated with Fusarium root rot resistance in common beans (Phaseolus vulgaris). M.S. Thesis, Michigan State University.

Zuiderveen, G.H. (2015). The genetics of anthracnose resistance in common bean. Master's Thesis, Michigan State University, East Lansing MI. 68pp.

Annex 2: Description of the 138 Ugandan common bean germplasm screened for resistance to rust disease

S/N	‡Genotype	Genotype Type	Stress response	Gene pool
1	NABE 1	Commercial	Susceptible to multiple constraints	Andean
2	NABE 2	Commercial	BCMV resistant/ Drought tolerant	Mesoamerican
3	NABE 3	Commercial	Bean common mosaic virus BCMV resistant	Mesoamerican
4	NABE 4	Commercial	CBB resistant/ALS	Andean
5	NABE 5	Commercial	CBB resistant	Andean
6	NABE 6	Commercial	Unknown	Mesoamerican
7	NABE 11	Commercial	CBB resistant/ALS	Andean
8	NABE 13	Commercial	Root rot/low soil fertility tolerant	Andean
9	NABE 14	Commercial	Root rot/low soil fertility tolerant	Andean
10	NABE 15	Commercial	Anthracnose tolerant	Andean
11	NABE 16	Commercial	Anthracnose tolerant	Andean
12	NABE 17	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
13	NABE 18	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
14	NABE 19	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
15	NABE 20	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
16	NABE 21	Commercial	Anthracnose, BCMV, ALS tolerant	Andean

17	NABE 22	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
18	NABE 23	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
19	K131	Commercial	BCMV/black root/ anthracnose resistant	Mesoamerican
20	K132	Commercial	Unknown	Andean
21	DAB 474	Introduced	Drought tolerant	Andean
22	DAB 475	Introduced	Drought tolerant	Andean
23	DAB 478	Introduced	Drought tolerant	Andean
24	DAB 479	Introduced	Drought tolerant	Andean
25	DAB 480	Introduced	Drought tolerant	Andean
26	DAB 482	Introduced	Drought tolerant	Andean
27	TU	Introduced	Anthracnose differential	Mesoamerican

S/N	‡Genotype	Genotype Type	Stress response	Gene pool
28	TO	Introduced	Anthracnose differential	Mesoamerican
29	Michigan dark red kidney	Introduced	Anthracnose differential	Andean
30	Michelite	Introduced	Anthracnose differential	Mesoamerican
31	Widusa	Introduced	Anthracnose differential	Mesoamerican
32	PI207262	Introduced	Anthracnose differential	Mesoamerican
33	AB 136	Introduced	Anthracnose differential	Mesoamerican

34	G2333	Introduced	Anthracnose differential	Mesoamerican
35	SCN-4	Introduced	Drought tolerant	Mesoamerican
36	SCN-6	Introduced	Drought tolerant	Mesoamerican
37	SEN-80	Introduced	Drought tolerant	Mesoamerican
38	SCN-5	Introduced	Drought tolerant	Mesoamerican
39	SEN-34	Introduced	Drought tolerant	Mesoamerican
40	DOR-500	Introduced	Drought tolerant	Andean
41	SCR-5	Introduced	Drought tolerant	Mesoamerican
42	SCR-35	Introduced	Drought tolerant	Mesoamerican
43	SCN-10	Introduced	Drought tolerant	Mesoamerican
44	SCN-12	Introduced	Drought tolerant	Mesoamerican
45	SCN-37	Introduced	Drought tolerant	Mesoamerican
46	DOR-364	Introduced	Drought tolerant	Andean
47	SEN-95	Introduced	Drought tolerant	Mesoamerican
48	SCN-8	Introduced	Drought tolerant	Mesoamerican
49	SEN-46	Introduced	Drought tolerant	Mesoamerican
50	SCN-1	Introduced	Drought tolerant	Mesoamerican
51	SCR-26	Introduced	Drought tolerant	Mesoamerican

52	SEN-56	Introduced	Drought tolerant	Mesoamerican
53	SCR-18	Introduced	Drought tolerant	Mesoamerican
54	SEN-92	Introduced	Drought tolerant	Mesoamerican
S/N	‡Genotype	Genotype Type	Stress response	Gene pool
55	SCN-3	Introduced	Drought tolerant	Mesoamerican
56	SCR-25	Introduced	Drought tolerant	Mesoamerican
57	SEN-90	Introduced	Drought tolerant	Mesoamerican
58	California small white (CSW)643	Introduced	Rust differential,1983	Mesoamerican
59	PC50	Introduced	Rust differential,2002	Andean
60	US#3	Introduced	Rust differential,1983	Andean
61	NEP 2 (G5693)	Introduced	Rust differential,1983	Mesoamerican
62	Redland Pioneer	Introduced	Rust differential,2002	Andean/Mesoamerican
63	GN1140	Introduced	Rust differential,2002	Mesoamerican
64	Early Gallatin	Introduced	Rust differential,2002	Andean
65	#Mexico 309	Introduced	Rust differential,2002	Mesoamerican
66	Compuesto Negro Chimaltenango(CNC)	Introduced	Rust differential,2002	Mesoamerican
67	Montcalm	Introduced	Rust differential,2002	Andean
68	DAB 476	Introduced	Drought tolerant	Andean

69	DAB 477	Introduced	Drought tolerant	Andean
70	Mexico 235	Introduced	Rust differential,2002	Mesoamerican
71	Ecuador 299	Introduced	Rust differential,1983	Mesoamerican
72	Kentucky Wonder (KW) 814	Introduced	Rust differential,1983	Mesoamerican
73	CIAT Aurora	Introduced	Unknown	Unknown
74	51051	Introduced	Rust differential,1983	Mesoamerican
75	CNCPI181996	Introduced	Unknown	Unknown
76	Aurora	Introduced	Rust differential, 2002	Mesoamerican
77	Teebus	Introduced	Rust resistant	Unknown
78	#Ouro Negro	Introduced	Rust resistant	Mesoamerican
79	PI 181996	Introduced	Rust differential,2002	Mesoamerican
80	PI 260418	Introduced	Rust differential,2002	Andean
81	Golden Gate Wax (GGW)	Introduced	Rust differential,2003	Andean

S/N	†Genotype	Genotype type	Gene pool	S/N	Genotype	Genotype type	Gene pool
82	Kamuli Yellow	††Landrace	Unknown	101	Kamuli black	Landrace	Unknown
83	Lira Yellow	Landrace	Unknown	102	Kamula	Landrace	Unknown

84	Kajeru	Landrace	Unknown	103	Kaborole red	Landrace	Unknown
85	Kinbwogegwa	Landrace	Unknown	104	Lira Pink	Landrace	Unknown
86	Kamwenge Purple	Land race	Unknown	105	Kaborole Purple	Landrace	Unknown
87	Mukono cream	Landrace	Unknown	106	Kitinda	Landrace	Unknown
88	Kamuli Purple	Landrace	Unknown	107	Obuhiumbaobukere	Landrace	Unknown
89	Mpigi Pink	Land race	Unknown	108	Wakiso cream	Landrace	Unknown
90	Masindi red	Land race	Unknown	109	Masindi Purple	Landrace	Unknown
91	Mutike	Landrace	Unknown	110	Nambale (U00143)	Landrace	Unknown
92	Kanyebwa long	Landrace	Unknown	111	Ndume (U00069)	Landrace	Unknown
93	Nkalyebawere	Landrace	Unknown	112	Mukono cream	Landrace	Unknown
94	Mbarara Purple	Landrace	Unknown	113	Kamwenge cream	Landrace	Unknown
95	Kapchorwa White	Landrace	Unknown	114	Zebra	Landrace	Unknown
96	Kaborole Maroon	Landrace	Unknown	115	Kanyebwa (U00271)	Landrace	Unknown
97	Nabufumbo	Landrace	Unknown	116	Wakiso brown	Landrace	Unknown
98	Bumwufu	Landrace	Unknown	117	Mpigi white	Landrace	Unknown
99	Lira White	Landrace	Unknown	118	Kamuli White	Landrace	Unknown
100	Kahura	Landrace	Unknown	119	Kaborole cream	Landrace	Unknown
120	Mukono cream	Landrace	Unknown	131	Mukono black	Landrace	Unknown

121	Kankulyembaluke	Landrace	Andean	131	U00236	Landrace	Unknown
122	Kanyawama	Landrace	Unknown	132	Kamuli pink	Landrace	Unknown
123	Roba	Landrace	Unknown	133	Apac cream	Landrace	Unknown
124	Masindi yellow	Landrace	Andean	134	Masindi cream	Landrace	Unknown
125	Kamuli red	Landrace	Unknown	135	Kamwenge Maroon	Landrace	Unknown
126	Kamwenge red	Landrace	Unknown	136	Masaka red	Landrace	Unknown
127	Apac pink	Landrace	Unknown	137	Masaka yellow	Landrace	Unknown
128	Kanyamunyo	Landrace	Unknown	138	Nyekera	Landrace	Unknown
129	Apac pink	Landrace	Unknown				

Annex 2: Drought nursery and yield obtained under both irrigated and non-irrigated trial

NAME	ORIGIN	Nebraska Code	ADP CODE	Irrigated (kg/ha)	Non-Irrigated (kg/ha)
EG 21	AF-5	NE27-14-100	ADP-100	1267	279
JESCA	AF-7	NE27-14-102	ADP-102	1528	1142
OPS-RS4	AF-18	NE27-14-113	ADP-113	1388	0
OPS-RS1	AF-19	NE27-14-114	ADP-114	1043	60
A-800	AF-21	NE27-14-116	ADP-116	1027	112
JENNY	AF-28	NE27-14-123	ADP-123	892	0
RUHONDELA	TZ-25	NE27-14-25	ADP-25	559	115
MRONDO	TZV-41	NE27-14-41	ADP-41	1011	824
RH NO.12	TZV-45	NE27-14-45	ADP-45	384	28
MSOLINI	TZV-48	NE27-14-47	ADP-47	1148	604
WALLACC 773-V98	BC-149	NE27-14-603	ADP-603	779	158
1132-V96	BC-152	NE27-14-605	ADP-605	564	186
MAULASI	TZV-62	NE27-14-61	ADP-61	695	582
OAC LYRICK	BC-344	NE27-14-616	ADP-616	252	197
RED RIDER	BC-347	NE27-14-617	ADP-617	945	536
AC ELK	BC-351	NE27-14-618	ADP-618	1229	176
MAULASI	TZV-63	NE27-14-62	ADP-62	205	46
DOLLY	BC-401	NE27-14-624	ADP-624	494	0
BADILLO	BCV-34	NE27-14-626	ADP-626	0	0
H9659-21-1	BCV-500	NE27-14-627	ADP-627	1126	35
H9659-27-7	BCV-501	NE27-14-628	ADP-628	1471	253
CAPRI	BC-95	NE27-14-641	ADP-641	2074	526
CARDINAL	BC-108	NE27-14-643	ADP-643	881	398

RED KLOUD	BC-148	NE27-14-648	ADP-648	621	89
KARDINAL	BC-254	NE27-14-657	ADP-657	1359	223
KRIMSON	BC-261	NE27-14-660	ADP-660	1280	914
USCR-CBB-20	BC-264	NE27-14-663	ADP-663	855	214
VA-19	BC-277	NE27-14-667	ADP-667	712	99
CRAN-09	BC-318	NE27-14-668	ADP-668	814	136
HOOTER	BC-397	NE27-14-678	ADP-678	936	532
IJR	BCV-272	NE27-14-683	ADP-683	813	185
PINK PANTHER	BC-398	NE27-14-687	ADP-687	832	220
BUKOBA	TZ-7	NE27-14-17	ADP-7	146	0
NJANO-DOLEA	TZV-72	NE27-14-71	ADP-71	195	0
MASUSU	TZV-74	NE27-14-73	ADP-73	1925	295
KABLANKETI	TZV-84	NE27-14-80	ADP-80	0	83
KABLANKETI	TZV-85	NE27-14-81	ADP-81	728	17
KABLANKETI	TZV-92	NE27-14-88	ADP-88	445	24
W616560	TZV-95	NE27-14-91	ADP-91	1348	0
Bilfa 4	AF-2	NE27-14-97	ADP-97	62	0
MARQUIS	NE1-11-27	NE28-14-46	MARQUIS	654	260
MATTERHORN		NE28-14-45	MATTERHORN	867	41
MERLOT		NE28-14-49	MERLOT	691	72
NE14-09-26	10F-0025	NE28-14-5	SB-740	1034	0
NE14-09-16	10F-0018	NE28-14-3	SB-743	793	0
NE14-09-49	10F-0045	NE28-14-7	SB-747	1277	0
NE14-09-85	10F-0073	NE28-14-11	SB-754	702	197
NE14-09-19	NE 1419	NE28-14-16	SB-761	1196	69
NE14-09-87	10F-0075	NE28-14-12	SB-770	1848	237

NE14-09-106	10F-0090	NE28-14-13	SB-774	367	99
NE14-09-23	10F-0023	NE28-14-4	SB-776	489	262
NE14-09-6	10F-0012	NE28-14-1	SB-781	1291	55
NE14-09-111	10F-0095	NE28-14-14	SB-783	1617	237
NE14-09-50	10F-0046	NE28-14-8	SB-787	1177	92
NE14-09-113	10F-0298	NE28-14-15	SB-791	707	0
NE14-09-10	10F-0015	NE28-14-2	SB-793	714	0
NE14-09-78	10F-0069	NE28-14-10	SB-804	1072	123
NE14-09-46	10F-0043	NE28-14-6	SB-812	262	0
NE14-09-65	10F-0058	NE28-14-9	SB-815	260	251
STAMPEDE		NE28-14-50	STAMPEDE	1682	52

Preliminary yield (kg/ha) for drought bean lines from CIAT

S/N	Line	Yield kg/ha	S/N	Line	Yield kg/ha
1	SMC 45	1700	85	SER 384	1300
2	SMC 44	1950	87	SER 386	1700
3	SMC 146	1650	88	SER 387	1000
4	SMC 147	1750	90	SER 389	1500
5	SMC 148	1150	91	SER 390	900
6	SMC 150	1600	92	SER 391	1700
7	SMC 151	2250	93	SMC 165	1800
8	SMC 152	2150	94	SMC 166	900
9	SMC 153	2000	95	SMC 167	900
10	SMC 154	1400	96	SMC 168	1275
11	SMC 155	969	97	SMC 169	1000

S/N	Line	Yield kg/ha	S/N	Line	Yield kg/ha
12	SMC 156	1850	98	SMC 170	1250
13	SMC 157	1500	99	SMC 171	1000
14	SMC 158	1750	100	SMC 172	750
15	SMC 159	1700	101	SMC 173	1000
16	SMC 160	2500	103	SMC 175	688
17	SMC 149	1938	104	SMC 176	1500
18	SMC 161	1125	105	SMC 177	750
19	SMC 164	1750	106	SMC 178	500
20	SMN 57	1700	107	SMC 179	875
21	SMN 58	1750	108	SMC 180	1000
22	SMN 59	1500	109	SMC 181	1250
23	SMN 60	1813	110	SMC 182	1250
24	SMN 61	1950	111	SMC 183	1281
25	SMN 62	600	112	SMC 184	1250
26	SMN 63	1200	113	SMC 185	1281
27	SMR 99	2100	114	SMC 186	1250
28	SMR 100	2188	115	SMC 187	938
29	SMR 101	1600	116	SMC 188	1750
30	SMR 102	2208	117	SMC 189	1688
31	SMR 103	2250	118	SMC 190	1063
32	SMR 104	1958	119	SMC 191	875
33	SMR 105	1500	120	SMC 192	1250
34	SMR 106	2438	121	SMC 193	1750
35	SMR 107	1906	122	SMC 194	1438

S/N	Line	Yield kg/ha	S/N	Line	Yield kg/ha
36	SMC 162	4125	123	SMC 195	1375
37	SMR 108	1200	124	SMC 196	1188
38	SMR 109	1850	125	SMC 197	1063
39	SMR 110	1500	126	SMC 198	1000
40	SMR 111	1800	127	SMC 199	750
41	SMR 112	1300	128	SMC 200	500
42	SMR 113	3750	129	SMC 201	1125
43	SMR 114	1667	131	SMC 203	750
44	SMR 15	3250	132	SMC 204	1750
45	SMR 116	2875	133	SMC 205	750
46	SMR 117	1750	134	SMC 206	900
47	SMR 118	1163	135	SMC 207	1250
48	SMR 119	2750	136	SMC 208	1313
49	SMR 123	2450	139	SMC 211	1438
50	SMR 124	2500	140	SMN 64	1938
51	SMR 125	2875	142	SMR 132	813
52	SMR 126	2000	143	SMR 133	1469
53	SMR 127	2000	144	SMR 134	1250
54	SMR 128	1400	146	SMR 136	1250
55	SMR 129	1550	147	SMR 137	1250
56	SMR 130	1450	148	SMR 138	938
57	SMR 131	1333	150	SMR 140	750
58	SEC 45	1425	151	SMR 141	625
59	SEC 46	1550	152	SMR 142	1083

S/N	Line	Yield kg/ha	S/N	Line	Yield kg/ha
60	SEC 47	1250	153	SMR 143	1875
61	SEC 48	1525	154	SMR 144	1594
62	SEC 49	1250	155	SMR 145	1063
63	SEC 50	1750	156	SMR 146	813
64	SEC 51	2100	157	SMR 147	1000
65	SEC 52	1150	158	SMR 148	1000
66	SEC 53	1200	159	SMR 149	1000
67	SEC 54	1400	160	SMR 150	906
69	SEC 56	1050	162	SMR 152	2063
70	SEC 57	1950	164	SMR 153	1938
71	SEC 58	1450	165	SMR 155	1563
72	SEC 59	1250	166	SMR 156	1250
73	SEC 60	1785	167	SMR 157	1375
74	SEC 61	1950	168	SMR 158	1250
75	SEC 62	950	169	SMR 159	1286
76	SER 379	1100			
77	SER 380	900			
78	SER 381	850			
79	SER 382	600			
80	SER 383	1700			

Evaluation of families of the drought tolerant larges seed genotypes in 2015B

SN	Seed population	No. of families selected
1	PIC-008	13
2	PIC-040	17
3	PIC-012	12
4	PIC-033	13
5	PIC-009	15
6	PIC-027	12
7	PIC-101	11
8	PIC-007	12
9	PIC-004	12
10	PIC-023	12
11	PIC-036	12
12	PIC-011	12
13	PIC-105B	12
14	PIC-035	12
15	PIC-030	12
16	PIC-105A	12
17	PIC-098A	12
18	PIC-026	11
19	PIC-010	12
20	PIC-001	12
21	PIC-028	13
22	PIC-003	12
23	PIC-002	13
24	PIC-013	12

SN	Seed population	No. of families selected
25	PIC-006	6
26	PIC-017	11
27	PIC-024	6
28	PIC-005	12
29	PIC-034	12
30	PIC-038	11
31	PIC-103	12
32	PIC-029	12
33	PIC-014	12
34	PIC-031	12
35	PIC-099B	12
Total		416

Milestones

October 1, 2015 – March 31, 2016

Feed the Future Innovation Lab for Collaborative Researchon Grain Legumes

Report on the Achievement of "Milestones of Progress"

(For the Period: October 1, 2015-- March 31, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by April 1, 2016

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

	Abbreviated name of institutions																	
	MSU			UNL			NACCRI			ZARI			Institution 5			Institution 6		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Milestones by Objectives	4/1/16	Y	N *	4/1/16	Y	N *	4/1/16	Y	N *	4/1/16	Y	N *	4/1/16	Y	N *	4/1/16	Y	N *
	(Tick mark the Yes or No column for identified milestones by institution)																	
Objective 1	Integrate traditional and marker-assisted selection (MAS) approaches to combine resistances to economically important foliar diseases, drought and impro																	
1.1. Evaluation of Integrated Nursery	0			0			x	x		x	x		0			0		
1.2. Identification of resistance sources	0			0			0			x	x		0			0		
1.3. Crossing and backcrossing resistance sources	0			x	x		x	x		x	x		0			0		
1.4. Evaluation of lines for BNF	x	x		0			0			0			0			0		
1.5. Population development for genetic studies	0			0			0			0			0			0		
1.6. Screening for cooking time	x	x		0			0			0			0			0		
1.7. Canning evaluation of lines	x	x		0			0			0			0			0		
1.8. Evaluation of elite lines for cooking time bioavailability	0			x	x		0			0			0			0		
1.9 Assembling a Legume Innovation Lab nurseries for drought tolerance (andean and mesoamerican). Coordinate with t	0			x	x		x	x		x	x		0			0		
1.10 Develop protocol across MA and A and disseminate and perhaps train local researchers. Drought (terminal, intermitte	0			0			x	x		0			0			0		
1.11 Seed multiplication	0			0			x	x		0			0			0		
1.12 Site identification. BNF (sandy soils and low organic matter content)	0			0			0			0			0			0		
1.13 Field testing	0			0			x	x		x	x		0			0		
Objective 2:	Characterize pathogenic and genetic variability of isolates of foliar pathogens collected in Uganda, Zambia and identify sources of resistance to angular leaf																	
2.1. Anthracnose race characterization, screening	x	x		0			x		x	x		x	0			0		
2.2. Angular Leaf Spot characterization, screening	0			0			x	x		x		x	0			0		
2.3. Rust characterization, screening	0			x	x		x	x		x	x		0			0		
2.4. Common Bacterial Blight Screening	0			x	x		x	x		x	x		0			0		
2.5 Compile data base of past pathogen collections	0			0			x	x		x		x	0			0		
Objective 3:	Use single nucleotide polymorphism (SNP)-based genome-wide association mapping to uncover regions associated with drought tolerance, disease resista																	
3.1. SNP marker development linked to major resistance genes	x	x		0			0			0			0			0		
3.2. SNP marker associated with BNF	x	x		0			0			0			0			0		
3.3. SNP markers associated with drought	x			0			0			0			0			0		
3.4. MAS for disease screening	0			0			0			0			0			0		
3.5 Plant regional BNF and drought nurseries for genotyping	0			0			0			0			0			0		
3.6 Fingerprinting lines/populations with SNP markers	0			0			0			0			0			0		
3.7. Association mapping	x	x		0			0			0			0			0		
3.8 Farmer preference results for fast cooking bean lines	0			0			x	x		0			0			0		

cont.

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 the	**x**	**x**		**0**			**0**			**0**			**0**			**0**		
4.2 Conduct and evaluate the effectiveness of initial phenometric measurements of contrasting genotypes	**x**	**x**		**0**			**0**			**0**			**0**			**0**		
4.3 Identify differences among genotypes with contrasting responses to abiotic (heat, light, and drought) stresses.	**x**	**x**		**0**			**0**			**0**			**0**			**0**		
4.4 Evaluate and continue development of new techniques for measuring plant responses to stress, i.e., photosynthetic fluo	**x**	**x**		**0**			**0**			**0**			**0**			**0**		
4.5 Focus new methodologies on drought stress	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 5:	**Capacity Building**																	
5.1. Graduate Student training	**x**	**x**		**x**	**x**		**0**			**0**			**0**			**0**		
5.2. Short term training for colloborators and technician (SNP Markers applications)	**0**			**0**			**0**			**0**			**0**			**0**		
5.3 Short term training of graduate students/collobarators on phenometrics and bioinformatics	**0**			**0**			**0**			**0**			**0**			**0**		
5.4 Train PhD or Msc students	**0**			**0**			**0**			**0**			**0**			**0**		
5.6 Short term training for technicians/project personnel in host countries on the use of different screening protocols (drou	**0**			**x**		**x**	**0**			**x**	**x**		**0**			**0**		
Name of the PI reporting on milestones by institution	James Kelly			James Steadman, Ca			Stanley Nkalubo			Kennedy Muimui			PI name			PI name		
Name of the U.S. Lead PI submitting this Report to the MO	James Kelly																	
																	11-Apr-16	
	Signature																**Date**	

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

Explanation for achievement NOT completed by April 1- 2016

Uganda: Anthracnose screening was not initially possible because of the unfavourable screening conditions in the screnhouse, we have now set up a chamber where this will b possible

Zambia; Anthracnose and ALS characterization was not done due to the fact that the the pathologist was not available

Data for pathogen screening will be initiated for this year

UNL: Regarding training: The drought protocols were discussed by e-mail and through the meetings in Livingstone, Zambia

The rust/disease training will be conducted in 2016 in both Uganda and in Lincoln, NE.

April 1, 2016 – September 30, 2016

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: April 1, 2016 -- September 30, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2016

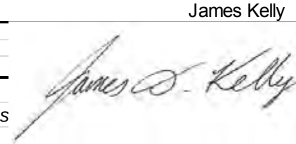
Project Title: **S01.A3 Improving Genetic Yield Potential of Andean Beans with Increased Resistances to Drought and Major Foliar**

	Abbreviated name of institutions																	
	MSU			UNL			NACCRI			ZARI			Institution 5			Institution 6		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Milestones by Objectives	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***
	(Tick mark the Yes or No column for identified milestones by institution)																	
Objective 1	**Integrate traditional and marker-assisted selection (MAS) approaches to combine resistances to economically important foliar diseases, drought**																	
1.1. Evaluation of Integrated Nursery	0			0			x	x		x	x		0			0		
1.2. Identification of resistance sources	0			x	x		x	x		x	x		0			0		
1.3. Crossing and backcrossing resistance sources	0			x	x		x	x		x	x		0			0		
1.4. Evaluation of lines for BNF	0			0			x	x		x	x		0			0		
1.5. Population development for genetic studies	0			x	x		x	x		x	x		0			0		
1.6. Screening for cooking time	x	x		0			0			0			0			0		
1.7. Canning evaluation of lines	0			0			0			0			0			0		
1.8. Evaluation of elite lines for cooking time bioavailability	x	x		0			0			0			0			0		
1.9 Assembling a Legume Innovation Lab nurseries for drought t	0			0			0			x	x		0			0		
1.10 Develop protocol across MA and A and disseminate and pe	0			0			x		x	x		x	0			0		
1.11 Seed multiplication	x	x		0			x	x		x			0			0		
1.12 Site identification. BNF (sandy soils and low organic matter	0			0			0			0			0			0		
1.13 Field testing	0			0			x			x	x		0			0		
Objective 2:	**Characterize pathogenic and genetic variability of isolates of foliar pathogens collected in Uganda, Zambia and identify sources of resistance to a**																	
2.1. Anthracnose race characterization, screening	x	x		0			x	x		x		x	0			0		
2.2. Angular Leaf Spot characterization, screening	0			0			x	x		x	x		0			0		
2.3. Rust characterization, screening	x		x	x		x	x	x		x	x		0			0		
2.4. Common Bacterial Blight Screening	x	x		x	x		x	x		x	x		0			0		
2.5 Compile data base of past pathogen collections	0			0			x	x		x		x	0			0		

cont.

Objective 3:	**Use single nucleotide polymorphism (SNP)-based genome-wide association mapping to uncover regions associated with drought tolerance, dise**																	
3.1. SNP marker development linked to major resistance genes	**x**	x		**0**			**0**			**0**			**0**			**0**		
3.2. SNP marker associated with BNF	**x**	x		**0**			**0**			**0**			**0**			**0**		
3.3. SNP markers associated with drought	**x**	x		**x**		x	**0**			**0**			**0**			**0**		
3.4. MAS for disease screening	**x**	x		**x**	x		**0**			**0**			**0**			**0**		
3.5 Plant regional BNF and drought nurseries for genotyping	**x**		x	**0**			**0**			**0**			**0**			**0**		
3.6 Fingerprinting lines/populations with SNP markers	**x**		x	**0**			**0**			**0**			**0**			**0**		
3.7. Association mapping	**x**	x		**x**		x	**0**			**0**			**0**			**0**		
3.8 Farmer preference results for fast cooking bean lines	**x**	x		**0**			**0**			**0**			**0**			**0**		
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 co	**x**	x		**0**			**0**			**0**			**0**			**0**		
4.2 Conduct and evaluate the effectiveness of initial phenometri	**x**	x		**0**			**0**			**0**			**0**			**0**		
4.3 Identify differences among genotypes with contrasting respo	**x**	x		**0**			**0**			**0**			**0**			**0**		
4.4 Evaluate and continue development of new techniques for mea	**x**	x		**0**			**0**			**0**			**0**			**0**		
4.5 Focus new methodologies on drought stress	**x**	x		**0**			**0**			**0**			**0**			**0**		
Capacity Building																		
5.1. Graduate Student training	**x**	x		**x**	x		**x**	x		**0**			**0**			**0**		
5.2. Short term training for colloborators and technician (SNP Ma	**0**			**0**			**0**			**0**			**0**			**0**		
5.3 Short term training of graduate students/collobarators on pher	**0**			**0**			**0**			**0**			**0**			**0**		
5.4 Train PhD or Msc students	**0**			**x**	x		**0**			**0**			**0**			**0**		
5.5 On-country training (BNF). Collaborate with the MA Legume	**0**			**0**			**0**			**0**			**0**			**0**		
5.6 Short term training for technicians/project personnel in host c	**0**			**x**		x	**x**	x		**0**			**0**			**0**		

Name of the PI reporting on milestones by institution	James Kelly	James Steadman, Carl	Stanley Nkalubo	Kennedy Muimui	PI name	PI name
Name of the U.S. Lead PI submitting this report to the MO	James Kelly					



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Date

** Please provide an explanation for not achieving the milestones on a s*

Performance Indicators

Indicators Overall

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. number	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	3	6	6	5	3	3	0
	Total number by sex	2	0	0	6	1	3	6	6	5	3	3	0
	Number of women	1	0	0	3	1	1	1	1	1	0	0	0
	Number of men	1	0	0	3	0	2	5	5	4	3	3	0
	Total number by New/continuing	3	0	2	3	1	3	6	6	5	3	3	0
	New	1	0	1	1	0	1	0	0	0	0	0	0
	Number of women	0	0	0	0	0	0	0	0	0	0	0	0
	Number of men	0	0	0	0	0	0	0	0	0	0	0	0
	Continuing	2	0	1	2	1	2	6	6	5	3	3	0
	Number of women	0	0	0	0	0	0	0	0	1	0	0	0
	Number of men	0	0	0	0	0	0	0	3	4	3	3	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	14	12	15	15	0
	Total number	6	0	0	12	13	28	14	14	12	15	15	0
	Number of women	3	0	0	5	6	20	5	5	7	7	7	0
	Number of men	3	0	0	7	7	8	9	9	5	8	8	0
	Numbers by Type of individual	6	0	0	12	13	28	14	14	12	15	15	0
	Producers	0	0	0	0	0	0	2	2	2	0	0	0
	Number of women	0	0	0	0	0	0	0	0	2	0	0	0
	Number of men	0	0	0	0	0	0	0	0	0	0	0	0
	People in government	6	0	0	12	13	26	10	10	8	10	10	0
	Number of women	0	0	0	0	0	0	0	0	4	5	5	0
	Number of men	0	0	0	0	0	0	0	0	4	5	5	0
	People in private sector firms	0	0	0	0	0	2	2	2	2	5	5	0
	Number of women	0	0	0	0	0	0	0	0	1	3	3	0
	Number of men	0	0	0	0	0	0	0	0	1	2	2	0
	People in civil society	0	0	0	0	0	0	0	0	0	0	0	0
	Number of women	0	0	0	0	0	0	0	0	0	0	0	0
	Number of men	0	0	0	0	0	0	0	0	0	0	0	0

cont.

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	14	16	15	15	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	3	0	0	6	0	4	8	8	9	8	8	0
	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	4	4	3	3	0
	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	2	3	4	4	0

Notes:

These indicators are developed under the Feed the Future Monitoring System. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

MSU

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:

Institution 1 Name (one sheet per institition):

Indic. number	Output Indicators	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 training	2	0	2	2	0	1	2	2	2	1	1	0
	Total number by sex	0	0	0	2	0	1	2	2	2	1	1	0
	Number of women				1		0						
	Number of men				1		1	2	2	2	1	1	
	Total number by New/continuing		0	2	2	0	1	2	2	2	1	1	0
	New	1		1	1		1						
	Number of women												
	Number of men												
	Continuing	1		1	1		0	2	2	2	1	1	
	Number of women												
	Number of men								2	2	1	1	
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	0	0	0	0	0	0	0
	Number of women												
	Number of men												
	Numbers by Type of individual									0		0	
	Producers												
	Number of women												
	Number of men												
	People in government												
	Number of women												
	Number of men												
	People in private sector firms												
	Number of women												
	Number of men												
	People in civil society												
	Number of women												
	Number of men												
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. 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, leave it blank.
There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

Uganda

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:

Institution 2 Name (one sheet per institition):

Indic. number	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 tr	0	0	0	1	0	1	3	3	2	1	1	0
	Numbers by Sex	0	0	0	2	0	1	3	3	2	1	1	0
	Number of women				1	0	0	1	1	1	0	0	
	Number of men				1	0	1	2	2	1	1	1	
	Numbers by New/Continuing	0	0	0	1	0	1	3	3	2	1	1	0
	New				0			0	0		0	0	
	Number of women												
	Number of men												
	Continuing				1		1	3	3	2	1	1	
	Number of women									1			
	Number of men									1	1	1	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Numbers by Sex	4	0	0	10	8	9	9	9	7	9	9	0
	Number of women	2			4	4	5	3	3	5	4	4	
	Number of men	2			6	4	4	6	6	2	5	5	
	Numbers by Type of individual	4	0	0	10	8	9	9	9	7	9	9	0
	Producers							2	2	2			
	Number of women									2			
	Number of men									0			
	People in government	4			10	8	7	5	5	3	4	4	
	Number of women									2	2	2	
	Number of men									1	2	2	
	People in private sector firms						2	2	2	2	5	5	
	Number of women									1	3	3	
	Number of men									1	2	2	
	People in civil society												
	Number of women												
	Number of men												
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	0	0	6	1	8	10	10	10	11	11	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	2			4		4	6	6	7	6	6	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance				2		2	2	2	2	3	3	
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance					1	2	2	2	1	2	2	

Notes:

These indicators are developed under the Feed the Future Monitoring System. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

Zambia

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:

Institution 3 Name (one sheet per instititon):

Indic. number	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 tr	1	0	0	0	1	1	1	1	1	1	1	0
	Total number by sex	2	0	0	2	1	1	1	1	1	1	1	0
	Number of women	1	0		1	1	1						
	Number of men	1	0		1	0	0	1	1	1	1	1	
	Total number by New/continuing	1	0	0	0	1	1	1	1	1	1	1	0
	New	0				0					0	0	
	Number of women												
	Number of men												
	Continuing	1				1	1	1	1	1	1	1	
	Number of women												
	Number of men								1	1	1	1	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Total number	2	0	0	2	5	19	5	5	5	6	6	0
	Number of women	1			1	2	15	2	2	2	3	3	
	Number of men	1			1	3	4	3	3	3	3	3	
	Numbers by Type of individual							5	5	5	6	6	0
	Producers												
	Number of women												
	Number of men												
	People in government	2			2	5	19	5	5	5	6	6	
	Number of women									2	3	3	
	Number of men									3	3	3	
	People in private sector firms												
	Number of women												
	Number of men												
	People in civil society												
	Number of women												
	Number of men												
7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	1	0	0	2	0	0	4	4	6	4	4	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	1			2			2	2	2	2	2	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance							2	2	2			
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance									2	2	2	

Notes:

These indicators are developed under the Feed the Future Monitoring System. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

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 (SO1.A4)

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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. The small red cultivar 'Paraisito Mejorado 2- Don Rey' with excellent seed type, disease resistance and abiotic stress tolerance was released in Honduras. Seed of multiple disease resistant black bean cultivar 'XRAV-40-4' and red mottled bean breeding line PR0737-1 was multiplied in Haiti. 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. The yellow bean germplasm line PR1146-138 with BGYMV, BCMV and leafhopper resistance was released. The bruchid, BCMV and BCMNV resistant red kidney germplasm AO-1012-29-3-3A was also formally 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. Novel 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). Tepary adaptation trials have been conducted in Honduras, Nicaragua, El Salvador, Tanzania and Burkina Faso. Molecular markers of the *I* gene that confers resistance to BCMV and the *Ur-3* and *Ur-11* genes for resistance to rust have been developed and are being used for indirect selection for resistance. GWAS enabled fine mapping of the recessive *bc-1*^{2} gene and discovery of the genomic location for the *bc-u* gene for resistance to BCMV and BCMNV. GWAS was also used to identify new genes and QTL for halo blight resistance on chromosomes Pv04, Pv05 and Pv10. When data from the alpha-amylase inhibitor (AAI) amplification was analyzed, it was discovered that the products

differed by 45bp, and that the polymorphism was completely diagnostic between bean lines known to be susceptible and resistant to the common bean weevil. A workshop dealing with abiotic stress was offered to bean researchers from Central America and Haiti at the University of Puerto Rico. Héctor Martínez from Guatemala, Carl Didier Joseph from Haiti and Iveth Rodríguez from Honduras are pursing M.S. degrees at the UPR and Carlos Maldonado from Guatemala and Lucy Lund from the U.S. are receiving M.S. degree training at NDSU. Several B.S. degree students have opportunities to work with the bean research program at Zamorano.

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 Feed the Future 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 Mexico, 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. Collaborative research supported by the Feed the Future Legume Innovation Laboratory has 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 Feed the Future 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 year. This Feed the Future 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 multi-year 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 Feed the Future 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 Feed the Future 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 BGYMV. Evaluations have been 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 continues 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. Ninety three genotypes from the BASE 120 trial were screened against a *Macrophomina phaseolina* isolate from Juana Diaz, Puerto Rico (Mp-JD). Six of the 93 genotypes evaluated had low disease severity. 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 bean. In addition to pyramiding these traits within tepary, interspecific crosses with common bean are being used as a long-term effort to introgress these traits into tepary bean. This effort represents the first systematic attempt to genetically improve cultivated tepary bean.

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, 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 Feed the Future 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 and the *Bgp-1* gene for resistance to pod deformation in the presence of GYMV. Dr. Phil McClean and Dr. Phil Miklas have 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.

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 Feed the Future 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 have focused 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 Feed the Future 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 Feed the Future 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, ashy stem blight, web blight, efficiency for biological nitrogen fixation and high temperatures. Testing sites have been chosen to produce reliable results for screening for specific traits.

In collaboration with Bioversity International and CATIE, more than 2000 trials using the methodology of "massive participatory evaluation" were evaluated by farmers in the Trifinio region (borders of Guatemala, El Salvador and Honduras) which is part of the Central American "dry corridor". Another 1000 trials were conducted in the departments of Matagalpa and Jinotepe in Nicaragua. The small red and black lines included in these trials were developed by the project in collaboration with national bean research institutions.

Table 1. Bean trials distributed to Central American and Caribbean Bean Research Network collaborators during 2015-2016.

Trial name	Small red	Small black	Countries
Regional bean adaptation nursery (VIDAC)	42 entries + 2 checks	55 entries + 2 checks	7
Regional yield and adaptation trial (ECAR)	14 entries + 2 checks	14 entries + 2 checks	7
Regional Rojo de Seda Nursery (VIROS)	22 entries + 3 checks	--	3
Bean variety validation trial (COVA)	9 entries + 1 check	9 entries + 1 check	4
Regional angular leaf spot trial (ERMAN)	10 entries + 2 checks		5
Regional web blight trial (ERMUS)	14 entries + 2 checks		5
Biofortified bean trial (AGROSALUD)	8 entries + 2 checks		6
Regional BNF trial (ERFBN)	8 entries + 2 checks		3
Regional high temperature trial (ERSAT)	20 entries + 4 checks		6
Regional drought trial	22 entries + 2 checks		6

(ERSEQ)		
Regional low fertility trial (ERBAF)	22 entries + 2 checks	5

Greater tolerance to abiotic stress
Although disease resistance is the primary focus of this Feed the Future Legume Innovation Lab 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 were 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 were inoculated with efficient *Rhizobium* strains to allow indirect selection for enhanced BNF. Several S01.A4 Co-Principal Investigators also participate in the Feed the Future Innovation Lab for Climate Resilient Beans. This extends the range of environments that promising bean lines can be screened for adaptation to abiotic stress. Results from the BASE 120 trials conducted at Isabela, Puerto Rico identified the black bean cultivar XRAV-40-4 to have among the best root nodulation scores.

Bruchid resistance
Red kidney bean breeding lines developed by Dr. Paul Kusolwa (Sokoine University of Agriculture) and Dr. Jim Myers (Oregon State University) were screened in Puerto Rico for bruchid and virus (BCMV and BCMNV) resistance. One of the bruchid and virus resistant lines, AO-1012-29-3-3A, was formally released (Kusolwa et al., 2016). Dr. Kusolwa has used AO-1012-29-3-3A as a progenitor to transfer BCMV and BCMNV ($I + bc\text{-}1^2$) resistance into breeding lines for Tanzania. The same line has been used to introgress resistance to bruchids into different commercial seed types (black, small red, red mottled, light red kidney). A laboratory screening technique developed at the University of Puerto Rico was used to screen the RILs for bruchid resistance. A QTL analysis will be used at NDSU to explore the genetic basis of resistance to weevil derived from a cross with AO-1012-29-3. The effectiveness of using molecular markers for traits (null phaseolin, arcelin 2 and APA locus) associated with bruchid resistance is also under evaluation. During the past year, Dr. Rosas conducted a seed increase in Honduras of two black bean breeding lines that combine bruchid and virus resistance. There should be sufficient seed to conduct on-farm trials during the second growing season of 2016 to test the effectiveness of bruchid resistance with seed storage methods normally utilized by farmers.

Evaluation of bean diversity panels and identification of new sources of disease resistance
The Middle American (MDP) and Andean Diversity (ADP) panels have been 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 it was screened in Honduras and Puerto Rico for angular leaf spot. Performance of the Middle American Diversity Panel has been evaluated in low N environments in Central America and in Puerto Rico in 2016. The Middle American Diversity Panel has been screened in Puerto Rico for resistance to ashy stem blight. A screenhouse trial was planted in Juana Diaz, PR, to evaluate the reaction of the trial BASE 120 to the Macrophomina phaseolina isolate Mph-JD2. A suspension of inoculum of the pathogen was applied at the base of the bean plants. Disease severity was assessed at maturity based on the

CIAT (1-9) scale and stem microsclerotia colonization. Lines that showed resistance to Mph-JD2 were BAT 477, BIOF 2-106, SB-754, SER 78, SXB-405, SJC 730-79.

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 has been to incorporate newly identified resistance in tepary accessions into the ARS-TARS tepary breeding program, and to initiate the introgression of virus resistance from common bean into tepary bean. Advanced breeding lines developed from these and 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 Tepary Diversity Panel (TDP) and breeding lines selected for disease and abiotic stress tolerance. These breeding lines were initially tested through a shuttle breeding program with M. Brick at Colorado State University. This effort has focused 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. TDP accessions with higher efficiency for biological nitrogen fixation (BNF) were also identified in the thesis work of Ana Vargas. In 2016, over 10 accessions were identified in the Tepary Diversity Panel (TDP) with resistance to the NL3 strain of BCMNV. These 10 accessions are being tested against strains representing different pathogroups of BCMV and BCMNV at Prosser, WA to evaluate for broad resistance. Previously, TDP lines with tolerance to BGYMV and to ALS were identified in Honduras. Resistance to these diseases and BNF efficiency is being pyramided in the breeding program through a separate approach involving the generation of bulk breeding populations (bulked up to the F4 generation). These bulk breeding populations are currently undergoing selection of individual plants under both biotic and abiotic stress in Honduras and Puerto Rico in 2016. By project end (FY17) we expect to have tepary breeding lines with disease resistance loci for further pyramiding in future efforts. Superior lines have been included in the TAT and tested in the host countries including Burkina Faso, Tanzania, Angola, Honduras, Haiti, and the U.S. for potential future release. Through collaboration with the FtF-ARS Legumes Project, the TDP has been genotyped using GBS, the diversity of tepary analyzed, and the nutritional composition of tepary compared to common bean in a recent publication, thus providing valuable information for current and future breeding efforts.

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

This project has leveraged 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. SCAR markers 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-1*^{2})
- Bean rust (Ur-3, Ur-4, Ur-5, Ur-11)
- Common bacterial blight (SAP-6, Xa11.4, Pv07-QTL)

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 Feed the Future 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.
- InDel marker selection. 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. Feed the Future 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 have been conducted to enhance the capacity of host country bean research programs to develop and release superior-performing bean cultivars that 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 was provided during FY16 at NDSU for Feed the Future Legume Innovation Laboratory scientists and graduate students 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 Puerto Rico in August 2016 to train technical personnel from Central America and the Caribbean concerning bean research related to abiotic stress. Topics included research related to breeding for greater resistance to drought and high temperature and greater tolerance to soils having low soil fertility. Participants had the opportunity to observe research plots in Isabela and Juana Diaz Substations and evaluate genotypes grown in sterile sand for nodulation in selected for early nodulation. This workshop was conducted in collaboration with the Feed the Future (FtF) Innovation Lab for Climate Resilient Beans and the FtF USDA-ARS Bean Research Team. The workshop presentations will be posted on the FtF USDA-ARS Bean Research Team Web Site.
- 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 Feed the Future 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.

Major Achievements

Development, testing and release of improved bean cultivars

- The BGYMV, BCMV and BCMNV resistant black bean line MEN2201-64ML was released in Honduras as ‘Lenca Precoz’. This early maturity line has also performed well in drought-prone regions of Haiti. During the upcoming year, seed of MEN2201-64ML will be distributed to farmers in Central America and Haiti.
- 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 was 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. Phil Miklas found XRAV-40-4 to

be well adapted to the Western U.S. bean production region and may be a candidate for release as an early maturity cultivar. There is interest among Western U.S. seed producers to market high-quality bean seed in Central America and the Caribbean.

- The small red line MIB 397-72 was released in Honduras as the biofortified bean cultivar “Honduras Nutritivo”. The original MIB 397 line was developed at CIAT and tested in Central America as part of the regional project Agrosalud. The line MIB 397-72 is a selection for resistance to BGYMV using field testing and SCAR markers. This cultivar contains 25% more iron than traditional small red cultivars.
- The small red line RS 901-6 developed by Zamorano was released in collaboration with INTA in Nicaragua as the cultivar “INTA Jinotega”. This cultivar was selected for resistance to BGYMV, earliness and “Rojo de Seda” commercial grain type.
- 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 regional nursery will be distributed by Dr. Juan Carlos Rosas to collaborators in Central America and the Caribbean.
- 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 ensure that progeny from these crosses will also have multiple virus resistance. F5 black bean lines with good agronomic type were selected from these populations. These lines were 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.
- 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. 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. A manuscript describing the release of PR1146-138 was published in the J. Plant Reg (Beaver et al., 2016). Yellow bean breeding lines that combine resistance to BGYMV, BCMV and BCMNV have been developed

- 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. These lines were 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. Because Durango race beans have performed well in Eastern Africa, the pinto lines were sent to Dr. Phil Miklas for evaluation in Tanzania. The pinto lines had high levels of disease resistance and good seed yield potential when tested in Mbeya, 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 and other promising lines from the UPR were sent to Mr. Isaac Dramadri for evaluation in Uganda and Dr. Kelvin Kamfwa for evaluation in Zambia. Miklas sent a BCMNV resistant Kablanketi breeding line to Dr. Kamfwa in Zambia.
- 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 less 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 BGYMV resistant 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 additional sources 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.
- 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 virulence of Phaeoisariopis griseola isolate ALS-9029-JD2 from Juana Diaz, PR and isolate ALS-900-ISAD from Isabela, PR was determined by inoculating 76 bean lines of the BASE 120 trial in two different screenhouse trials. The only bean genotypes resistant to both isolates were G-21212 and SER 125 with disease severity scores below 3 and no synnemata emerging after 24 hours of leaf incubation under humid chamber conditions. Moderate resistant lines to the same isolate were ALS 0532-6, TARS HT-1, TARS MST-1, BNF 1205-31, RCB 593, SEF 14, SEF 15, PR1418-15, PR0806-81, NCB 280, SER 16, FNB 1210-48, SER 118, PR1165-3, SB 747, SB 757 and BFS 29. Important sources of resistance for the two isolates from Juana Diaz and Isabela in Puerto Rico were identified.

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 Feed the Future Legume Innovation Lab project will support the on-farm testing of MEN-2201-64ML in Haiti and 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. This line has been recently released in Honduras as the cultivar ‘Lenca Precoz’.
- The small red bean breeding line IBC-301-204, selected at Zamorano for resistance to BGYMV, BCMV and tolerance to low fertility, was released in Nicaragua as ‘INTA Centro Sur’.
- The small red bean breeding line RS 901-6, selected at Zamorano for earliness, resistance to BGYMV, BCMV and tolerance to drought and the highly preferred “Rojo de Seda” commercial grain type, was recently released in Nicaragua as the cultivar ‘Rojo Jinotega’.
- The small red bean breeding line SJC 730-79, selected at Zamorano for resistance to BGYMV, BCMV and tolerance to drought and high temperatures was 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) strains.

- Many of the best performing entries in BASE 120 trials conducted in low N soils at Isabela, Puerto Rico are breeding lines and cultivars developed by S01.A4 project breeding program. Most of these lines also possess resistance to BGYMV and BCMV.

Bruchid resistance

- Rojo' backcross lines selected in collaboration with Paul Kulsolwa at Sokoine University and Jim Myers at Oregon State University 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 was released as improved germplasm (Kusolwa et al., 2016).
- The 'Rojo' backcross lines were used as parents to develop Andean and Middle American lines with bruchid resistance. Black, red and white 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 have been evaluated for adaptation and for resistance to local eco-types of bruchids. A Zamorano student evaluated lines selected in Puerto Rico for bruchid resistance. The lines were infested with a Honduran ecotype of Zabrotes subfasciatus (the Mexican bean weevil) and found to be resistant. ICTA researchers confirmed the resistance of lines from Puerto Rico after screening with two ecotypes of A. obtectus and one ecotype of Zabrotes subfasciatus from Guatemala. These results 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 post-harvest losses in Central America and the Caribbean.
- 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.
- The low frequency of F4 breeding lines with high levels of resistance to weevils (< 10%) in several different populations suggests that, in addition to the complex APA locus, there are other genetic factors associated with resistance to the common bean weevil. The UPR obtained from Dr. Kelvin Kamfwa a recombinant inbred line (RIL) population that segregated for resistance to bruchids. The RILs are derived from the cross between 'Solwezi', a bean landrace variety from Zambia, and AO-1012-29-3, a breeding line with resistance to common bean weevil. During the past year, we phenotyped the RILs for reaction to bruchids. Dr. Kamfwa conducted a QTL analysis for bruchid resistance and found significant QTL peaks on chromosomes Pv04 and Pv10.

- The ICTA bean research program has generated several populations from crosses between sources of resistance to bruchid and major diseases. Seed of two bruchid resistant black beans has been increased at Zamorano. This seed will be used to evaluate the bruchid resistance of these lines using seed storage practices of Honduran farmers.

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 plant 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 of differential genotypes for Macrophomina phaseolina (Mp), a screenhouse trial was established to evaluate the response of common bean, tepary and interspecific (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.
- The Haitian landrace lima bean variety 'Beseba' expressed a high level of resistance to BGYMV in trials conducted at Zamorano. This allows this lima bean to be planted near common bean without risking the spread of BGYMV.

Genetic Improvement of Tepary Beans

- Tepary bean breeding lines are being 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 accessions from the TDP that show necrotic and resistant reactions when inoculated with the NL-3 isolate of BCMNV. This resistant reaction was confirmed with ELISA for over 10 genotypes. BCMV and BCMNV are currently major constraints to tepary bean production.
- Recombinant Inbred Line (RIL) populations were developed and evaluated to identify genes and molecular markers for BCMV 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, Tanzania and Burkhina Faso. A set of eight tepary lines will be evaluated in Guatemala "dry corridor" by 100 farmers in collaboration with Bioversity International and CATIE under the methodology massive participatory evaluation.

- Through the USDA-FtF project and a USDA Postdoc, the Tepary Diversity Panel (TDP) composed of 314 accessions was developed and genotyped with SNP markers using GBS. This represents the first comprehensive genotyping of all currently available tepary accessions between the USDA and CIAT collections. This panel has been evaluated for a number of different traits including agronomic traits in the field under abiotic stress, and CBB, BNF, and response to NL3 inoculation. QTL on chromosomes 1 and 11 of tepary bean (using common bean as the reference genome) were found for resistance to BCMNV.
    - 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 non-inoculated 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 nodulate 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 based 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 bean 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 compared 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.

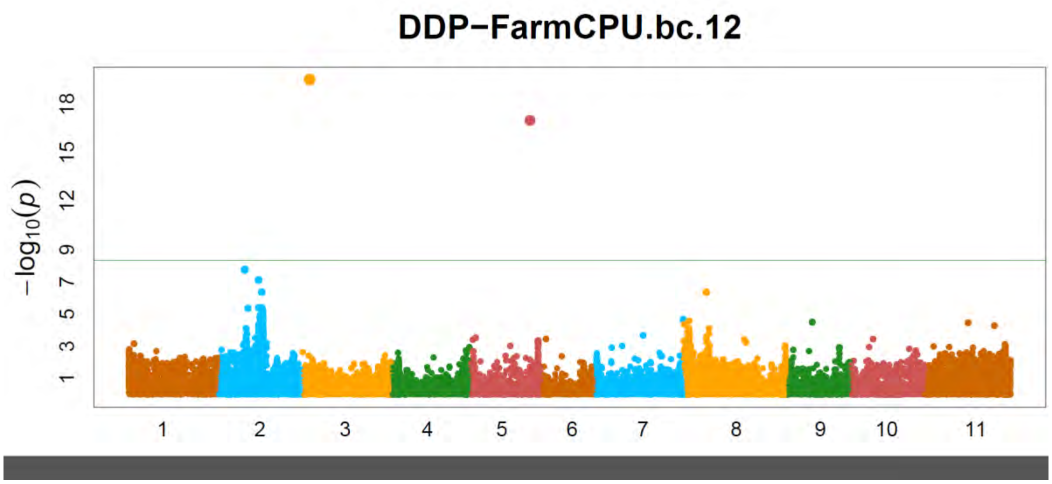
- A collaborative tepary bean genome sequencing effort is being formed with HudsonAlpha, NDSU, Michigan State Univ., and USDA-ARS. The goal of this effort would be to produce the first reference genome of Phaseolus acutifolius. This should lead to a better understanding of the genetic basis of factors that allow tepary beans to be more tolerant to abiotic stresses such as heat and drought.

<u>Development of molecular markers for traits of economic importance</u>

BCMV, halo blight and BGYMV resistance

New SNP-based markers for MAS of the *I* gene that confers resistance to BCMV have been developed and are being used for indirect selection for this resistance in our breeding program and by CIAT. Meanwhile a candidate gene for *I* has been identified. Primers spanning the genomic region containing this gene are being used to sequence the gene in resistance and susceptible lines in order to develop gene-based markers and to provide the molecular tools for eventual cloning of the gene. For GWAS, more than 1000 lines representing three diversity panels – Andean, Durango, and Snap bean, were phenotyped for reaction to NL-3 strain to detect presence of the *I* gene and were genotyped with available SNP data sets possessing approximately 25,000 (Porch lab), two million (McClean lab), and 30,000 (Porch/Hart lab) SNPs, respectively. The Durango and Snap bean diversity panels were also screened with NL-8 strain. The GWAS for 200 Durango lines with reaction to both NL-3 and NL-8 strains of BCMNV with 2 million SNPs enabled fine mapping of the recessive *bc-1*^{2} gene and discovery of the genomic location for the *bc-u* gene. The GWAS peak for *bc-1*^{2} is located between two candidate genes which are being sequenced for more in depth analysis. This finding of the *bc-u* gene was unexpected and supports the power that GWAS analyses can have for detecting and fine mapping epistatic genes. SNP-based markers for detection of *bc-u* have been developed but await generation of F_2 populations and F_3 progeny tests for validation. The *bc-u* gene can be critical because it is required for expression of *bc-1*^{2}, *bc-2*^{2}, and *bc-3* genes in the absence of the *I* gene. Being able to detect the *bc-u* gene with markers enables more precise characterization and genotyping of resistance to BCMV and BCMNV and will facilitate mapping and development of markers for the elusive *bc-2*^{2} locus. For example presence of *bc-u* as detected by these SNP-based markers seems to enhance the resistance response of *I* + *bc-1*^{2} materials to the NL-3 strain of BCMNV.

Figure 1. Manhattan plot detecting *bc-1*^{2} and *bc-u* genes.



A global collaboration (S01.A4; ARC-South Africa; Warwick University, UK; and Starke Ayres Seed Company) was sparked by a presentation by Andy Tock, a Ph.D. candidate from University of Warwick, Wellesbourne, UK, at the PanAfrican Legume conference in Zambia. His presented results on mapping halo bacterial blight resistance to Race 6 complimented our unpublished results. Together these collaborative results encompassing linkage mapping in four RIL populations and GWAS of 400 ADP lines in the field have revealed new genes and QTL for halo blight resistance on chromosomes Pv04, Pv05 and Pv10. SNP-based markers are in development and have been requested by CIAT recently to address a critical need for deploying halo blight resistance in Ethiopia.

The presence of the 5398 SNP chip enables rapid development of linkage maps with dense marker coverage for QTL discovery. We are revisiting an old RIL population Dorado/XAN 176 from UPR-breeding program (1992) that was sparsely populated with RAPD markers but nonetheless was used to discover and generate markers for the SAP6 QTL for common bacterial blight resistance and the SW12 QTL for resistance to BGYMV resistance. Both resistance-linked RAPD markers were converted to SCAR markers and have been widely used for MAS. The SW12 marker has been used widely by CIAT, the UPR, Zamorano and other programs for breeding beans resistant to BGYMV. The Dorado/XAN 176 RIL population has been submitted for SNP genotyping in order to develop a denser linkage map to contribute to ongoing efforts by S01.A4 and CIAT researchers to develop more tightly-linked breeder-friendly markers for these two QTL. A better marker for SW12 QTL is considered a critical need for breeding for high levels of resistance to BGYMV because of recent severe outbreaks of the disease in Central America. 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. Individual F_5 plants were selected at Zamorano for normal and deformed pods. $F_{5:6}$ plant rows will be screened for BGYMV resistance during the upcoming growing season. The data will be used by Dr. Phil McClean at NDSU to identify a molecular marker for this important gene for resistance to BGYMV.

Bruchid resistance

A collaborative breeding effort among Paul Kulsolwa (SUA, Tanzania), Dr. Jim Myers (Oregon

State University) and Dr. Jim Beaver (University of Puerto Rico) resulted in the development of breeding lines in which the arcelin (ARC or ARL)-phytohemagluttin (PHA)-alpha-amylase inhibitor (AAI) locus (collectively known as the APA locus) from tepary accession G40199 was introduced. This locus is presumed to be the source of bruchid resistance and results in significantly reduced seed storage damage by the common and Mexican bean weevil. A molecular analysis of these lines and the tepary source of resistance was initiated by Ms. Lucy Lund, a graduate student of Dr. Phil McClean (North Dakota State University). A series of primers were designed across the three genes within the APA locus. The goal was to search for any molecular difference that distinguished the resistant from susceptible lines. Seed of the RIL population from Dr. Kelvin Kamfwa that was screened in Puerto Rico for resistance to bruchids was sent to Dr. Phil McClean to identify candidate markers for resistance genes.

When data from the AAI amplification was analyzed, it was discovered that the products differed by 45bp, and that the polymorphism was completely diagnostic between the resistance source, the resistant lines, the two susceptible recipient lines and two susceptible checks. That difference is depicted in Figure 1. Sequence analysis of the PCR products revealed that the 45bp difference resulted in the deletion of the lectin domain, a domain that is common to many LegB genes.

Figure 1. Amplification of common bean genotypes with primers designed to the alpha-amylase gene from the APA locus. The first four lanes are the Middle American resistant lines PR1464-1 and PR1464-6 and the Andean resistant lines AO1012-29-3-1A and AO1012-29-3A. The next four susceptible lines are XRAV-40-4 and Rojo, the recipient parents, and Verano, and Badillo, two standard susceptible checks. The last lane is line G19833, the genotype used to develop the common bean reference genome sequence. The upper band is 275bp and the lower band is 230bp.

Multiple clones from the fragment generated by amplifying each of the resistant lines were sequenced to determine if the original source of resistance contained a single or multiple copies of the AAI gene. From that analysis it was determined that at least two copies of the gene existed for each line, and that each copy had unique sequence signatures. Additionally, the two copies were separated (at the amino acid sequence) using neighbor-joining phylogenetic tree analysis. That tree is show in Figure 2.

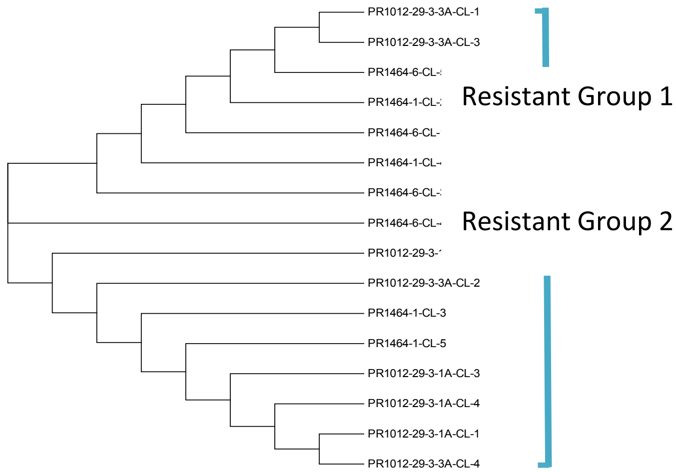


Figure 2. Neighbor-joining tree based on the amino acid sequence data for the four bruchid resistant lines developed by introgressing the resistant phenotype from tepary bean G40199. Two distinct groups of sequences are noted.

Given that the arcelin, and not the alpha-amylase locus, it is thought to be the causative protein associated with resistance, a sequence analysis of multiple clones of arcelin-specific amplification products was performed. This study focused on the four resistant lines, the tepary source, and other tepary lines. To date all of the sequence data has been collected and is now being analyzed. A few early analyses have been performed. First, the common bean genome consists of multiple LegB genes, genes with the lectin domain such as the members of the APA locus. One question of concern was the APA genes distinct from the other LegB proteins, and the answer from the neighbor-joining phylogenetic analysis is yes, the form a unique cluster distinct from the members of the APA locus. That is noted in Figure 3. Also observed was that the arcelin sequences were distinctly different from the phytohemagluttin (PHA) and alpha-amylase inhibitor (AAI) proteins, which together formed a cluster among themselves. Furthermore, the arcelin sequence data formed two distinct clusters. Sequence analysis demonstrated that the tepary donor G40199 contains two distinct classes of arcelin sequences, two sequences that are indeed related (because of their relationship to only each other, and not to the other lectin containing genes). What is yet to be determined if these two clusters actually map in the same vicinity in the genome of the tepary source, and thus also in the recipients from the introgression effort.

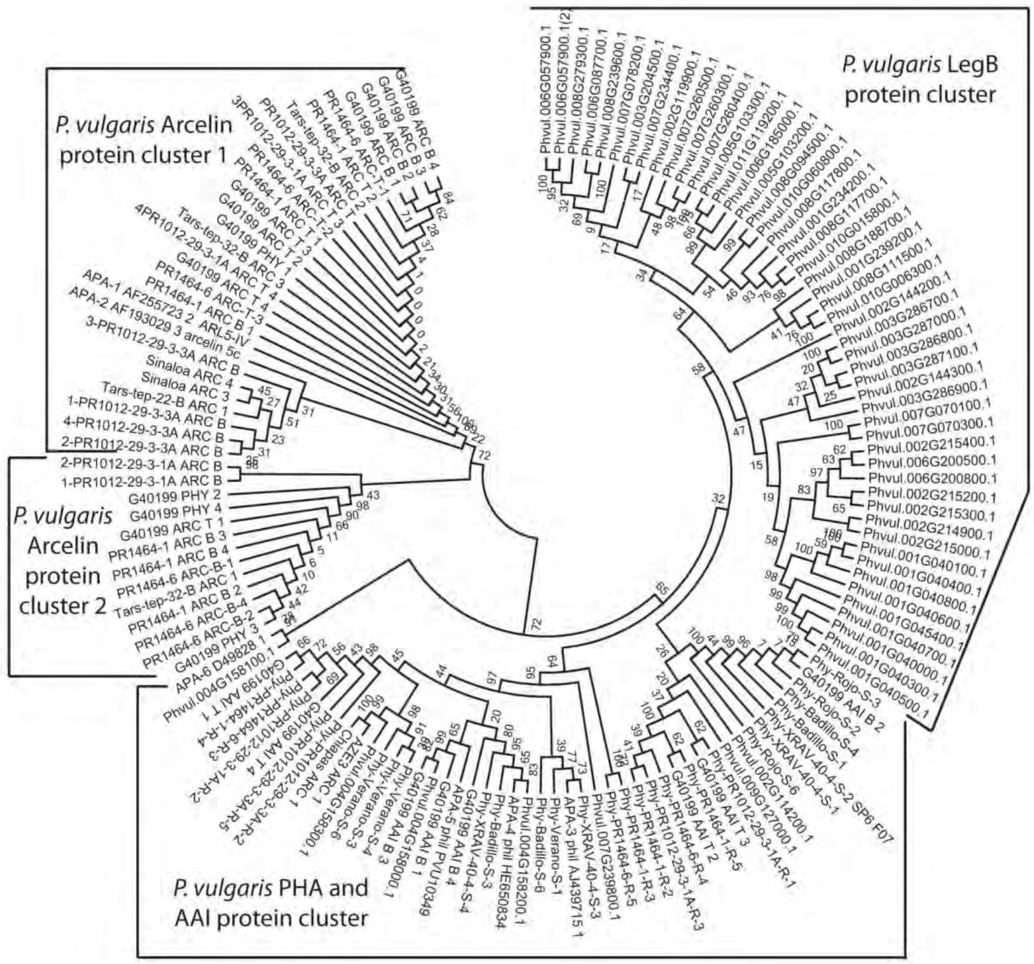


Figure 3. Neighbor-joining tree of *P. vulgaris* arcelin, PHA, AAI, and other lectin containing proteins, and *P. acutifolius* arcelin proteins

Bean rust resistance

At the distal end of chromosome Pv11 of common bean, a large cluster of coiled-coil, nucleotide-binding site, leucine-rich (CNL) repeat genes (n~50) is located. CNL regions have been discovered to act as dominant resistance genes in many species. In addition, many resistance specificities are located at this locus. Principal among those are the bean rust resistance gene *Ur-3*, *Ur-6*, and *Ur-11*. Because of their importance, developing highly functionally molecular markers linked to these loci has been a goal for years. Dr. McClean's group, along with Dr. Phil Miklas (USDA/ARS, Prosser WA) and Dr. Talo Pastor Corrales (USDA/ARS, Beltsville) have collaborated on a molecular marker development effort.

Dr. Pastor Corrales screened 301 members of the Middle American Diversity Panel (MDP) to assess their response against bean rust races that can discover *Ur-3* and *Ur-11* specificity. Previously, Dr. McClean's group had placed the Ur-3 resistance gene in the vicinity of 47 Mb on Pv11. In addition, a group of 5 indel markers were noted to co-segregate with Ur-3 resistance in 24 genotypes. This year the MDP was scored for those markers. That data is found in table 1.

Table 1. Genetic analysis of the MDP and UI 114 x C-20 F_2 population with indel markers associated with the *Ur-3* resistance locus of common bean. The MDP data represents the number of mismatches out of 301 lines with percentage mismatches in parentheses. The F_2 data represents the number of recombinants in a population of 811 individuals.

Indel marker position (bp) on Pv11	# MDP mismatches	# F_2 recombinants
46,961,210	18 (6%)	0
46,981,156	10 (3%)	0
46,985,504	10 (3%)	unknown
47,016,881	13 (4%)	2
47,768,400	31 (10%)	9

The data clearly places *Ur-3* at the proximal end of these markers. Importantly, two markers at 46,981,156 bp and 46,985,504 bp have a very high (but not perfect) diagnostic ability. They are certainly worthy of implementation in breeding programs once, the allelic state of the parents in a cross have been determined. Additional work is underway at this time to further map additional indel markers that are proximal of the marker at 46,961,210. The goal is to discover a marker that shows recombinants in the F2 population. This result will place *Ur-3* is a definitive interval from which a candidate gene can be discovered.

Similar efforts are underway, but not as advanced, for *Ur-6* and *Ur-11*. For *Ur-6*, a F_2 population of ~2000 individual is ready for screening with race 47 (uncovers the *Ur-6* resistance specificity). Additionally, the MDP will be screened also in the next year and a similar analysis will be performed. For *Ur-11*, 30 F1 plants are being grown and F2 seeds will be harvested. That F2 population will be challenged with the appropriate bean rust race to score for the *Ur-11* resistance specificity. That data will be coupled with a molecular screening for the 5 indel markers discovered this year to be closely associated with *Ur-11*. These markers were discovered by scoring the MDP and looking for markers with only a few mismatches. That data is presented in table2. The table shows that we have two perfect markers that can be immediately implemented for the screening for the *Ur-11* resistance locus in common bean.

Table 2. Genetic analysis of the MDP with indel markers associated with the *Ur-11* resistance locus of common bean. The MDP data represents the number of mismatches out of 301 lines with % mismatches in parentheses.

Indel marker position (bp) on Pv11	# MDP mismatches	# F_2 recombinants
47,956,000	4 (1%)	0
48,242,933	0 (0%)	0
48,356,332	2 (0.6%)	unknown
48,414,723	0 (0%)	2
48,459,800	3 (1%)	9

Importantly, we have now placed to very important resistance specificities in very close proximity of each other. The *Ur-3* locus maps to the 11b cluster of CNL genes on Pv11, while the *Ur-11* locus maps to the 11e cluster. With further mapping of this locus, using the same approach described here, other resistance specificities can be fine-mapped and very functional markers with a high-degree of reliability can be developed.

The better more tightly linked markers for the *Ur-3* and *Ur-11* rust resistance genes developed to date by S01.A4 (NDSU) and ARS (Beltsville) are being used for MAS and characterization of advanced breeding lines. These markers are easier to assay and more diagnostic than the previous RAPD based markers, and are expected to have worldwide utility for detection of the genes across market classes and breeding programs. New dry bean cultivar releases for University Idaho and Colorado State University, and some multiple disease resistant germplasm within S01.A4 breeding materials were more effectively characterized for rust resistance using these new markers.

Research Capacity Strengthening

Feed the Future Legume Innovation Lab plant breeders assist bean research programs in Guatemala and Haiti to develop the capacity to develop 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 numerous populations having different breeding objectives 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 used funds 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 Feed the Future Legume Innovation Lab and CIAT scientists to meet with bean researchers to plan collaboration for the upcoming year. During the past year, the project collaborated with INTA to commemorate the International Year of the Pulse at the PCCMCA meeting in Costa Rica. Dr. Porch made an invited presentation entitled "Técnicas para desarrollar frijol con mayor resistencia al cambio climático" at a plenary session of the PCCMCA.

This Feed the Future Legume Innovation Lab project continues to collaborate with many CRSP alumni institutions. This collaboration extends the potential impact of Feed the Future 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:

- Andean bean lines with multiple virus resistance sent to Kelvin Kamfwa in Zambia and Mr. Isaac Dramadri in Uganda.
- Bruchid resistance research with Paul Kusolwa at Sokoine Agricultural Univ. in Tanzania.
- Evaluation of red mottled and black bean breeding lines by IDIAF collaborators 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 and Tanzania.
- Rhizobium Inoculant production in Haiti.

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	Abiotic stress research techniques[1]
Type of training	Workshop
Countries benefiting	Costa Rica, El Salvador, Nicaragua, Honduras, Guatemala, Haiti
Location and dates of training	Puerto Rico August 2016
Number receiving training (by gender)	3 F, 14 M
Host institution(s)	University of Puerto Rico
Institution providing training	Zamorano, UPR, USDA-ARS

[1] Workshop co-sponsored by the USAID Climate Resilient Beans project.

Degree Training

Table 3. Summary of graduate degree training of Legume Innovation Lab project S01.A4 during FY16.

Name of trainee	Héctor Martínez	Iveth Rodríguez	Diego Rodríguez	Didier Joseph	Ana Vargas	Bernardo Mateo	Carlos Maldonado	Lucy Lund
Country of citizenship	Guatemala	Honduras	Ecuador	Haiti	Nicaragua	Dom. Rep.	Guatemala	U.S.
Gender	M	F	M	M	F	M	M	F
H.C. institution	ICTA	Zamorano	INIAP	NSS	None	None	ICTA	None
Training institution	UPR	UPR	UPR	UPR	UPR	UPR	NDSU	NDSU
Supervising CRSP PI	J.S. Beaver	T,G. Porch	C. Estevez	J.S. Beaver	T.G. Porch	J.S. Beaver	Juan Osorno	Phil McClean
Degree program	M.S.	M.S.	M.S.	M.S.	M.S.	M.S.	M.S.	M.S.
Field or discipline	Plant breeding	Plant breeding	Plant breeding	Plant Pathology	Plant breeding	Plant breeding	Plant breeding	Plant genomics
Research project title	Web blight resistance	Drought-heat tolerance	ALS resistance	Bean seed quality	Tepary bean breeding	Bruchid resistance	Resistance to anthracnose	Mol. genetics res. to bruchids
Start date	Aug. 2015	Aug. 2015	Aug. 2015	Jan. 2016	Aug. 2014	Aug. 2015	Aug. 2015	July 2015
Completion date	Jul. 2017	Jul. 2017	Jul. 2017	Dec. 2017	May 2016	May 2016	Dec. 2017	June 2017
Particip	Yes	Yes	No	Yes	No	No	Yes	No

Name of trainee	Héctor Martínez	Iveth Rodríguez	Diego Rodríguez	Didier Joseph	Ana Vargas	Bernardo Mateo	Carlos Maldonado	Lucy Lund
ant trainee and registered on TraiNet?								

Table 4. Summary of undergraduate degree training of Legume Innovation Lab project S01.A4 during FY16.

Name of trainee	Sara Salgado	Priscila Campos	Jorge Chanaluisa	Klever Arroba	Segundo Gavilanes	Belky Cabana	Enrique Zevallos	Elisa Solis	María Besilla	Katya Rivera	Daniel Daza	Andrés Rosas
Country of citizenship	Ecuador		Ecuador	Ecuador	Ecuador	Peru	Peru	Guatemala	Ecuador	Honduras	Ecuador	Ecuador
Gender	F	F	M	M	M	M	M	F	M	F	M	
H.C. institution	None	None	None	None	None	None	None	None	None	None	None	None
Training institution	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano
Supervising CRSP PI	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas
Degree program	B.S.	B.S.	B.S.	B.S.	B.S.	B.S.	B.S.	B.S.	B.S.	B.S.	B.S.	B.S.
Field or discipline	Agronomy	Agronomy	Agronomy	Agronomy	Agronomy	Agronomy	Agronomy	Agronomy	Agronomy	Agronomy	Agronomy	Agronomy

Research project title	ALS resistance	Web blight Resistance	Web blight resistance	BGYMV resistance	BGYMV resistance	Low fertility tolerance	Low fertility tolerance	Low fertility tolerance	Low fertility tolerance	Heat tolerance	Rhizobium	Rhizobium
Start date	Jan. 2016	Jan. 2016	Jan. 2016	Jan. 2016	Jan. 2016	Jan. 2016	Jan. 2016	Jan. 2016	Jan. 2016	Jan. 2016	Jan. 2016	Jan. 2016
Completion date	Nov. 2016	Nov. 2016	Nov. 2016	Nov. 2016	Nov. 2016	Nov. 2016	Nov. 2016	Nov. 2016	Nov. 2016	Nov. 2016	Nov. 2016	Nov. 2016
Participant trainee and registered on TraiNet?	No	No	No	No	No	No	No	No	No	No	No	No

Name of trainee	Ivan Alarcon	Kevin Burgos	Fatima Avaroma	Fatima Arteaga	Edhinson Espinoza
Country of citizenship	Ecuador	Ecuador	Bolivia	El Salvador	Ecuador
Gender	M	M	F	F	M
H.C. institution	None	None	None	None	None
Training institution	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano
Supervising CRSP PI	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas
Degree program	B.S.	B.S.	B.S.	B.S.	B.S.
Field or discipline	Agronomy	Agronomy	Agronomy	Agronomy	Agronomy
Research project title	Drought tolerance	Drought tolerance	Bruchid resistance in tepary	Bruchid resistance in tepary	BNF
Start date	Jan. 2016	Jan. 2016	Jan. 2016	Jan. 2016	Jan. 2016
Completion date	Nov. 2016	Nov. 2016	Nov. 2016	Nov. 2016	Nov. 2016
Participant trainee and registered on TraiNet?	No	No	No	No	No

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.

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 Feed the Future 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. 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 and ICTA/Guatemala, and UPR to 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 MAS Frijol project coordinated by MSU in collaboration with Technoserve and DICTA in Honduras. In addition, Zamorano trained a technician and provided *Rhizobium* strains and peat to DICTA´s lab supported by this project.

Haiti

During the summer of 2016, 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 2016. The NGOs Zanmi Agrikol and Hands Together produced seed of DPC-40 during 2016. This seed was sold to small-scale farmers in the Central Plateau and Gonaives.

Explanation for Changes

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 past year, Zamorano and other bean research programs in Central America needed to increase the production of basic seed to replenish stocks for the 2016 growing seasons.

Self-Evaluation and Lessons-Learned

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

The bruchid collection at the Isabela Substation was infested with what appears to be mites. In addition to reducing the ability of the bruchids to reproduce, the mites cause technical personnel working with the bruchids to have an unpleasant itching sensation. We plan to establish a new colony of bruchids.

During the past year, leafhopper (*Empoasca krameri*) infestations were observed in black bean trials at Jutiapa and San Jerónimo, Guatemala and Damien, Haiti. Resistance to this pest needs to be included as a breeding objective, especially for beans produced under dry conditions.

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. Prophete, G. Démosthène, and T.G. Porch. 2016. Registration of PR1146-138 Yellow Bean Germplasm Line. J. Plant Registrations. 10:145-148.

Beaver J.S., González, A., Mateo, B., Rosas, J.C., Trukhina, Y., and Porch T.G. 2016. Development of black bean lines that combine bruchid and multiple virus resistance. Poster presented at the 2016 PanAfrican Grain Legume and World Cowpea Conference held in Livingstone, Zambia from 28 February to 4 March 2016.

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.

De Ron, A.M., Papa, R., Bitocchi, E., González, A.M., Debouck, D.G., Brick, M.A., Fourie, D., Marsolais, F., Beaver, J., Geffroy, V., McClean, P., Santalla, M., Lozano, R. Yuste-Lisbona, F.J. and P.A. Casquero. 2015. Common bean. P. 1-36. *In* Handbook of Plant Breeding: Grain Legumes. Springer-Verlag, New York.

Estevez de Jensen, C., T.G. Porch, J. Colley, O. Gonzalez, Timothy Porch and J.S Beaver. 2016. Virulence of *Macrophomina phaseolina* isolates in common bean (*Phaseolus vulgaris*) genotypes. Poster presented at the 2016 PanAfrican Grain Legume and World Cowpea Conference held in Livingstone, Zambia from 28 February to 4 March 2016.

Estevez de Jensen. 2016. Reacción de las líneas del BASE 120 a la mancha angular en Puerto Rico. Poster presented at the 2016 Annual Meeting of the PCCMCA held in San José, Costa Rica from 5 to 7 May 2016.

Estevez de Jensen, C., Rodriguez, D., T.G. Porch and J.S. Beaver. 2016. Reaction of the BASE 120 Lines to angular leaf spot in Puerto Rico. Poster presented at the 2016 PanAfrican Grain Legume and World Cowpea Conference held in Livingstone, Zambia from 28 February to 4 March 2016

Humphries, S., J.C. Rosas, M. Cerna, J. Jiménez, F. Sierra, O. Gallardo, C. Avila y M. Barahona. 2015. Synergies at the interface of farmer-scientific partnerships: Agricultural innovation through participatory research and plant breeding in Honduras. Agriculture and Food Security 4:27. 17p.

Humphries, S., J.C. Rosas y M. Gomez. 2016. A farmer-NGO-scientist synergy. Farming Matters, The Netherlands, 32(1):14-16.

Hart, J., A.G Vargas, M.A. Brick, J. Burridge, J.S. Beaver and T.G. Porch .2016. Genome-wide association studies of morphological and agronomical traits in cultivated tepary beans (*Phaseolus acutifolius*). Poster presented at the 2016 PanAfrican Grain Legume and World Cowpea Conference held in Livingstone, Zambia from 28 February to 4 March 2016.

Kusolwa P.M, J.R. Myers, T.G. Porch, Y. Trukhina, A. González-Vélez and J.S. Beaver. 2016 Registration of AO-1012-29-3-3A red kidney bean germplasm line with bean weevil, BCMV, and BCMNV Resistance. Journal of Plant Registrations 10:149-153.

Lorenzo Vázquez, G., A. González, C. Estévez de Jensen, T.G. Porch and J.S. Beaver. 2016. Evaluación en Puerto Rico líneas del ensayo BASE 120 para adaptación al estrés abiótico. Paper presented at the 2016 Annual Meeting of the PCCMCA held in San José, Costa Rica from 5 to 7 May 2016.

Mateo, B. 2016. Selección de líneas de frijol que combinan resistencia al gorgojo común con resistencia a los virus BGYMV, BCMV y BCMNV. M.S. Thesis, University of Puerto Rico, Mayaguez, Puerto Rico.

Mateo, B., Beaver J.S., González A., Trukhina Y., and T.G. Porch. 2016. Desarrollo de líneas de frijol que combinan resistencia a los gorgojos y múltiples virus. Poster presented at the 2016 Annual Meeting of the PCCMCA held in San José, Costa Rica from 5 to 7 May 2016.

Rodriguez, D., T.G. Porch and J.S. Beaver. 2016. Reaction of the BASE 120 Lines to angular leaf spot in Puerto Rico. Poster presented at the 2016 PanAfrican Grain Legume and World Cowpea Conference held in Livingstone, Zambia from 28 February to 4 March 2016.

Porch, T.G. 2016. Técnicas para desarrollar frijol con mayor resistencia al cambio climático. Paper presented at the 2016 Annual Meeting of the PCCMCA held in San José, Costa Rica from 5 to 7 May 2016.

Porch, T. G., K. Cichy, W. Wang, D., M. Brick, J. S. Beaver, D. Santana-Morant, and M. Grusak. 2016. Nutritional composition and cooking characteristics of tepary bean (Phaseolus acutifolius Gray) in comparison with common bean (Phaseolus vulgaris L.). Genetic Resources and Crop Evolution doi:10.1007/s10722-016-0413-0

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Prophete, E.H., G. Demosthene, J.S. Beaver, J.C. Rosas and T.G. Porch 2016. Breeding black beans for Haiti with multiple virus resistance. Poster presented at the 2016 PanAfrican Grain Legume and World Cowpea Conference held in Livingstone, Zambia from 28 February to 4 March 2016.

Rosas, J.C., J.S. Beaver, T.G. Porch, S.E. Beebe, J.D. Burridge and J.P. Lynch. 2016. Evaluation of common bean lines for adaptation to high temperatures in Honduras. Poster presented at the 2016 PanAfrican Grain Legume and World Cowpea Conference held in Livingstone, Zambia from 28 February to 4 March 2016.

Rosas, J.C. 2016. Resultados del SISTIVER 2015 de la red de frijol de Centroamérica y el Caribe. Paper presented at the 2016 Annual Meeting of the PCCMCA held in San José, Costa Rica from 5 to 7 May 2016.

Rosas, J.C. 2016. Evaluaciones de líneas de frijol tolerantes a las altas temperaturas en Honduras. Paper presented at the 2016 Annual Meeting of the PCCMCA held in San José, Costa Rica from 5 to 7 May 2016.

Rosas, J.C. 2016. Adaptación de frijol a suelos deficientes en nitrógeno mediante el mejoramiento de la nodulación. Paper presented at the 2016 Annual Meeting of the PCCMCA held in San José, Costa Rica from 5 to 7 May 2016.

Winham, D.M., A.E. Bries, M.B. Reddy, K.A. Cichy, T.G. Porch and M.A. Brick. 2016. White tepary bean shows higher in vitro iron bioavailability than brown tepary or common bean. Paper presented at the 2016 PanAfrican Grain Legume and World Cowpea Conference held in Livingstone, Zambia from 28 February to 4 March 2016.

Valentín Torres, S., M.M. Vargas, G. Godoy-Lutz, T.G. Porch, and J.S. Beaver. 2016. Isolates of *Rhizoctonia solani* can produce both Web Blight and Root Rot Symptoms in Common Bean (*Phaseolus vulgaris* L.). Plant Disease 100:1351-1357.

Vargas, A.G. 2016. Estudio de la reacción al Virus del Mosaico Necrótico Común del Frijol (BCNMV) y la habilidad de fijación biológica del nitrógeno (FBN) en frijol tépari (*Phaseolus acutifolius* A. Gray) e introgresión de la FBN al frijol común (*Phaseolus vulgaris* L.). M.S. Thesis. University of Puerto Rico, Mayaguez, Puerto Rico.

Vargas, A.G., J. Hart, C. Estevez de Jensen, J. Beaver. 2016 Evaluation of the tepary bean (*Phaseolus acutifolius*) diversity panel for response to the NL 3 Strain of Bean Common Mosaic Necrosis Virus (BCMNV) and for biological nitrogen fixation with *Bradyrhizobium* strains. Presentation made at the 2016 PanAfrican Grain Legume and World Cowpea Conference held in Livingstone, Zambia from 28 February to 4 March 2016.

Professional Recognition

James Beaver received a certificate of recognition from the House of Representatives of the Commonwealth of Puerto Rico for contributions to local agriculture.

Data Management

A revised data management plan was submitted to the Feed the Future Legume Innovation Laboratory Management Office in July 2016. Scientists interested in using a data set generated with support from the Feed the Future 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 deposit the information in the USAID Development Data Library (DDL).

Milestones

October 1, 2015 – March 31, 2016

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Report on the Achievement of "Milestones of Progress"

(For the Period: October 1, 2014 -- March 31, 2015)

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

Project Title: 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.

	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	**4/1/16**	**Y**	**N***	**4/1/16**	**Y**	**N***	**4/1/16**	**Y**	**N***	**4/1/16**	**Y**	**N***	**4/1/16**	**Y**	**N***	**4/1/16**	**Y**	**N***	**4/1/16**	**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							
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							
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											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							
1.6 Support the development of bean breeding populations in Guatemala and Haiti with the goal of releasing a locally-produced cultivar by the end of the five-year extension period.										X	X		X								
1.7 Test the performance of bruchid resistant lines when exposed to natural infestation	X						X	X													

cont.

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												
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	X	X						
2.4																					
2.5																					
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
3.2 Investigate efficacy of available markers for bruchid resistance genes (Arc2, Arl3, PHA and aAl3).		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																					

cont.

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 A workshop will be held in Honduras in December 2014 to train technical personnel concerning bean research techniques with the goal of improving the quality of field research.								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 will be completed at the UPR of Ana Vargas (Nicaragua).		X	X																		
4.5 M.S. degree training at NDSU of two bean researchers from Central America or the Caribbean																	X	X			
Name of the PI reporting on milestones 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

April 1, 2016 – September 30, 2016

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, 2014

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	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**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		
1.2 Multiply and maintain breeder and foundation seed stocks of recently-released bean cultivars	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								
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		
1.5 Evaluate pathogen variability and resistance to angular leaf spot, powdery mildew and web blight.	X			X			X			X			X								
1.6 Support the development of bean breeding populations in Guatemala and Haiti with the goal of releasing a locally-produced cultivar by the end of the five-year extension period.										X			X								
1.7 Test the performance of bruchid resistant lines when exposed to natural infestation	X						X						X								

cont.

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.																					
2.2 The CIAT tepary bean germplasm collection will be evaluated for BGYMV in Honduras.																					
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3.4 Evaluate the genetics of web blight resistance through conducting association mapping analysis																					
3.5																					

cont.

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.							
4.2 A workshop will be held in Honduras in December 2014 to train technical personnel concerning bean research techniques with the goal of improving the quality of field research.							
4.3 Undergraduate students at Zamorano will be provided opportunities to participate in bean research activities related to Legume Innovation Lab project objectives.							
4.4 M.S. degree training will be completed at the UPR of Ana Vargas (Nicaragua).							
4.5 M.S. degree training at NDSU of two bean researchers from Central America or the Caribbean							
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**

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

Performance Indicators

Indicators Overall

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	21	18	22	0
	Total number by sex	7	8	13	10	10	12	13	13	0
	Number of women	3	3	2	2	2	6	6	6	0
	Number of men	4	5	11	8	8	6	7	7	0
	Total number by New/continuing	7	8	13	10	10	12	13	13	0
	New	5	6	13	7	7	9	9	9	0
	Number of women			0	0	0	4	4	4	0
	Number of men			0	0	0	5	5	5	0
	Continuing	2	2	0	3	3	3	4	4	0
	Number of women			0	0	0	2	2	2	0
	Number of men			0	0	0	1	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	65	65	63	73	84	72	71	71	0
	Total number	65	65	63	73	84	72	71	71	0
	Number of women	21	21	15	29	34	16	32	28	0
	Number of men	44	44	48	44	50	56	39	43	0
	Numbers by Type of individual	65	65	63	73	74	72	71	71	0
	Producers	30	30	17	37	41	26	43	43	0
	Number of women			0	0	2	5	7	7	0
	Number of men			0	0	6	21	21	36	0
	People in government	23	23	37	24	23	36	17	17	0
	Number of women			0	3	6	9	5	5	0
	Number of men			0	4	13	27	12	12	0
	People in private sector firms	12	12	9	12	10	10	11	11	0
	Number of women			0	1	2	2	3	3	0
	Number of men			0	4	8	8	8	8	0
	People in civil society	0	0	0	0	0	0	0	0	0
	Number of women			0	0	0	0	0	0	0
	Number of men			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	124	124	125	118	119	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	65	65	84	67	67	67	67	68	0
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	37	37	42	39	39	39	33	33	0
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	17	17	17	22	22	23	23	23	0

Notes:

These indicators are developed under the Feed the Future Monitoring System. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

UPR

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

Institution: UPR

Indic. number	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) Degree Training: Number of individuals who have received degree training	2	2	2	3	3	4	3	3	0
	Total number by sex	2	2	2	3	3	3	3	3	
	Female	1	1	1	1	1	1	1	1	
	Male	1	1	1	2	2	2	2	2	
	Total number by New/continuing	2	2	2	3	3	3	3	3	0
	New	0	0	2	1	1	1	0	0	
	Number of women									
	Number of men						1			
	Continuing	2	2	0	2	2	2	3	3	
	Number of women						1	1	1	
	Number of men						1	2	2	

cont.

2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training									
	Total number by sex[1]	4	4	4	4	4	17	4	4	0
	Women	2	2	2	2	2	3	2	2	
	Men	2	2	2	2	2	14	2	2	
	Numbers by Type of individual	4	4	4	4	4	17	4	4	0
	Producers	0	0	0	0			0	0	
	Number of women									
	Number of men									
	People in government	4	4	4	4	4	17	4	4	
	Number of women						3	1	1	
	Number of men						14	3	3	
	People in private sector firms	0	0	0	0			0	0	
	Number of women									
	Number of men									
	People in civil society	0	0	0	0		0	0	0	
	Number of women						0		0	
	Number of men						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)	18	18	18	20	20	21	22	22	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	7	7	7	7	7	7	7	7	0
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	7	7	7	8	8	8	9	9	0
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	4	4	4	5	5	6	6	6	0

Notes:

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collection sheet under the FTFMS system. Where an indicator does not

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[1] Abiotic stress workshop held in Puerto Rico in August 2016 in collaboration with the CRIB project.

USDA-ARS-TARS

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

Name: USDA-ARS-TARS

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) Degree Training: Number of individuals who have received degree tr	0	0	0	0	0	0	0	0	0
	Numbers by Sex	0	0	0	0	0	0	0	0	0
	Female	**0**	**0**	0						
	Male	**0**	**0**	0						
	Numbers by New/Continuing			0	0	0	0	0	0	0
	New									
	Number of women									
	Number of men									
	Continuing									
	Number of women									
	Number of men									
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training									
	Numbers by Sex	0	0	0	0	0	0	0	0	0
	Women	0	0	0						
	Men	0	0	0						
	Numbers by Type of individual	0	0	0	0	0	0	0	0	0
	Producers									
	Number of women									
	Number of men									
	People in government									
	Number of women									
	Number of men									
	People in private sector firms									
	Number of women									
	Number of men									
	People in civil society									
	Number of women									
	Number of men									

cont.

7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	14	14	13	6	6	6	6	7	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	7	7	6	2	2	2	2	3	0
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	4	4	4	2	2	2	2	2	0
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	3	3	3	2	2	2	2	2	0

Notes:

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NDSU

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

Name: NDSU

Indic. number	Output Indicators	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	1	1	1	1	1	1	3	3	0
	Total number by sex	1	1	1	1	1	1	2	2	0
	Female	0	0				1	1	1	
	Male	1	1	1	1	1	0	1	1	
	Total number by New/continuing	1	1	1	1	1	1	2	2	0
	New	1	1	1			0	1	1	
	Number of women						0	0	0	
	Number of men						0	1	1	
	Continuing				1	1	1	1	1	
	Number of women					0	1	1	1	
	Number of men					0	0	0	0	

cont.

2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training									
	Total number	2	2	0	0	7	7	1	1	0
	Number of women	1	1	0		3	3	1	1	
	Number of men	1	1	0		4	4	0	0	
	Numbers by Type of individual	2	2	0	0	7	7	1	1	0
	Producers					0	0	0	0	0
	Number of women									
	Number of men									
	People in government	2	2			7	7	1	1	0
	Number of women				3	3	3	1	1	
	Number of men				4	4	4			
	People in private sector firms					0				
	Number of women									
	Number of men									
	People in civil society					0				
	Number of women									
	Number of men									
7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	3	3	3	9	9	9	10	10	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	3	3	3	4	4	4	5	5	0
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	0	0	0	3	3	3	3	3	0
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	0	0	0	2	2	2	2	2	0

Notes:

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Zamorano

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

Name: Zamorano

Indic. number	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) Degree Training: Number of individuals who have received degree tr	4	5	9	6	6	16	12	16	
	Total number by sex	4	5	9	6	6	8	8	8	
	Female	2	2	1	1	1	4	4	4	
	Male	2	3	8	5	5	4	4	4	
	Total number by New/continuing	4	5	9	6	6	8	8	8	
	New	4	5	9	6	6	8	8	8	
	Number of women						4	4	4	
	Number of men						4	4	4	
	Continuing	0	0	0	0	0	0	0	0	
	Number of women									
	Number of men									
2	term training									
	Total number	24	24	32	16	20	10	11	11	
	Number of women	8	8	4	4	6	3	4	4	
	Number of men	16	16	28	12	14	7	7	7	
	Numbers by Type of individual	24	24	32	16		10	11	11	
	Producers	10	10	2	4	8	8	8	8	
	Number of women					2	2	2	2	
	Number of men					6	6	6	6	
	People in government	10	10	26	10	2	2	2	2	
	Number of women					1	1	1	1	
	Number of men					1	1	1	1	
	People in private sector firms	4	4	4	2	0	0	1	1	
	Number of women						0	1	1	
	Number of men						0	0	0	
	People in civil society						0	0	0	
	Number of women							0	0	
	Number of men						0	0	0	

cont.

7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	50	50	75	60	60	60	50	50	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	30	30	50	40	40	40	40	40	0
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	15	15	20	15	15	15	7	7	0
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	5	5	5	5	5	5	3	3	0

Notes:

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ICTA

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

Name: ICTA

Indic. number	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) Degree Training: Number of individuals who have received degree tr	0	0	1	0	0	0	0	0	0
	Total number by sex	0	0	1	0	0	0	0	0	0
	Women									
	Men			1						
	Total number by New/continuing	0	0	1	0	0	0	0	0	0
	New			1						
	Number of women									
	Number of men									
	Continuing									
	Number of women									
	Number of men									

cont.

2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training									
	Total number	20	20	7	30	30	15	30	30	0
	Number of women	5	5	4	15	15	3	15	15	
	Number of men	15	15	3	15	15	12	15	15	
	Numbers by Type of individual	20	20	7	30	30	15	30	30	0
	Producers	10	10		15	15		15	15	
	Number of women									
	Number of men								15	
	People in government	7	7	7	10	10	10	10	10	
	Number of women					2	2	2	2	
	Number of men					8	8	8	8	
	People in private sector firms	3	3		5	5	5	5	5	
	Number of women					1	1	1	1	
	Number of men					4	4	4	4	
	People in civil society									
	Number of women									
	Number of men									
7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	12	12	12	10	10	10	10	10	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	8	8	8	5	5	5	5	5	0
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	3	3	3	3	3	3	3	3	0
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	1	1	1	2	2	2	2	2	0

Notes:

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NSS-Haiti

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: NSS-Haiti

Name: NSS-Haiti

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) Degree Training: Number of individuals who have received degree tr	0	0	0	0	0	0	0	0	0
	Total number by sex	0	0	0	0	0	0	0	0	0
	Women									
	Men									
	Total number by New/continuing	0	0	0	0	0	0	0	0	0
	New									
	Number of women									
	Number of men									
	Continuing									
	Number of women									
	Number of men									
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training									
	Total number	15	15	20	23	23	23	25	25	0
	Number of women	5	5	5	8	8	4	10	6	
	Number of men	10	10	15	15	15	19	15	19	
	Numbers by Type of individual	15	15	20	23	23	23	25	25	0
	Producers	10	10	15	18	18	18	20	20	
	Number of women						3	5	5	
	Number of men						15	15	15	
	People in government									
	Number of women									
	Number of men									
	People in private sector firms	5	5	5	5	5	5	5	5	
	Number of women				1	1	1	1	1	
	Number of men				4	4	4	4	4	
	People in civil society									
	Number of women									
	Number of men									

cont.

7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	18	18	18	19	19	19	20	20	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	7	7	7	7	7	7	7	7	0
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	7	7	7	7	7	7	7	7	0
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	4	4	4	5	5	5	6	6	0

Notes:
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USDA-ARS-Prosser

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
Name: USDA-ARS-Prosser

Indic. number	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) Degree Training: Number of individuals who have received degree tr	0	0	0	0	0	0	0	0	0
	Total number by sex	0	0	0	0	0	0	0	0	0
	Female									
	Male									
	Total number by New/continuing	0	0	0	0	0	0	0	0	0
	New									
	Number of women									
	Number of men									
	Continuing									
	Number of women									
	Number of men									

cont.

2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training									
	Total number	0	0	0	0	0	0	0	0	0
	Number of women									
	Number of men									
	Numbers by Type of individual	0	0	0	0	0	0	0	0	0
	Producers									
	Number of women									
	Number of men									
	People in government									
	Number of women									
	Number of men									
	People in private sector firms									
	Number of women									
	Number of men									
	People in civil society									
	Number of women									
	Number of men									
7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	4	4	4	4	4	4	5	5	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	3	3	3	2	2	2	1	1	0
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	1	1	1	1	1	1	2	2	0
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	0	0	0	1	1	1	2	2	0

Notes:

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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

Collaborating Host Country and U.S. PIs and Institutions
Timothy J. Close and Bao-Lam Huynh, University of California, Riverside, USA
Benoit Joseph Batieno and 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

Abstract of Research and Capacity Strengthening Achievements
Multi-location screening of a cowpea aphid resistance panel was completed using uniform test protocols to characterize resistance to aphids and to identify cowpea aphid biotypes in three African and one US locations. Differences between US and African aphid populations were found based on molecular sequence, and three independent resistance QTL were discovered. Cowpea populations segregating for resistance to pod bugs, flower thrips and (or) aphids were advanced, phenotyped and genotyped for QTL discovery for use in marker-assisted breeding across project countries. Breeder and Foundation Seed were multiplied and distributed to farmers' organizations for Certified Seed production of five recently released large white-seeded varieties in Senegal and four pre-release LIL advanced lines in Burkina Faso. In California, advanced lygus, aphid and disease resistant blackeye lines were on-farm and on-station performance tested. Thirteen African students including four women engaged in degree training programs (7 PhD, 6 MS/MPhil). A capacity strengthening award to INERA supported development of modern cowpea seed storage capability in Burkina Faso. Continuous short-term training occurred with each Host Country through iterative data analysis and interpretation cycles, a workshop in Zambia and training visits to UCR.

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 agro-ecologies 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), mid-flowering 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 segregating populations with target traits, providing valuable trait discovery and breeding resources.

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 resistant to pests would increase marketing opportunities of cowpea farmers and traders in both West Africa and the US.

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 have tested 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 2015 and the seed shared among partners. 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– 2016 in field plots or in screenhouses, with 4-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. This multi-site phenotype screening for resistance response was repeated in FY16, following additional seed increases in NARS and UCR, to provide a minimum of 2 years of data at each location.

The resistance donors and susceptible controls were SNP genotyped in FY14, coordinated by UCR. 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. The 2016 screenhouse test in Senegal revealed the following reactions: Resistant (KN1, 58-57, Kvx 295-2-124-99, CB27, INIA 19); Moderately resistant (Sarc-1-57-2); Susceptible (Apagbaala, Bambey 21, IT82E-18) (table 2). The lines IT97K-556-6, Tvu 1158 and Vita 7 did not germinate. 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, confirmed in 2016. In Burkina Faso, the seedling-stage screening of the aphid resistance panel in pots at the INERA Saria Station gave results which confirmed those obtained from previous year screening with aphid from Kamboinse and Saria. Dr. Batieno, INERA received a visit from Dr. F. Kusi, SARI, Ghana at Kamboinse and Saria in September 2016 where he helped with the aphid screening trial (Figure 7). In California, lines Kvx 295-2-124-99, INIA 19, Sarc-1-57-2, IT97K-556-6 and Tvu 1158 were resistant. A comprehensive analysis of the multi-location screening results and preparation for publication are continuing.

In testing the mode of inheritance and the genetic relatedness of these lines, F1 populations were developed between each of these lines with Apagbaala (aphid susceptible popular variety in Ghana) and the resistant lines were also crossed with each other (Figures 1 and 2). These populations were advanced to the F2 at SARI. The segregation ratio in the F2 population between IT97K556-6 and Apagbala (Resistant and Susceptible) fit a 3:1 ratio for a single dominant gene ($\chi2 = 3.26$, $P = 0.0707$). The F2 were advanced to F3 and F3 families were screened; a (1R:2H:1S) segregation ratio confirming the presence of a major gene controlling resistance. Segregation in the SARC-1-57-2 x IT97K556-6 F2 fit a 15R:1S phenotypic ratio ($\chi2 = 1.57$, $P = 0.20$) indicating two independent for aphid resistance operated in in the F2 population. The F2 resistant plants were selfed to produce the F3, which segregated into a ratio of 9 homozygous resistant, 6 segregating and 1 homozygous susceptible, indicating dominance at two loci and confirming the F2 test. Using SSR marker analysis for the SARC-1-57-2 resistance together with genomewide SNP markers, as part of Richard Agyare's SARI –UCR training we were able to map the major resistance locus from this donor to cowpea linkage group (LG) 10, using two SNP-genotypes biparental RIL populations. This finding also confirmed that the SARC-157-2 aphid resistance is distinct from that in the IT97K556-6 line, which is controlled by a major gene on LG7 and a minor gene on LG1 From this work breeders can pyramiding of different resistant genes into elite cowpea varieties.

The IT97K-556-6 source of aphid resistance was used to introgress the two resistance QTLs into two main US blackeye varieties, CB46 and CB50 by recurrent backcrossing. Linkage of resistance to pink eye color was broken and the advanced lines positive for QTL SNP marker alleles (BC5F2) were grown under aphid pressure in 2016 at the UC Kearney Research Center. The best performing lines will be multiplied in greenhouse culture this winter for expanded field performance testing in FY17.

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. Five samples were also collected in different fields in the Bambey, Senegal area. Aphid samples from SARI, Tamale, Ghana and UCR, Parlier, Fresno Co. California were used to compare old-world and new world *Aphis craccivora* by complete sequencing of their mitochondrial genomes (mitogenomes). The comparison showed only very minor differences between the sequences (99.7% identity), reflecting only very recent divergence of the old and new world forms. A joint paper for this work is in preparation. From the wild donor IITA line TVNu1158 a RIL population has been developed for mapping QTL and it was 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, during the 2016 rainy season, the RIL populations Sanzi x Vita 7; 58-77 x Yacine were planted each in two trials with flower Thrips control and no spray comparison plots. Data were obtained on number of peduncles and pods and number of Thrips in five flowers for the first population. Thrips damage rating was also obtained for both populations. The families derived from crosses of resistant (Sanzi x 58-77) and large seeded varieties (ISRA-3178 and ISRA-3217) were advanced to the F4 during the off-season and rainy saeson. The M4 generation of selected Yacine lines was also evaluated and additional selections made. Promising results were obtained for the second time after 8 months of Yacine and Melakh M4 lines tests for reaction to bruchids.

At SARI, Ghana, Dr. Kusi received seed in FY15 of the Sanzi x Vita7 and Yacine x 58-77 RIL populations from Senegal for phenotyping for flower thrips tolerance (Figure. Given the limited seeds per line received, the populations were planted to increase seeds. In FY15 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. The two RIL populations were planted in two locations during this FY16 main cropping season in Manga in the Sudan Savanna and Tamale in the Guinea Savanna. Initial data on Thrips samples showed high insect counts against some of the lines in Tamale, while the counts in Manga were low. Data from the two locations are currently being compiled and the results will be used for QTL mapping. 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 inbred populations segregating for seed color (including white) and flower thrips resistance were 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. A second parent is SARC1-57-2, which carries aphid resistance. The SARI team is phenotyping these populations using the previously described experimental protocols. 280 single-seed derived F7 families were leaf sampled and the samples sent to UCR where they were DNA-extracted and SNP genotyped 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. A total of 251 recombinant inbred lines were evaluated for Striga and flower thrips. Different reactions of cowpea RILs to Striga were found in the field and in pot experiments; 27 RILS were found resistant similar to the resistance donor IT97K-499-35, while 224 RILs were susceptible. A low number of flower thrips occurred after the flower sampling, due to the weather conditions. This made the screening for flower thrips more challenging. The level of thrips infestation was very low at the Manga station, as was found in the other populations being phenotyped, and could be due to the bad weather during the dry season. The harmattan period dry season was unusually prolonged over three months and was followed immediately by very high day and night temperatures with very low relative humidity.

In Burkina Faso, nine cowpea genotypes (TVx3236, Nafi, Tiligré, Gourgou, Komcalle, KVx165-14-1, KN-1, KVx780-1, KVx780-6) were screened for flower thrips tolerance (Figures 5 and 11). From this screening genotypes lKVx780-1 and KVx780-6 (both close to release), plus KVx165-14-1, and

TVx3236 have shown good tolerance levels to flower thrips. Nafi has shown a higher level of tolerance compared to the other released varieties (table 3 and figure 5). Crosses are being made between tolerant genotypes and released susceptible varieties and will be genotyped and phenotyped for genetic analysis and marker discovery.

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. To identify genes or QTL for resistance to pod-sucking bugs we used biparental resistant x susceptible segregating populations in Burkina Faso in FY14 and FY15 to map QTL and initiate their selection as a new breeding target. The primary resistance donor is IT86D-716. Problems with germination in these populations resulted in insufficient data sets for mapping. 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 were genotyped through LGC Genomics and the F2 and F3 populations are being phenotyped for pod bug resistance in Burkina Faso, in collaboration with Dr. Dabire. A second set of segregating materials was developed from crosses between six parents involving the resistant IT86D-716 to provide more viable populations. Leaf material from the new sets at F7 has been collected in FY16 and will be SNP genotyped during late 2016, for QTL mapping resistance to pod bugs, striga, aphids, and bruchids contained in the same population set.

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 are being 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. As described above under Objective 1.1, aphid samples from SARI, Tamale, Ghana and UCR, Parlier, Fresno Co. California were used to compare old-world and new world *Aphis craccivora* by complete sequencing of their mitochondrial genomes (mitogenomes). The comparison showed only very minor differences between the sequences (99.7% identity), reflecting only very recent divergence of the old and new world forms. A joint paper for this work is in preparation. In Burkina Faso, pod bugs were collected from Kamboinse, Pobe-Mengao and Farako-Ba. In Senegal samples were obtained for cowpea aphids in the Bambey production area.

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. Populations were advanced to the BC3F5 and BC5F3 stages and leaf samples were collected and some were SNP genotyped. 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 and SNP genotyped. A change in the Ghana BT cowpea project leadership put our part in this effort on hold during this main season. 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 and February-March 2016 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, a new version of Melakh resistant to Striga was obtained through marker-assisted selection. The selected BC4 F3 families were multiplied during the rainy season. Additional multiplication will be done during the 2017 off-season for on-farm demonstration. Also the line ISRA-3006 was multiplied which was obtained from a cross between the local variety Baye Ngagne and Mougne, both with the same seed type. This line was yield-tested earlier and had good performance with larger grain size and same color. Dr. Cisse decided to promote it as a variety because it is earlier maturing than the local variety. Preparation was made for additional seed multiplication during the upcoming off-season for on-farm demonstration during the next rainy season in 2017. The cowpea MAGIC population was multiplied during the off-season and introduced in a preliminary yield trial at the ISRA/CNRA Bambey station during the 2016 rainy season. Data were obtained on time to flowering, maturity, numbers of peduncles and pods, 100-grain weight and yield. The 5 varieties released in 2015 (Lisard, Thieye, Leona, Kelle and Sam) were again multiplied on 0.5 ha each in 2016 for additional Foundation Seed production at the Bambey station. RESOPP received Breeder Seed obtained during the off-season to multiply on 1 ha each for Foundation Seed production during the rainy season. The new version of Striga resistant Melakh and ISRA-3006 were multiplied for Breeder Seed on about 0.01 ha.

In Burkina Faso, 20 pre-release CRSP advanced lines developed by the breeding team were on-farm performance tested in 2013, and a sub-set of the best nine lines were re-evaluated in 2014. Multi-location 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 these were re-evaluated in the 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 had to be delayed due to non-project issues. Breeder seed of the best lines chosen for release submission based on main season 2014 and 2015 and off-season 2015 performance data were produced at Saria during the main season 2016 (June – October). About 20 kg of Breeder Seed of each of these lines will be available at the INERA Saria Station, and will be used to initiate Foundation Seed production in the FY17 off-season assuming lines are approved for release. Three field days were organized on these lines being readied for release (Figure 8). The First Lady of Burkina Faso paid a special visit to one of our trial sites at Gourcy, where the project team is supporting farmers for Certified Seed multiplication covering 10 ha (Figures 9 and 10).

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 2014, 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 2015 (harvested in October-November 2015) to assess commercial yield performance. Seed size and yield data from the trials are presented in Tables 4-6, 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 4), 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 4-fold 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.

Trials comparing yield and grain quality of five new blackeye breeding lines together with CB46Rk^2, CB46, and CB50 were conducted under early-planted, double-flush production conditions at the Kearney Station (table 4). Two most promising lines were evaluated together with CB46Rk^2 and CB46 in large strip plots in a Tulare County commercial blackeye field. Overall the yields were higher than in 2014. Some advanced lines had higher grain yield than CB46 at Kearney, and two lines had equivalent yield to CB46 at the Tulare Co. farmer field location (table5). Some lines also combine the advantage of stronger, broad-based resistance to root-knot nematodes and resistance to Fusarium wilt Race 4 (table4). They have seed size that is consistently the same or larger than CB46 but less than CB50. CB46Rk^2, a new version of CB46 with improved resistance to root-knot nematodes, performed best in 2015 at Kearney (table4). In 2015 three lines first selected in 2007-2009 were evaluated under insect unprotected conditions at Kearney. These lines resulted from a long-term breeding effort to combine lygus resistance with high quality grain and high production. They were selected based on their performance in similar trials conducted in 2010 to 2014. Lygus pressure was heavy but late in 2015, resulting in grain yield loss of more than 50% in the check CB46 in comparison with the protected conditions in the same field (table6). The unprotected yields were significantly higher than CB46 for two advanced lines, N2 and 07KN-74, confirming strong yield ability under lygus pressure. From the 2015 trials, we chose the most promising lines (combination of yield, seed quality and resistance) for performance testing in the 2016 main season.

Four trials were planted in May 2016 in Tulare Co. with four lines (CB46, N2, 10K-29, CB46Rk2) in large 0.5 acre field-length 6-row strips (harvested October 2015) in four different farmer fields. Trials at the UC Kearney station were planted in June 2016 with seven lines (CB46, CB46Rk2, two 10K lines and three N lines) in four-extended row 4-fold 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 which will be entering the seed multiplication and distribution process in each country. During the 2016 main rainy season in Burkina Faso new varieties were multiplied as Breeder Seed on 1.5 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 2017. Opportunities exist to initiate baseline data for the releases through the impact analyses under the LIL project led by Dr. M. Maredia.

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

Short-term Training. Short-term training of a young scientist from SARI and a member of the LIL research team, Richard Yaw Agyare took place at the UCR from March 29 to September 26, 2016. This training was made possible through the LIL SO1.A5 host country institutional capacity strengthening award to SARI. The objective was to train Richard in modern breeding techniques, to improve research output of the LIL project. Training included greenhouse, laboratory, on-station and on-farm experimentation, and molecular data processing. He made cowpea crosses, phenotyped for aphid and foliar thrips resistance, cleaned bad and non-informative SNPs, handled SNP genotypic data in both bi-parental populations and a diversity collection, constructed genetic linkage maps, applied quantitative trait loci analysis (QTL) and principal component analysis (PCA), and designed cleaved amplified polymorphic SNP (CAPS) primers using Primer 3. He also acquired skills in using computer software MST Map, QTL IciMapping, Merge Map, TASSEL, Microsoft Excel and CurlyWhirly for molecular analysis. His work at UCR found SSR marker CP171F/172R associated with aphid resistance in SARC 1-57-2 and mapped the locus to cowpea linkage group 10. This resistance to aphids in SARC 1-57-2 was found to be different from the aphid resistance loci discovered in IT97K-556-6.

Training in molecular breeding for young trainee breeders and NARS scientists was continued in FY15-16. Continuous short-term training occurred 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 continue periodic intensive training, we convened a two-day training workshop in February 2016 in Livingstone, Zambia prior to the World Cowpea Conference, using training modules developed by the UC-R team and by the CGIAR GCP Integrated Breeding Platform program (IBP) Breeding Management System (BMS). 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 field-book, leaf assay, and field phenotyping protocols.

Degree Training. We conducted degree training for two graduate students in the report period at UCR and eleven in Africa, three in Senegal, six in Ghana and two in Burkina Faso. The trainees are described in detail under Section VI 2. In Ghana, the LIL project collaborated with Innovation Lab for Climate Resilient Cowpea and the national Universities to engage five second-year M.Phil. and one Ph.D. students co-supervised on topics developed from the LIL project at SARI. Mahamat Hissene Halime completed on August 2016 her Ph.D. training at Dakar University working on improving drought adaptation through combination of different mechanisms. The RIL from the cross Mouride x IT93K-503-1 was used as the experimental population. Zida Serge Felicien, one of the Burkina team members, registered at the University of Ouagadougou for a Ph.D. and is partially supported. He will be using the UCR platform for genotyping and short time training. Coulibaly Soumabere is conducting his M.Sc. on pod sucking bug resistance in Burkina Faso.

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 multi-location field screening and screenhouse seedling screening during FY15 and FY16. 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. This has allowed differentiating biotypes, for example between Senegal and California CB27 has a resistant reaction in Senegal while susceptible in California. Reaction in Senegal and Ghana seems to highlight similar biotypes in the two zones.

Sets of F1 and F2 populations were made from aphid resistant x drought tolerant line crosses at SARI, Ghana.

F1 and F2 populations were made from aphid resistant x Striga resistant farmer-preferred variety crosses by INERA, Burkina Faso.

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.

Aphid resistance loci were genetically mapped to three different cowpea chromosomes.

The mitochondrial genomes of cowpea aphid populations from Ghana and California were completely sequenced and compared for their relatedness, in cooperation with LIL project SO1.B1.

Under Objective 1.2 – Flower thrips resistance

Segregating populations were developed in Senegal and Ghana from mutagenesis or from hand crosses using three sources of thrips resistance. These are in various stages of phenotyping and genotyping for QTL mapping. Tolerant lines were identified in Burkina Faso and crosses are planned to be made in the 2017 off-season.

Under Objective 1.3 – Pod bug resistance

A new segregating population between IT86D-716 and Nafi was developed in Burkina Faso for use in QTL mapping for pod bug resistance, and is under phenotyping and genotyping analysis.

Under Objective 2.2 – Variety releases

Formal release of five large white-seeded CRSP cowpea varieties in Senegal by ISRA was followed up with additional Breeder and Foundation Seed production of each variety and distribution to Farmers' organizations for Certified Seed development.

An improved version of Melakh with Striga resistance was developed by ISRA, Senegal and multiplied for Breeder Seed. The line ISRA-3006 with speckled black grain (Mougne type) was also multiplied for Breeder Seed and will be introduced in demonstration on-farm locations next season.

Four pre-release CRSP advanced cowpea lines were re- evaluated in multi-location tests at Saria, Pobe, and Kamboinse during the 2015 main rainy season and re-tested 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 re-scheduled for FY17. Breeder seeds of each of these lines was produced at the INERA Saria Station to initiate Foundation seed production in the FY16 off-season.

Thirteen African students (4 female, 9 male) have engaged in degree training programs within the project, including seven PhD and six Master's degree students.

The project was awarded Capacity Strengthening awards from the MSU management entity, which were used for the development of cowpea seed cold storage capability upgrade with backup generator for INERA, Burkina Faso ISRA, Senegal, and off-season field irrigation for INERA, Burkina Faso. This capacity project was completed in Summer 2016 and is now functional and offering optimal conditions for cowpea seed conservation (see Section V).

Research Capacity Strengthening

Approval through the LIL was granted to fund INERA, Burkina Faso breeding activity enhancement at Kamboinse research station by developing a seed storage cold room and to acquire a power generator to ensure access to continuous electricity for the storage of Breeder and Foundation seed by the INERA cowpea breeding program.

Human Resource and Institution Capacity Development

Short-Term Training

Please see Section III, Objective 3, for a description of the short-term training activities.

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 Legume Innovation Lab 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 Legume Innovation Lab 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 Legume Innovation Lab 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: Completed in August 2015
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Completed

Trainee 4
Name of trainee: Zida Serge Felicien
Country of Citizenship: Burkina Faso
Gender: male
Host Country Institution Benefitting from Training: Burkina Faso
Institution providing training: INERA
Supervising Legume Innovation Lab PI: Drabo and J. Batieno
Degree Program: Ph.D. University of Ouagadougou
Field or Discipline: Plant breeding
Research Project Title (if applicable): :
Start Date: 2016 (field research)
Projected Completion Date: Dec. 2019
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: KNUST, SARI and UCR
Supervising Legume Innovation Lab PI: R. Akromah (F. Kusi mentor)
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: 2014
Projected Completion Date: Dec 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Completed

Trainee 6
Name of trainee (First and Last Name): Poda Saadon Leandre
Country of Citizenship: Burkina Faso
Gender: male
Host Country Institution Benefitting from Training: INERA, Burkina Faso
Institution providing training: KNUST, SARI and UCR
Supervising Legume Innovation Lab PI: R. Akromah and F. Kusi
Degree Program: M.Phil. Plant Breeding
Field or Discipline: Plant breeding
Research Project Title: Phenotyping cowpea for Striga and flower thrips resistance in Northern Ghana
Start Date: 2014
Projected Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active

Trainee 7
Name of trainee (First and Last Name): Godfred Agyeman Duah
Country of Citizenship: Ghana
Gender: male
Host Country Institution Benefitting from Training: Ghana
Institution providing training: UDS, SARI and UCR
Supervising Legume Innovation Lab PI: N. Opoku and F. Kusi
Degree Program: M.Phil. Biotechnology
Field or Discipline: Biotechnology
Research Project Title: Genetic relatedness of the cowpea aphid resistance panel
Start Date: 2014
Projected Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No

Training Status: Active

Trainee 8
Name of trainee (First and Last Name): Mohammed Abdul Ganiu
Country of Citizenship: Ghana
Gender: male
Host Country Institution Benefitting from Training: Ghana
Institution providing training: UDS, SARI and UCR
Supervising Legume Innovation Lab PI: B. Badii and F. Kusi
Degree Program: M.Phil. Agronomy
Field or Discipline: Agronomy
Research Project Title: Evaluation of aphid resistance panel to Aphis craccivora, Koch (Homoptera: Aphididae) in Ghana
Start Date: 2014
Projected Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active

Trainee 9
Name of trainee (First and Last Name): Gloria Tetteh-Kubi
Country of Citizenship: Ghana
Gender: Female
Host Country Institution Benefitting from Training: Ghana
Institution providing training: UCC, SARI and UCR
Supervising Legume Innovation Lab PI: M. Botchey, F. Kusi and Aaron Tetteh Asare
Degree Program: Ph.D. Entomology Plant Breeding
Field or Discipline: Plant breeding
Research Project Title: Improving Field Resistance of Cowpea Genotypes to Cowpea Aphid
Start Date: 2014
Projected Completion Date: 2018
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active

Trainee 10
Name of trainee (First and Last Name): Patrick Attamah
Country of Citizenship: Ghana
Gender: Male
Host Country Institution Benefitting from Training: Ghana
Institution providing training: KNUST, SARI and UCR
Supervising Legume Innovation Lab PI: R. Akromah and F. Kusi
Degree Program: M.Phil. Plant Breeding
Field or Discipline: Plant breeding
Research Project Title: Screening and genetic analysis of drought tolerance in SARI's favorite cowpea lines

Start Date: 2014
Projected Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active

Trainee 11
Name of trainee (First and Last Name): Mouhamadou Moussa Diangar
Country of Citizenship: Senegal
Gender: Male
Host Country Institution Benefitting from Training: ISRA
Institution providing training: WACCI
Supervising Legume Innovation Lab PI: N. Cisse
Degree Program: Ph.D. Plant Breeding
Field or Discipline: Plant Breeding
Research Project Title (if applicable): : : Cowpea resistance to Striga
Start Date: January 2015
Projected Completion Date: August 2019
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active

Trainee 12
Name of trainee (First and Last Name): Mahamat Hissene Halime
Country of Citizenship: Chad
Gender: Female
Host Country Institution Benefitting from Training: ITRAD
Institution providing training: UCAD, ISRA
Supervising Legume Innovation Lab PI: N. Cisse
Degree Program: Ph.D. Biotechnology and Plant Breeding
Field or Discipline: Plant Breeding
Research Project Title: Combining different mechanisms for improved drought adaptation
Start Date: January 2012
Projected Completion Date: Completed August 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Completed

Trainee 13
Name of trainee: Coulibaly Soumabere
Country of Citizenship: Burkina Faso
Gender: male
Host Country Institution Benefitting from Training: Burkina Faso
Institution providing training: INERA
Supervising Legume Innovation Lab PI: Drabo and J. Batieno
Degree Program: M.Sc. University of Ouagadougou
Field or Discipline: Plant breeding
Research Project Title: Genetics of pod sucking bug resistance in B. Faso

Start Date: March 2016 (field research)
Projected Completion Date: March 2017
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active

Achievement of Gender Equity Goals

The project continued to give technical support to women farmer groups who are in the cowpea production systems. During the year under review two hundred farmers, about 70% women, were exposed to new improved cowpea varieties that are resistant to Striga and aphids by SARI, Ghana. They were trained in best agricultural practices suitable for cowpea production using IPM principles to reduce indiscriminate application of chemical insecticides. Also the LIL project at SARI in collaboration with University of Cape Coast engaged 220 farmers, more than 50% women, in participatory variety selection as part of the effort to develop Striga resistant varieties for the Striga endemic zone of Ghana. Also in collaboration with AGRA Inoculant project, ten FBOs in cowpea production from ten districts in the Upper East region of Ghana were educated in integrated management of insect pests of cowpea as well as other good agricultural practices. In Senegal, with the farmers' organization RESOPP and the IITA/USAID Cowpea Out-Scaling Project in West Africa (COSP) training of its members on seed production and post-harvest operations was continued. More than 200 women producers were trained in FY15-16. In Burkina Faso, 215 women producers were trained on cowpea production and seed storage and about 50 women conducted demonstration tests in FY16. In the Certified Seed production group of 58 farmers, 39 were women and 19 men. Plans were made for a training program for women on cowpea processing and finance management to be held in November 2016. The project has four female graduate student trainees embedded in the research program.

Explanation for Changes

The Ghana team is phenotyping for flower thrips resistance of the two RIL populations following seed increases at UCR. The flower thrips population densities were too low to have adequate phenotyping scores and will require repeating.

In Burkina Faso, the pod-sucking bug phenotype screening is on-going. Because of seed failures in 2014-15, additional segregating populations were generated and are being grown for phenotyping in late 2016, and in 2017. Leaf samples were sent in October 2016 to UCR for genotyping.

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 of the above activities.

Self-Evaluation and Lessons-Learned

Overall we have had a successful workplan period in 2015-16. 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, such as in Burkina with pod bug tolerant populations 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 Ghana where flower thrips 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. Re-sampling 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 planning and training meetings at UCR and in Zambia in 2016.

Scholarly Accomplishments

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. 1-9. DOI 10.1007/s00122-015-2611-0.

Roberts, P. A., Huynh, B.L., Frate, C.A. 2016. Blackeye improvement. University of California Dry Bean Research Annual Progress Report 2015. 1-8.

Burridge, J., Schneider, H. M., Bao-Lam Huynh B. L., Roberts P.A., Bucksch A., Lynch J.P. 2016. Genome-wide association mapping and agronomic impact of cowpea root architecture. Theoretical and Applied Genetics. In press.

Sinclair T.R., Manandhar A., Belko N., Riar M., Vadez V., Roberts P.A. 2015. Variation among cowpea genotypes in sensitivity of transpiration rate and symbiotic nitrogen fixation to soil drying. Crop Science 55:2270-2275.

Boukar O., Fatokun C. A., Huynh B.L., Roberts P.A., Close T.J. 2016. Genomic tools in cowpea breeding programs: status and perspectives. Frontiers in Plant Science 7:757 (pp 1-13).

Ndiaye M., Sarr M.P., Cisse N., Ndoye I. 2015. Is the recently described *Macrophomina pseudophaseolina* pathogenically different from *Macrophomina phaseolina*? African Journal of Microbiology Research 9(45):2232 -2238. DOI: 10.5897/AJMR2015.7742.

Lalsaga W.J.A., Nana R., Sawadogo M., Sawadogo N., Kiebre M., Drabo I. 2016. Field assessment of ten cowpea genotypes [*Vigna unguiculata* (L.) Walp.] for drought tolerance. International Journal of Innovation and Applied Studies 14(4):1005-1014. ISSN 2028-9324

Batieno B.J., Danquah E., Tignegre J.B., Huynh B.L., Drabo I., Close T.J., Ofori K., Roberts P.A., Ouedraogo T.J. 2016. Application of marker-assisted backcrossing to improve cowpea (*Vigna unguiculata* L. Walp) for drought tolerance. Journal of Plant Breeding and Crop Science. Accepted 10/172016.

Conference Paper Abstract (Edited) – Word Cowpea Conference

Agyeman-Duah, G., Kusi, F.,Opoku, N. 2016. Genetic Relatedness of Cowpea Aphid Resistance. Proceedings of Joint 2016 Pan African Grain Legume and World Cowpea Conference, 28 February to 4 March 2016, AVANI Victoria Falls Resort and Conference Centre Livingstone, Zambia.

Attamah, P., Akromah, R., Kusi, F.,Nyadanu, D. 2016. Screening and Genetic Studies of Drought Tolerance among SARI Favourite Cowpea Lines. Proceedings of Joint 2016 Pan African Grain Legume and World Cowpea Conference, 28 February to 4 March 2016, AVANI Victoria Falls Resort and Conference Centre Livingstone, Zambia.

Kusi, F. 2016. Participatory Integrated Pest Management for Increased Cowpea Production in Northern Ghana. Proceedings of Joint 2016 Pan African Grain Legume and World Cowpea Conference, 28 February to 4 March 2016, AVANI Victoria Falls Resort and Conference Centre Livingstone, Zambia.

Kusi, F., Padi, F. K., Obeng-Ofori, D., Sugri I., Asante, SK. 2016. Deployment of the Cowpea Aphid Resistance Gene for Cowpea Improvement in Ghana. Proceedings of Joint 2016 Pan African Grain Legume and World Cowpea Conference, 28 February to 4 March 2016, AVANI Victoria Falls Resort and Conference Centre Livingstone, Zambia.

Owusu, Y. E., Akromah, R., Kusi, F., Denwar. N. 2016. Inheritance of Extra-Early Maturity in Cowpea. Proceedings of Joint 2016 Pan African Grain Legume and World Cowpea Conference, 28 February to 4 March 2016, AVANI Victoria Falls Resort and Conference Centre Livingstone, Zambia.

Poda, L. S., Kusi, F. Akromah, R., Ouedraogo, T. J., Tignegre, J. B., Batieno. J. 2016. Genetic Mapping of Striga and Thrips Resistance in Cowpea Population in Northern Ghana. Proceedings of Joint 2016 Pan African Grain Legume and World Cowpea Conference, 28 February to 4 March 2016, AVANI Victoria Falls Resort and Conference Centre Livingstone, Zambia.

Tetteh Kubi, G., Botchey, M., Asare T. A., and Kusi, F. 2016. Improving the Field Resistance of Cowpea Genotypes to Cowpea Aphid. Proceedings of Joint 2016 Pan African Grain Legume and World Cowpea Conference, 28 February to 4 March 2016, AVANI Victoria Falls Resort and Conference Centre Livingstone, Zambia.

Student Theses (Defended)

Attaamah P. (2016). Screening and genetic analysis of drought tolerance in SARI’s favorite cowpea lines. M.Phil. Thesis, Kwame Nkrumah University of Science and Technology, 99 p.

Poda, S. L. (2016). Phenotyping for Striga gesnerioides and Megalurothrips sjostedti resistance in cowpea populations in Northern Ghana. M.Phil. Thesis, Kwame Nkrumah University of Science and Technology, 116 p.

Progress in Implementing Impact Pathway Action Plan

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 genome-wide markers and followed by ICI-mapping to identify significant QTLs. The various populations for QTL discovery are at different stages of this process and require multi-year and multi-location 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) were released in Senegal in 2015, and entered the seed development pipeline with Breeder and Foundation seed production in 2015 and 2016. In Burkina Faso, a set of four white-seed pre-release advanced lines are awaiting formal release action by the national variety release committee. Meanwhile in anticipation of release, Breeder Seed was produced by INERA in 2015 and 2016. In California, advanced breeding lines are in different advanced stages of final testing, which in 2016 included large-scale strip trial testing and warehouse processing using five different farer production fields in the San Joaquin Valley. These data will help to determine decisions on variety releases for the US blackeye cowpea market.

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
TVNu-1158	Aphid resistant source	IITA
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. Aphid resistance panel screening results, Senegal, 2016: Planting: 24/05/2016. Date of infestation: 03/06/2016. Date 1st observation: 15 06/2016. Date 2nd observation: 22/06/2016.

Genotypes	Nr plants : 6/3	Nr dead pl.: 6/15	Nr dead pl. : 6/22	Nr plants :6/22
KN - 1	6	1	1	4
58 - 77	2	0	0	2
KVx 295 - 2-124-99	6	0	1	5
Bambey 21	5	2	3	0
Apagbaala	6	3	3	0
IT 82E - 18	5	2	1	2
CB27	4	0	0	4
INIA 19	3	1	0	2
IT97K - 556 - 6	0	_		
Sarc 1 - 57 -2	5	1	2	2
TVU - 1158	0	_	_	_

Table 3. Classification of INERA cowpea varieties from Burkina Faso based on their levels of flower thrips susceptibility. 2016

Ranking	Varieties		Mean
1	KN-1		4,5222A
2	KVx165-14-1		1,6250 B
3	Komcallé		1,0000 B
4	kVx780-6		0,9524 B
5	Gourgou		0,5833 B
6	Tiligré		0,5238 B
7	Nafi		0,4167 B
8	KVx780- 1		0,4091 B
9	TVx3236		0,0500 B
R^2 0.727755	CV:75.62488	SqR.MSE =1.099156	Average #Thrips per flower =1.453431
Prob	LSD 5%	Pr > F <.0001	

Table 4. New blackeye breeding lines and checks tested at Kearney REC in 2015: 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 wilt Race 4.

Entry	Yield (lb/ac)	100-seed wt (g)	Galling M. incognita	Galling M. javanica	Galling M. incognita Muller	Fusarium Race 4 index
CB46Rk2	5218	21.8	1.0	2.7	2.9	0.0
N2	5182	21.6	1.2	1.2	3.8	0.2
N17	4951	22.1	1.1	1.2	3.1	4.8
CB46	4940	21.3	1.6	3.4	4.2	4.9
N5	4899	21.5	0.8	1.5	3.5	0.8
10K-77	4062	24.0	0.9	1.7	3.7	5.0
CB50	3995	27.0	-	-	-	0.0

10K-29	3866	22.9	2.4	2.9	4.2	0.0
Mean	4639	22.8				
CV%	14	4				
LSD(0.05)	928	1.4				

Trial planted on June 2 and cut on October 13 (133 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 5. New blackeye lines and check CB46 tested in a production field strip trial in Tulare Co. in 2015.

Entry	Total area (ac)	Seed weight (lb)	Yield (lb/ac)	100-seed wt (g)
N2	0.558	1590	2849	20.9
10K-29	0.558	1590	2849	23.2
CB46	0.558	1520	2724	21.6
CB46Rk2	0.557	1450	2603	18.8

Trial planted on May 22, cut September 25 (126 days), and machine-harvested on October 12.

Table 6. **Grain yield, 100-seed weight, and lygus grain damage of 4 advanced blackeye lines and CB46 when grown under insect-unprotected conditions at Kearney REC in 2015.**

Entry	Yield (lb/ac)	100-seed wt (g)	Lygus damage (%)
07KN-74	3276	23.0	25
N2	2698	21.8	22
CB46Rk2	2085	20.7	25
CB46	2054	20.0	36
10K-29	1952	22.3	28
Mean	2413	21.5	27
CV%	10	7	33
LSD(0.05)	387	2.3	14

Trial planted on June 2, cut on October 13 (133 days), and machine-harvested on October 27.

Figure 1. Screening of F2 population between KVX x SARC1-57-2 showing all the progenies resistant to aphids in Ghana – indicating the same gene is controlling resistance in the two parent lines.

Figure 2. Screening of an F2 population between IT99K-556-6 x SARC1-57-2 showing a ratio of 15:1 resistant and susceptible to aphids in Ghana – indicating different genes are controlling resistance in the two lines, confirmed by QTL mapping.

Figure 3. Greenhouse solar dryer using material from the LIL to facilitate drying of cowpea during the rainy season.

Figure 4. Phenotyping of cowpea GWAS lines in Ghana: Field performance evaluation for yield, screening for drought tolerance using both seed-box and field protocols for seedling-stage and terminal drought stage tolerance, repectively.


GWAS
TERMINAL DROUGHT
SCREENING
WET PLOT


GWAS
TERMINAL DROUGHT
SCREENING
DRY PLOT

Figure 5. Plot of flower thrips numbers indicating susceptibility and resistance levels. INERA, Burkina Faso, 2016.

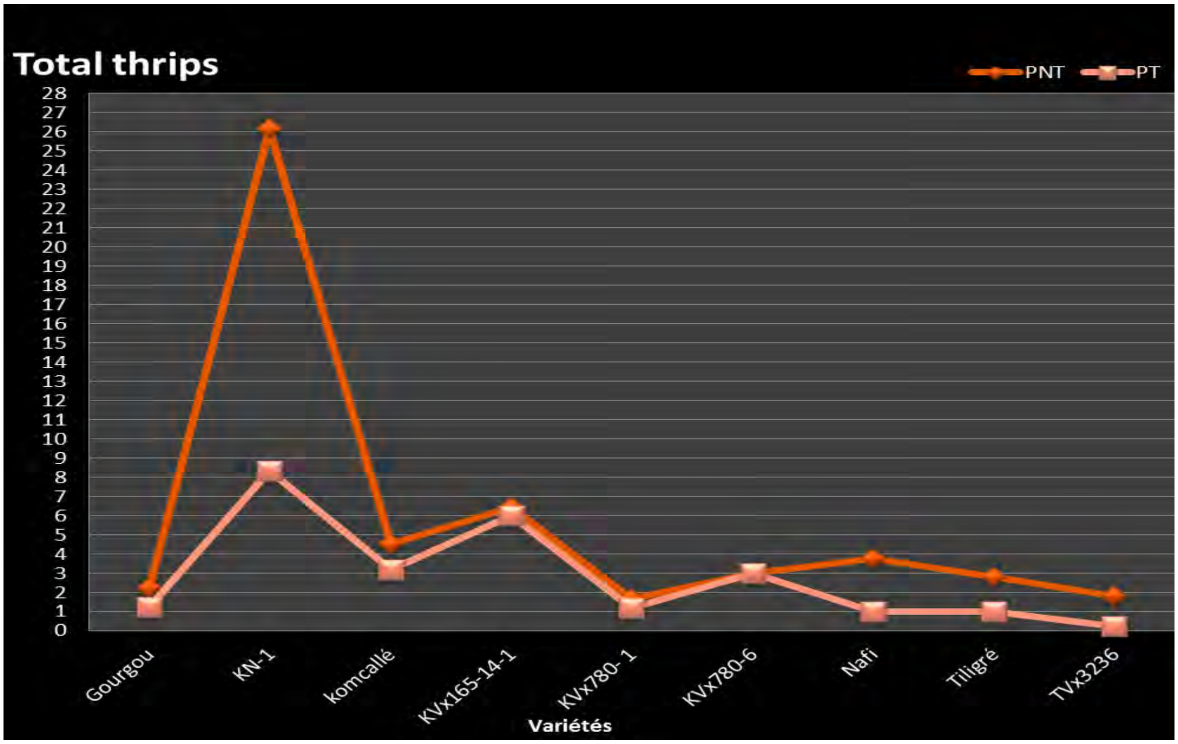

Figure 6. Dr. Kusi from SARI, Ghana visiting the INERA Saria Research Station, Koudougou for research exchange between the project NARS partners.

Figure 7. Dr. Batieno Discussing with Dr. Kusi from SARI, Ghana on the aphid trial at the INERA Saria Research Station, Koudougou, Burkina Faso.

Figure 8. Farmer field day to review LIL-INERA cowpea breeding plots at Pobé-Mengao, October 2016.

Figure 9. INERA-hosted field visit for the Burkina Faso First Lady to review the 10-ha cowpea Certified Seed production plot at Gourcy, Burkina Faso, 2016.

Figure 10. Burkina Faso First Lady receiving explanation by LIL HC PI Dr. Batieno on the 10-ha cowpea Certified Seed production, Gourcy, B. Faso, 2016.

Figure 11. Flower Thrips screening trial setup with infestation containment on plants with netting. INERA, Burkina Faso, 2016.

Milestones

October 1, 2015 – March 31, 2016

Feed the Future Innovation Lab for Collaborative Researchon Grain Legumes

Report on the Achievement of "Milestones of Progress"

(For the Period: October 1, 2015-- March 31, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by April 1, 2016

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	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**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	x	x		x	x		0			x	x		0			0		
1.1.2 insect samples collected	x	x		x	x		x	x		x	x		0			0		
1.1.3 3rd differential test	0			0			0			0			0			0		
1.1.4 2nd phenotype progenies	0			0			0			0			0			0		
1.1.5 genotype progenies	x	x		x			x	x		x	x		0			0		
Objective 1.2:	**Breeding and Trait Discovery -Flower Thrips Resistance**																	
1.2.1 2nd phenotype 2 RILs for QTL	0			0			0			0			0			0		
1.2.2 insect samples collected	0			0			x	x		x	x		0			0		
1.2.3 2nd phenotype 3 F7 populations	0			0			0			x	x		0			0		
1.2.4 genotype F7 populations	x	x		0			0			x	x		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			0			0			0		
1.3.2 insect samples collected	0			x	x		0			x	x		0			0		
1.3.3 advance to F4 from 1.3.1	0			0			0			0			0			0		
1.3.4 genotype F3 from 1.3.3	0			0			0			0			0			0		
1.3.5 QTL discovery - ICI mapping	0			0			0			0			0			0		

cont.

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**			**x**	**x**		**0**			**0**			**0**			**0**		
2.2.2 on-farm test & Breeder Seed	**0**			**x**	**x**		**0**			**0**			**0**			**0**		
2.2.3 advanced yield trials	**0**			**0**			**0**			**0**			**0**			**0**		
0	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 3:	**Increase capacity of NARS in Burkina Faso, Ghana and Senegal to serve the cowpea sector**																	
3.1 Short term training	**x**			**x**			**x**			**x**	**x**		**0**			**0**		
3.2 Degree training	**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**			**0**		
Name of the PI reporting on milestones by institution	P. Roberts			I. Drabo			N. Cisse			F. Kusi			PI name			PI name		

Name of the U.S. Lead PI submitting this Report to the MO: P. Roberts

Signature

Date

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

Enhance Institutional Research Capacity Relative to Grain Legumes

April 1, 2016 – September 30, 2016

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: April 1, 2016 -- September 30, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2016

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	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**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 3rd differential test	x	x		x	x		x	x		x	x		0			0		
1.1.4 2nd 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 2nd phenotype 2 RILs for QTL	x	x		0			x	x		x	x		0			0		
1.2.2 insect samples collected	0			0			x	x		x	x		0			0		
1.2.3 2nd phenotype 3 F7 populations	0			0			0			x	x		0			0		
1.2.4 genotype F7 populations	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	x	0			x	x	x	0			0		
1.3.2 insect samples collected	0			x	x		0			x		x	0			0		
1.3.3 advance to F4 from 1.3.1	0			x	x		0			0			0			0		
1.3.4 genotype F3 from 1.3.3	0			0			0			0			0			0		
1.3.5 QTL discovery - ICI mapping	x		x	x		x	0			x		x	0			0		

cont.

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**			**x**	x		**x**	x		**0**			**0**			**0**		
2.2.2 on-farm test & Breeder Seed	**x**	x		**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		**x**	x		**x**	x		**x**	x		**0**			**0**		
3.2 Degree training	**x**	x		**x**	x		**x**	x		**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**		
Name of the PI reporting on milestones by institution	P. Roberts			I. Drabo			N. Cisse			F. Kusi			PI name			PI name		
Name of the U.S. Lead PI submitting this report to the MO	P. Roberts																	

Signature **Date** #####

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

Performance Indicators

Overall 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. number	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	13	12	15	0
	Total number by sex	10	4	7	11	12	12	11	12	13	12	15	0
	Number of women	5	2	4	5	5	5	5	6	5	5	6	0
	Number of men	5	2	3	6	7	7	6	6	8	7	9	0
	Total number by New/continuing	10	4	7	11	12	11	11	12	12	12	14	0
	New	5	2	4	5	5	4	5	6	6	5	4	0
	Number of women	0	0	0	0	0	0	0	0	2	0	2	0
	Number of men	0	0	0	0	0	0	0	0	4	1	1	0
	Continuing	5	2	3	6	7	7	6	6	6	7	10	0
	Number of women	0	0	0	0	0	0	0	0	2	0	3	0
	Number of men	0	0	0	0	0	0	0	0	4	0	6	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	2810	4360	4560	0
	Total number by sex	531	333	538	1910	1907	2045	2520	2760	2810	4360	4560	0
	Number of women	196	116	191	659	663	878	963	1050	1098	1753	1953	0
	Number of men	335	217	347	1251	1244	1167	1557	1710	1712	2607	2607	0
	Numbers by Type of individual	531	333	538	1910	1907	2035	2520	2760	2820	4360	4640	0
	Producers	430	270	434	1670	1670	1790	2145	2360	2408	3440	3640	0
	Number of women						0	0	0	450	0	600	0
	Number of men						0	0	0	453	0	200	0
	People in government	39	27	38	110	110	110	120	140	122	400	440	0
	Number of women						0	0	0	40	0	92	0
	Number of men						0	0	0	42	0	48	0
	People in private sector firms	24	16	26	78	85	90	195	205	215	365	365	0
	Number of women						0	0	0	90	0	112	0
	Number of men						0	0	0	85	0	53	0
	People in civil society	38	20	40	52	42	45	60	55	75	155	195	0
	Number of women						0	0	0	28	0	42	0
	Number of men						0	0	0	32	0	43	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	289	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	172	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	101	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	16	26	26	0

Notes:

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

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UC Riverside

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, and FY 16

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

Institution 1 Name: UC Riverside

Indic. number	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 tr	3	0	3	3	3	3	2	2	2	2	2	0
	Total number by Sex	3	0	3	3	3	3	2	2	2	2	2	0
	Number of women	1		1	1	1	1	1	1	1	1	1	
	Number of men	2		2	2	2	2	1	1	1	1	1	
	Total number by New/continuing	3	0	3	3	3	3	2	2	2	2	2	0
	New	1		1	1	1	1	1	1	1	1	1	
	Number of women									1			
	Number of men												
	Continuing	2		2	2	2	2	1	1	1	1	1	
	Number of women												
	Number of men									1			
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Total number	10	12	12	10	0	10	10	0	10	10	10	0
	Number of women	3	3	3	3		3	3		3	3	3	
	Number of men	7	9	9	7		7	7		7	7	7	
	Numbers by Type of individual	10	12	12	10	0	0	10	0	10	10	10	0
	Producers			0									
	Number of women												
	Number of men												
	People in government			0									
	Number of women												
	Number of men												
	People in private sector firms			0									
	Number of women												
	Number of men												
	People in civil society	10	12	12	10			10		10	10	10	
	Number of women									3			
	Number of men									7			
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. Disaggregate where applicable. Just providing 'totals' will not be approved.
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ISRA Senegal

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, and FY 16

Project Name:Genetic improvement of cowpea to overcome biotic stress and dro

Institution 2 Name: ISRA Senegal

Indic. number	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 tr	3	0	2	3	3	3	2	2	2	2	2	0
	Total number by Sex	3	0	2	3	3	3	2	2	3	2	2	0
	Number of women	**2**		2	**2**	**2**	2	**1**	**1**	2	**1**	1	
	Number of men	**1**		0	**1**	**1**	1	**1**	**1**	1	**1**	1	
	Total number by New/continuing	3	0	2	3	3	2	2	2	2	2	2	0
	New	2		2	2	2	1	1	1		1	0	
	Number of women												
	Number of men										1	0	
	Continuing	1		0	1	1	1	1	1	2	1	2	
	Number of women									1		1	
	Number of men									1		1	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Total number	200	0	205	300	307	375	310	460	500	550	550	0
	Number of women	80		80	150	157	205	160	250	280	300	300	
	Number of men	120		125	150	150	170	150	210	220	250	250	
	Numbers by Type of individual	200	0	205	300	307	375	310	460	500	550	550	0
	Producers	160		162	240	240	300	240	365	403	440	440	
	Number of women									235			
	Number of men									168			
	People in government	12		13	20	20	20	20	30	32	35	35	
	Number of women									15		17	
	Number of men									17		18	
	People in private sector firms	8		10	8	15	20	15	25	25	30	30	
	Number of women									10		12	
	Number of men									15		18	
	People in civil society	20		20	32	32	35	35	40	40	45	45	
	Number of women									20		22	
	Number of men									20		23	
3	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	53	0	53	48	0	48	60	60	60	60	60	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	25		25	25		25	30	30	30	30	30	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	20		20	15		15	20	20	20	20	20	
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	8		8	8		8	10	10	10	10	10	

Notes:

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INERA Burkina Faso

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, and FY 16

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

Institution 3 Name: INERA Burkina Faso

Indic. number	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 tr	2	2	2	2	3		4	5	3	5	7	0
	Total number by Sex	2	2	2	2	3	0	4	5	3	5	7	0
	Number of women	1	1	1	1	1	1	2	3	1	2	3	
	Number of men	1	1	1	1	2	2	2	2	2	3	4	
	Total number by New/continuing	2	2	2	2	3	3	4	5	3	5	6	0
	New	1	1	1	1	1	1	2	3	3	2	3	
	Number of women									1		2	
	Number of men									2		1	
	Continuing	1	1	1	1	2	2	2	2	0	3	3	
	Number of women									0		1	
	Number of men									0		2	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Total number	115	115	115	450	450	510	600	700	700	800	1000	0
	Number of women	45	45	40	150	150	190	200	200	215	250	450	
	Number of men	70	70	75	300	300	320	400	500	485	550	550	
	Numbers by Type of individual	115	115	115	450	450	510	600	700	710	800	1080	0
	Producers	90	90	92	350	350	410	400	490	500	600	800	
	Number of women									215		600	
	Number of men									285		200	
	People in government	15	15	13	60	60	60	60	70	50	65	105	
	Number of women									25		75	
	Number of men									25		30	
	People in private sector firms	10	10	10	40	40	40	140	140	150	135	135	
	Number of women									80		100	
	Number of men									70		35	
	People in civil society									10		40	
	Number of women									5		20	
	Number of men									5		20	
3	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	80	80	80	142	142	155	160	160	211	200	350	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	60	60	60	120	120	130	130	130	130	150	300	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	20	20	20	20	20	23	25	25	75	40	40	
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance				2	2	2	5	5	6	10	10	

Notes:

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SARI Ghana

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, and FY 16

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

Institution 4 Name: SARI Ghana

Indic. number	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 tr	2	2	0	3	3	3	3	3	5	3	4	0
	Total number by Sex	2	2	0	3	3	3	3	3	5	3	4	0
	Number of women	1	1	0	1	1	1	1	1	1	1	1	
	Number of men	1	1	0	2	2	2	2	2	4	2	3	
	Total number by New/continuing	2	2	0	3	3	3	3	3	5	3	4	0
	New	1	1	0	1	1	1	1	1	2	1	0	
	Number of women												
	Number of men									2			
	Continuing	1	1	0	2	2	2	2	2	3	2	4	
	Number of women									1		1	
	Number of men									2		3	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-												
	Total number	206	206	260	1150	1150	1150	1600	1600	1600	3000	3000	0
	Number of women	68	68	68	356	356	480	600	600	600	1200	1200	
	Number of men	138	138	138	794	794	670	1000	1000	1000	1800	1800	
	Numbers by Type of individual	206	206	206	1150	1150	1150	1600	1600	1600	3000	3000	0
	Producers	180	180	180	1080	1080	1080	1505	1505	1505	2400	2400	
	Number of women												
	Number of men												
	People in government	12	12	12	30	30	30	40	40	40	300	300	
	Number of women												
	Number of men												
	People in private sector firms	6	6	6	30	30	30	40	40	40	200	200	
	Number of women												
	Number of men												
	People in civil society	8	8	8	10	10	10	15	15	15	100	100	
	Number of women												
	Number of men												
3	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	8	8	8	12	12	12	18	18	18	22	22	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	8	8	8	8	8	8	12	12	12	10	10	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	0	0	0	4	4	4	6	6	6	6	6	
	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	6	6	

Notes:

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

Lead U.S. Principal Investigator and University
Dr. Barry Pittendrigh, University of Illinois at Urbana-Champaign, October 1, 2015-July 15, 2016, and MSU, July 16, 2016-Present

Dr. Kenneth Paige,managing sub-contracts to HC partners, University of Illinois at Urbana-Champaign, July 16, 2016-Present

Collaborating Host Country and U.S. PIs and Institutions
Dr. Manuele Tamò, IITA-Benin (HC-PI)
Drs. Clémentine Dabiré-Binso and Fousséni Traore, INERA-Burkina Faso (HC-PI)
Mr. Laouali Amadou, INRAN-Niger (HC-PI) (Replacement for Dr. Ibrahim Baoua with Dr. Baoua still collaborating with our team)
Dr. Ibrahim Baoua, University of Maradi (collaborator with INRAN; funding goes through INRAN)
Dr. Stephen Asante, SARI, Ghana (HC-PI)
Dr. Moses Mochaih (Replacement for Dr. Haruna Braimah with Dr. Braimah still collaborating with our team), CRI- Ghana (HC-PI)
Dr. Julia Bello-Bravo, UIUC (US Co-PI)
Mr. Eustache Biaou, INRAB-Benin (HC-PI)(Replacement for Mr. Leonard Hinnou)

Abstract of Research and Capacity Strengthening Achievements
Over the past year we have continued to push forward our understanding of and solutions for the major pests of cowpeas in four West African countries: Benin, Niger, Burkina Faso and Ghana. Specifically, we have characterized pest populations through molecular tools, with a specific focus on mitochondrial polymorphisms. Solutions to these pest problems have been developed and pushed forward. These include across-country releases of biocontrol agents and a larger scale testing of neem and *Maruca*-specific viral combined sprays. We have also continued to 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 feedback on our Android App allowing collaborating organizations to easily access and use these materials in their educational programs. We have 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.

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 several USD per day. 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) developing strategies for 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 have and 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. These efforts are already being realized with local neem production businesses in Benin. We have continued to investigate biological control agents in our biocontrol pipeline and promising candidates have been released in the field, through approaches we have developed 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, (2) we have experimental data showing people people learn the same or more from the animations than from traditional extension presetnations 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 communities for pass off of our 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 non-commercial entities.

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. However, it is critical to note that our project has moved to the point where implementation has become a greater focus. 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 objectives 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.

<u>Objective 1. Define the pest problems</u>. (1) scouting, field experiments, and 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

The IITA, INERA, INRAN, CRI, and SARI teams all continue to perform efforts to understand pest populations during the cowpea cropping cycles and outside of these cycles. Insects found on diverse alternative host plants are stored in RNA later or 70% ethanol to be sent to UIUC for molecular analyses. Additionally, the INERA team has continued their experiments on understanding 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.

1.2 Molecular Analyses of pest populations

From IITA, UIUC/MSU has continued to receive pest populations for molecular analysis of insects that 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/MSU 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) have continued at UIUC and are now continuing at MSU. 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 the future. 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. We are nearing completion of a manuscript around these topics with the intent to submit it to a peer-review journal in the spring of 2017.

1.3 Computational Modeling, GIS systems and Online System

The UIUC/MSU 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/MSU 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 project. 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

IITA has continued olfactometric studies involving the egg parasitoid *Gryon fulviventre* as attracted by putative male aggregation pheromones of the coreid bug *Clavigralla tomentosicollis*. This study was carried out by Dr. Tamo's PhD student who was awarded an *icipe*-ARPPIS Ph.D fellowship late last year, to investigate the chemical ecology of this pest group (including *Clavigralla* spp. from West and East Africa). After having spent considerable time setting up separate rearing colonies for the different species, the student was able to report a first breakthrough in identifying some of the key components. The headspace volatile of both male and female *Clavigralla* spp. were collected without food and analysed, which allowed determining chemical profile (different components) for the three species (*C. tomentosicollis, C.*

shadabi and *C. elongata*). For each sex, headspace volatiles were collected over five times and analysed separately. After comparison of both male and female of each species, specific male-components were identified and are currently being characterized. Also, the student has started collecting and processing samples of these species in order to elucidate their population genetics.

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

We have continued investigating maternal factors responsible for the parasitization success in *T. javanus*, one of the best biocontrol candidates against the pod borer *Maruca vitrata*. This work is part of a joint Ph.D fellowship with the University of Montpellier (Anne-Nathalie Volkoff, UMR DGIMI). After a series of observations targeting the specific organs of the female genital tract of *T. javanus* (particularly the venom gland whose ultrastructure indicates it is of type 2 as observed in Braconidae), the study focused on phenotyping the parasitized larvae, and to investigate live stages of the parasitoid larva inside the body of the pod borer larva. This study yielded spectacular pictures of the different live stages which are given in the ANNEXES.

Further studies confirmed the ability of the parasitoid to discriminate already parasitized larvae and there is a high probability that the Doufour's gland might be involved in secreting marking volatiles.

2.3 PCR techniques for detecting endophytic strains of Beauveria bassiana available

After the initial success using three PCR primers available for the detection of *Beauveria bassiana* of which $SCB9_{677}$ revealed to be the best one for our *B. bassiana* Bb115 strain (which is the most virulent, so far, against the legume pod borer *Maruca vitrata*), we were confronted with technical issues when attempting to detect *B. bassiana* mycelium directly form plant tissue, which have been reported in literature with other strains on cereals. Hence, we have initiated new collaborative links with a specialized institute in Germany (Hochschule Geisenheim) in the hope to overcome this barrier.

At the same time, we have continued to investigate possible interactions between *B. bassiana* and the parasitoid *T. javanus*, in order to assess if there is any negative impact when using both in the field. Adult parasitoids treated with the entomopathogenic fungus *B. bassiana* under laboratory conditions were not negatively impacted in terms of longevity and fecundity. However, dead adult parasitoids sporulated with conidia of *B. bassiana*, indicating a possible synergistic effect in the field, as the conidia will be available during the cropping season for infecting the main target pest, the pod borer *M. vitrata*. These experiments hold out the hope that an entomopathogenic fungus might be combined with a biocontrol agent to have synergistic impact on a pest population.

2.4 Genetic improvement of cowpea to overcome biotic constraints to grain productivity (in collaboration with the UCR cowpea breeding team):

A manuscript is current being prepared between the UIUC/MSU and URC regarding biotype differences between cowpea aphids. We expect to submit the manuscript in the spring of 2017.

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)

In Benin, we released close to 50’000 adult parasitic wasp (32’000 *Therophilus javanus* and 17’000 *Phanerotoma syleptae*) which work in synergy by having two different modes of action, one being an ovo-larval parasitoid, and the other being a sturdier larval parasitoid which can detect the presence of caterpillars of *M. vitrata* inside flowers and pods of cowpea. The parasitoids were released with the participation of local communities, in 6 regions of Western Benin, on patches of wild alternative host for the pod borer, where the pest is feeding and reproducing during the off season, ready to invade cowpea fields with the onset of the cropping season.

Preliminary field data indicated a good establishment by both biocontrol agents/organisms already a few months after their initial releases.

In conjunction with the releases, together with field staff of the Ministry of Agriculture and INRAB, Benin, we have carried out practical training sessions in conducting releases of pod borer parasitoids, and also monitoring their establishment. At the same time, we have also carried out sensitization campaigns involving farming communities to explain, in very simple terms and using their own language, basic principles and rules of biological control and the releases campaigns being carried out in their communities. In particular, farmers were sensitized about the need to refrain from inappropriate use of chemical pesticides in order to preserve the just-released natural enemies.

We also initiated the same type of releases with INERA in Burkina Faso at several locations being part of a socio-economic study being carried out by Prof Mywish Maredia at MSU. A total of 11,000 *T. javanus* and 5000 *P. syleptae* individuals, were released both on natural vegetation and cowpea fields. Similar to the releases in Benin, we also carried out similar training and sensitization sessions with INERA technical staff and farming communities.

We expect these parasitoids to establish on patches of wild vegetation where they were released, and produce several generations thereby increasing the population size and colonizing neighboring patches where host plants for *M. vitrata* are present. With the onset of the rainy season and the beginning of the cowpea cropping seasons, the parasitoids will follow the *M. vitrata* populations migrating to the cowpea fields. We anticipate an overall reduction of the *M. vitrata* damage in a range of 30–50% depending on prevailing local conditions (such as, e.g., rainfall pattern, planting dates, and cowpea varieties planted). This effort is part of an overall IPM strategy for controlling cowpea pests which includes the use of resistant varieties and the safe and judicious use of pesticides (which we are planning to substitute with locally produced bio-pesticides in the longer term), combined with modern ICT approaches to empower low-literacy farmers to make informed decisions about pest control options.

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

Also this year we continued to supply adult individuals and pupae of the thrips parasitoids

Ceranisus femoratus collected in Southern Benin on patches of leguminous trees in hygromorphic areas, which were subsequently and hand-carried to the INERA labs at Farokoba, Burkina Faso, and released on host plants bearing high populations of flower thrips.

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

Unfortunately, after a series of attempts to repair the pump of the freeze-dryer which was sent to our HQ in Ibadan, it became clear that the pump had been damaged beyond repairs by previous attempts to fix it locally in Benin. It has therefore become necessary to order a new pump, which has been outsourced by our supply chain. The cost of it is not negligible (over 7000 USD including shipping) so we are negotiating with IITA about the purchase of this equipment through other funding mechanisms.

In the meantime, we have initiated talks with the Agricultural University of Ketou (just being renamed National University of Agriculture) for moving all activities related to the processing of the raw viral product (cadavers of virus-infected *M. vitrata* larvae produced by the women groups), which will include purification and processing into a commercial product, to their Agri-business School involving youth agri-preneurs. They have already had preliminary discussions with our main partner on the ground, the social enterprise SENS-Benin, and we hope to be able to get their full involvement in FY17.

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

Also this year, we have established demonstration plots in farmers' fields, targeting areas with high pest pressure as identified by last year's demonstration plots covering the whole country of Benin, which reached out to over 10,000 farmers. Results from last year's demonstration plots, which could not be reported in the last report because they only became available towards the end of the year, indicate quite some variability across regions, particularly because of different rainfall pattern, vegetation cover and preferred cowpea varieties used by the participating farmers. Data analysis is being finalize and a draft paper is being prepared. Overall, we can however confirm the good performance of the combination of the pod borer specific virus (MaviMNPV) + emulsifiable neem oil mixture, which has also been confirmed by IITA trials in Kano, Northern Nigeria, under very high pod borer population pressure. Similar scaling field trials have also taken place in Niger, with the the virus demonstration at the farmers level involving 2236 cowpea's producers in 75 villages (225 sites) from 2014-2016, which has allowt the farmers to test (MaviMNPV) + emulsifiable neem oil mixture on 13,500 m^2. Similar efforts have occurred in Burkina Faso.

3.1.5 Studies on the potential for use of biopesticides in the pest control market in Benin (IITA, MSU-Maredia, INRAB, and UIUC)

In Benin, we carried out two follow-up training sessions on the production of the MaviMNPV virus by the women's groups at two localities in Benin (Dassa and Glazoue), with the aim of optimizing the workflow and assuring quality control. The sessions took place July 29 to August 12 in Dassa with 15 participants in total (9 for clean *M. vitrata* production and 6 for the virus production), and July 15 to 27 in Glazoue, with 8 participants (4 each for clean *M. vitrata* production and 6 for the virus production. New 'village rearing labs' were established for this purpose in each of the localities, for separating the virus production from the production of healthy pod borer larvae. A technical staff from the Ministry of Agriculture (in charge of regulatory services and bio-pesticides) actively participated as a resource person throughout the sessions.

In a separate study, some 120 cowpea value chain actors including producers, market retailers and consumers in the Departments of Couffo, Littoral and Plateau were interviewed about their actual use of pesticides along the value chain. Among the producers, 77% responded they were using chemical pesticides for spraying their cowpea crops, while 23% were using home-made aqueous extracts prepared from neem leaves to protect their fields. Additionally, 65% of the market retailers were using non-chemical approaches to protect their stored cowpea grains, such as hermetic drums, solar drying and PICS bags, while 25% were still using chemical pesticides to protect their cowpea grains in storage. Consumers were largely (98%) aware of pesticide-related issues and were not using any chemicals for their own storage after buying from the market.

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 continued to explore pass-off of our educational materials to NGOs and government agencies for scaling. Over the past year all of these aforementioned activities have occurred. The INRAN team has used the neem and biocontrol animations in scaling sensitization projects. Through a separate funding stream, UIUC/MSU and IITA have also performed a project testing a diversity of animations (two on health and one on agriculture) in terms of learning gains, as compared to traditional extension approaches. In all three cases, the animations outperformed the traditional extension talks, in terms of learning gains of the participants. Learning gains efforts with farmers in Niger revealed the animations (for biocontrol and neem sprays) were highly effective in transmitting knowledge to farmers. 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. We are well-positioned to pass these materials to other groups that can integrate them into their educational programs.

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 FY16 and was funded by an outside source with no costs to the Legumes Innovations Lab (funded a grant from QED) (ca. 30 participants), four 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 5000 "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 of these USB cards has continued to occur to country extension programs, FARA, other West African inter-country institutions and many other organizations.

In August 16, 2016, SAWBO and all supporting materials and systems has been legally transferred to Michigan State University. With the move of the SAWBO team to MSU, the system to support the App has been moved and we will be releasing an updated version of the

App (1.1), with improved functions, in the fall of 2016. We also expect to release a 2.0 version, with more functions available for users.

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.

4.1 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

As in past years, 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. Previous years' training has set the stage for the current status of the project, such that we can now produce and release in larger-scale biological control strategies. Cross-training in this past year revolved around these scaling and deployment strategies.

4.3 Cross-Institutional Capacity Building for Biocontrol Agents

IITA, INERA and INRAN, due to ongoing collaborative efforts are all well-positioned to continue 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. Most importantly, we have moved to scaling the release of the biocontrol agents in Benin, Niger and Burkina Faso.

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.

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 analysis 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 and tested an App that has the potential to make all of the SAWBO materials highly accessible and the use of the system highly scalable. This will serve at the basis for the development of the 2.0 version that we expect to release before the end of the project. SAWBO received the Award for Entrepreneurial Excellence: Social Venture. Champaign County Economic Development Corporation, 2015.

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 ofaneem/MaviMNPV virus biopesticide and purchase equipment for parasitoids' multiplications. Training of staff has occurred in FY15-16 .Five INRAN staff including two PhD students attended short term training at Entomology laboratory in IITA Benin.. INRAN and INERA also received an award for this upcoming funding cycle (end date 9/30/16) and funding transfer issues are in progress for INERA.

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 Benefiting: Ghana
Location and dates of training: Accra and Cape Coast, spring/summer 2016
Location and dates of training: ca. 300 males and 300 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 Benefiting: Ghana, Niger, Burkina Faso, Benin (and Nigeria) as well as online global use
Location and dates of training: Ongoing across the above countries
Location and dates of training: ca. 500,000 males and 500,00 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 500,000 males and 500,000 females (which is what we are reporting), primarily through a TV station that broadcasts the SAWBO animations in Hausa to approximately 1-5 million viewers. 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 Benefiting: 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

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 fields related cowpea pest control – Estimated impact of 1980 or more farmers impacted.
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.

Degree Training

Name of trainee: 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 Innovation Lab PI: Dr. Barry Pittendrigh
Degree Program: PhD
Field or Discipline: Entomology
Research Project Title: 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
Type of Legume Innovation Lab Support: None

Name of trainee: Keon Mook Seong
Country of Citizenship: Korean
Gender: Male
Host Country Institution Benefitting from Training: UIUC
Institution providing training: UIUC
Supervising Innovation Lab PI: Dr. Barry Pittendrigh
Degree Program: PhD
Field of Discipline: Entomology
Research Project Title: Mitochondrial Genome Variability in Insect Pests of Cowpea
Start Date: Fall 2013
Project Completion Date: Fall 2017
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: None

Name of trainee: Djibril Aboubakar Souna
Country of Citizenship: Benin
Gender: Male
Host Country Institution Benefiting from Training: IITA
Institution providing training:
Supervising Innovation Lab PI: Dr. Manu Tamò
Degree Program: PhD
Field of Discipline: Entomology
Research Project Title: Bioecology of *Therophilus javanus*, a promising biocontrol candidate against *Maruca vitrata*
Start Date: 2014
Project Completion Date: 2018
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Hilaire Kpongbe
Country of Citizenship: Benin
Gender: Male
Host Country Institution Benefiting from Training: IITA
Institution providing training: IITA
Supervising Innovation Lab PI: Dr. Manu Tamò
Degree Program: PhD
Field of Discipline: Entomology
Research Project Title: Population genetics of pod sucking bugs *Clavigralla* spp. and comparison of aggregation pheromone profiles.
Start Date: 2015

Project Completion Date: 2018
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Judith Honfoga
Country of Citizenship: Benin
Gender: Female
Host Country Institution Benefiting from Training: IITA
Institution providing training: IITA
Supervising Innovation Lab PI: Dr. Manu Tamò
Degree Program: MSc
Field of Discipline: Entomology
Research Project Title: Detection and quantification of *Therophilus javaus* parasitism in *Maruca vitrata* larvae using species-specific qPCR primers
Start Date: 2014
Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Nazyath IMOROU
Country of Citizenship: Benin
Gender: Female
Host Country Institution Benefiting from Training: IITA
Institution providing training: IITA
Supervising Innovation Lab PI: Dr. Manu Tamò
Degree Program: MSc
Field of Discipline: Entomology
Research Project Title: Olfactory responses of T. javanus to frass of M. vitrata.
Start Date: 2015
Project Completion Date: 2017
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Nicolette Montcho
Country of Citizenship: Benin
Gender: Female
Host Country Institution Benefiting from Training: IITA
Institution providing training: IITA
Supervising Innovation Lab PI: Dr. Manu Tamò
Degree Program: MSc
Field of Discipline: Entomology
Research Project Title: Host finding behavior of *Therophilus javanus*, a novel parasitoid of the

pod borer *Maruca vitrata*
Start Date: 2015
Project Completion Date: 2017
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Fiacre Agbaka
Country of Citizenship: Benin
Gender: Male
Host Country Institution Benefiting from Training: IITA
Institution providing training: IITA
Supervising Innovation Lab PI: Dr. Manu Tamò
Degree Program: MSc
Field of Discipline: Entomology
Research Project Title: Interactions between *Phanerotoma syleptae* and *Therophilus javanus.*
Start Date: 2015
Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Completed
Type of Legume Innovation Lab Support: None

Name of trainee: Carmel TOSSOU
Country of Citizenship: Benin
Gender: Male
Host Country Institution Benefiting from Training: IITA
Institution providing training: IITA
Supervising Innovation Lab PI: Dr. Manu Tamò
Degree Program: MSc
Field of Discipline: Entomology
Research Project Title: Host finding behavior of *Therophilus javanus* on selected host plants
Start Date: 2015
Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Completed
Type of Legume Innovation Lab Support: None

Name of trainee: Mesmin ALIZANON
Country of Citizenship: Benin
Gender: Male
Host Country Institution Benefiting from Training: IITA
Institution providing training: IITA
Supervising Innovation Lab PI: Dr. Manu Tamò
Degree Program: MSc
Field of Discipline: Entomology

Research Project Title: Life table studies of *Therophilus javanus* on artificial and natural substrates
Start Date: 2015
Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Sènan Ange Brinette
Country of Citizenship: Benin
Gender: Female
Host Country Institution Benefiting from Training: IITA
Institution providing training: IITA
Supervising Innovation Lab PI: Dr. Manu Tamò
Degree Program: MSc
Field of Discipline: Entomology
Research Project Title: Screening of Benin local isolates of *B. bassiana* against *Maruca vitrata*
Start Date: 2016
Project Completion Date: 2017
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Firmine AIZAN
Country of Citizenship: Benin
Gender: Femail
Host Country Institution Benefiting from Training: IITA
Institution providing training: IITA
Supervising Innovation Lab PI: Dr. Manu Tamò
Degree Program: BSc
Field of Discipline: Entomology
Research Project Title: Competition between *Phanerotoma syleptae* and *Therophilus javanus* under screenhouse conditions
Start Date: 2015
Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Completed
Type of Legume Innovation Lab Support: None

Name of trainee: Débora ADJAYI
Country of Citizenship: Benin
Gender: Female
Host Country Institution Benefiting from Training: IITA
Institution providing training: IITA
Supervising Innovation Lab PI: Dr. Manu Tamò

Degree Program: BSc
Field of Discipline: Entomology
Research Project Title: Effect of different *M. vitrata* larval densities on parasitisation success by *Therophilus javanus* under screenhouse conditions
Start Date: 2015
Project Completion Date: 2015
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Completed
Type of Legume Innovation Lab Support: None

Name of trainee: Aude GBAGUIDI
Country of Citizenship: Benin
Gender: Female
Host Country Institution Benefiting from Training: IITA
Institution providing training: IITA
Supervising Innovation Lab PI: Dr. Manu Tamò
Degree Program: BSc
Field of Discipline: Entomology
Research Project Title: Effect of different *Therophilus javanus* densities on parasitisation rates of *M. vitrata* under screenhouse conditions
Start Date: 2015
Project Completion Date: 2015
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Completed
Type of Legume Innovation Lab Support: None

Name of trainee: DRABO Edouard
Country of Citizenship: Burkina Faso
Gender: Male
Host Country Institution Benefiting from Training: INERA
Institution providing training: INERA and University Ouagadougou I Pr Joseph KI-ZERBO
Supervising Innovation Lab PI: Dr Fousséni TRAORE
Degree Program: MSc
Field of Discipline: Entomology
Research Project Title: Botanical extract use for cowpea pest management in Sudanian zones at Kamboinse
Start Date: 2015
Project Completion Date: 2017
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Théodore Y. OUEDRAOGO
Country of Citizenship: Burkina Faso
Gender: Male

Host Country Institution Benefiting from Training: INERA
Institution providing training: INERA and University Ouagadougou I Pr Joseph KI-ZERBO
Supervising Innovation Lab PI: Dr Fousséni TRAORE
Degree Program: MSc
Field of Discipline: Entomology
Research Project Title: Assessment of neem oil application periods for more efficiency in farmer fields.
Start Date: 2015
Project Completion Date: 2017
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Mariam DERA
Country of Citizenship: Burkina Faso
Gender: Female
Host Country Institution Benefiting from Training: INERA
Institution providing training: INERA and University Ouagadougou I Pr Joseph KI-ZERBO
Supervising Innovation Lab PI: Dr Clémentine DABIRE
Degree Program: PhD
Field of Discipline: Entomology
Research Project Title: New pests occurring in dry season on cowpea seed production plots.
Start Date: 2014
Project Completion Date: 2018
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Apolline SANON
Country of Citizenship: Burkina Faso
Gender: Female
Host Country Institution Benefiting from Training: INERA
Institution providing training: INERA and University Ouagadougou I Pr Joseph KI-ZERBO
Supervising Innovation Lab PI: Dr Clémentine DABIRE
Degree Program: PhD
Field of Discipline: Entomology
Research Project Title: Effectiveness of *Gryon fulviventre* for pod sucking bug biocontrol in cowpea field
Start Date: 2011
Project Completion Date: 2015
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Delayed
Type of Legume Innovation Lab Support: Partial

Name of trainee: Élisée DABRÉ

Country of Citizenship: Burkina Faso
Gender: Female
Host Country Institution Benefiting from Training: INERA
Institution providing training: INERA and University Ouagadougou
Supervising Innovation Lab PI: Dr Clémentine DABIRE
Degree Program: PhD
Field of Discipline: Entomology
Research Project Title: TBD
Start Date: 2011
Project Completion Date: 2019
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Maimouna Abdourahmane
Country of Citizenship: Niger
Gender: Female
Host Country Institution Benefiting from Training: INRAN
Institution providing training: INRAN / University of Maradi
Supervising Innovation Lab PI: Dr. Ibrahim Baoua and Dr. Amadou Laouali
Degree Program: PhD
Field of Discipline: Entomology
Research Project Title: 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
Project Completion Date: 2018
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Ousseina Abdoulaye
Country of Citizenship: Niger
Gender: Female
Host Country Institution Benefiting from Training: INRAN
Institution providing training: INRAN / University of Maradi
Supervising Innovation Lab PI: Dr. Ibrahim Baoua and Dr. Amadou Laouali
Degree Program: PhD
Field of Discipline: Entomology
Research Project Title: 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
Project Completion Date: 2018
Is trainee a USAID Participant Trainee and registered on TraiNet? No

Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Rahina Souley Mayaki
Country of Citizenship: Niger
Gender: Female
Host Country Institution Benefiting from Training: INRAN
Institution providing training: INRAN / University of Maradi
Supervising Innovation Lab PI: Dr. Ibrahim Baoua and Dr. Amadou Laouali
Degree Program: BSc
Field of Discipline: Entomology
Research Project Title: The effects of Neem grain-based biopesticide on the development of *Clavigralla tomentosicollis* at rural level in the region of Maradi
Start Date: 2012
Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Soumaila Abdou Issa
Country of Citizenship: Niger
Gender: Male
Host Country Institution Benefiting from Training: INRAN
Institution providing training: INRAN / University of Maradi
Supervising Innovation Lab PI: Dr. Ibrahim Baoua and Dr. Amadou Laouali
Degree Program: BSc
Field of Discipline: Entomology
Research Project Title: The effects of Neem grain-based biopesticide on the development of *Clavigralla tomentosicollis* at rural level in the region of Maradi
Start Date: 2012
Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Nafissatou Illa Boube
Country of Citizenship: Niger
Gender: Female
Host Country Institution Benefiting from Training: INRAN
Institution providing training: INRAN / University of Maradi
Supervising Innovation Lab PI: Dr. Ibrahim Baoua and Dr. Amadou Laouali
Degree Program: BSc
Field of Discipline: Entomology
Research Project Title: Study of the population dynamics of *Maruca vitrata* on station
Start Date: 2011

Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Rakia Gonda
Country of Citizenship: Niger
Gender: Female
Host Country Institution Benefiting from Training: INRAN
Institution providing training: INRAN / University of Maradi
Supervising Innovation Lab PI: Dr. Ibrahim Baoua and Dr. Amadou Laouali
Degree Program: BSc
Field of Discipline: Entomology
Research Project Title: Study of the biology of *Clavigralla tomentosicollis* in laboratory
Start Date: 2012
Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Kader Djibo Amadou
Country of Citizenship: Niger
Gender: Male
Host Country Institution Benefiting from Training: INRAN
Institution providing training: INRAN / University of Maradi
Supervising Innovation Lab PI: Dr. Ibrahim Baoua and Dr. Amadou Laouali
Degree Program: BSc
Field of Discipline: Entomology
Research Project Title: Study of the development cycle of *Clavigralla tomentosicollis* in laboratory conditions
Start Date: 2012
Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Haouaou Issaka
Country of Citizenship: Niger
Gender: Female
Host Country Institution Benefiting from Training: INRAN
Institution providing training: INRAN / University of Maradi
Supervising Innovation Lab PI: Dr. Ibrahim Baoua and Dr. Amadou Laouali
Degree Program: MSc
Field of Discipline: Entomology
Research Project Title: Effect of biopesticide neem seeds extract for the control cowpea pods

pest (*Maruca vitrata and Clavigralla tomentosicollis)* on station
Start Date: 2015
Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Eustache Biaou
Country of Citizenship: Benin
Gender: Male
Host Country Institution Benefiting from Training: INRAB/IITA
Institution providing training: INRAB / University of Benin
Supervising Innovation Lab PI: Dr. Adegbola/Dr. Manu Tamo
Degree Program: MSc
Field of Discipline: Social Sciences
Research Project Title: TBD
Start Date: 2015
Project Completion Date: TBD
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Deborah Anobil AMOSAH
Country of Citizenship: Ghana
Gender: Female
Host Country Institution Benefiting from Training: CSRI/CRI
Institution providing training: Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi
Supervising Innovation Lab PI: Dr. Haruna Braimah
Degree Program: BSc
Field of Discipline: Agriculture
Research Project Title: Neem control strategies on the pests of cowpea in Northern Ghana
Start Date: 2013
Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Samuel Abekah Kwesi
Country of Citizenship: Ghana
Gender: Male
Host Country Institution Benefiting from Training: SARI
Institution providing training: University for Development Studies, Tamale, Ghana
Supervising Innovation Lab PI: Dr. Stephen Asante
Degree Program: BSc

Field of Discipline: Entomology
Research Project Title: Evaluation of different storage methods for preserving cowpea grains against *Callosobruchus maculatus Fab.*
Start Date: 2016
Project Completion Date: 2017
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

Name of trainee: Akosua Addai Asare
Country of Citizenship: Ghana
Gender: Female
Host Country Institution Benefiting from Training: SARI
Institution providing training: University for Development Studies, Tamale, Ghana
Supervising Innovation Lab PI: Dr. Stephen Asante and Dr. Braimah
Degree Program: BSc
Field of Discipline: Entomology
Research Project Title:
Start Date: 2015
Project Completion Date: 2016
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training Status: Active
Type of Legume Innovation Lab Support: Partial

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. As a cross-collaborative effort with the Iowa State University team, they have tested (in Mozambique) the learning gains in female farmers (as compared to male farmers) and the data supports that the animations were effective in both groups, however, women experienced greater learning gains with the animations than with traditional extension talks.

Explanation for Changes

There were no changes in our work plan over this past year.

Self-Evaluation and Lessons-Learned

We have continued to recognize that there is a considerable amount of potential for cross-collaboration between projects, with other Innovations Labs and with other outside entities. As we head into the final year of this project, we will be continuing to place a heavy emphasis on research supporting pass-off strategies thereby increasing impact of the overall project.

Scholarly Accomplishments

Theses

Agbaka Fiacre, 2016. Etude des interactions entre Phanerotma syleptae et Therophilus javanus, (Bhat & Gupa) (Hymenoptera: Braconidae) deux parasitoïdes du lépidoptère Maruca vitrata Fabricius (Lepidoptera: Crambidae) ravageur du niébé au laboratoire. FAST/UAC, 38p

Ahongbonon Laurent, 2016. Etude de la table de vie de Phanerotoma syleptae (Hymenoptera: Braconidae), parasitoide ovo-larvaire de Maruca vitrata (Lepidoptera: Braconidae), ravageur du niébé, Vigna unguiculata (L.) Walp.. FAST/UAC, 31p

Alizanon Mesmin, 2016. Etude de la table de Therophilus javanus sur milieux naturel et artificiel. FAST/UAC, 36p

Tossou Carmelle, 2016. Test d'efficacité de Therophilus javanus '(Bhat & Gupa) (Hymenoptera: Braconidae) sur Maruca vitrata (Lepidoptera: Crambidae. FAST/UAC, 36p

Selected Presentations

Agunbiade, T.A., B.S. Coates, W. Sun, M. Ba, I. Baoua, M. Tamò, and B.R. Pittendrigh. 2016. IPM-Omics: From Genomics to Extension for Integrated Pest Management of Cowpea. Pan-African Grain Legume & World Cowpea Conference, Livingstone, Zambia, 28 February – 4 March, 2016. Poster Number 332.

Apkoffo, M.A.Y., M. Tamò, B. Datinon, A. Djihinto, and E. Dannon. 2016. Evaluation de quelques paramètres biologiques et de l'efficacité de Therophilus javanus Bhat et Gupta (Hymenoptera : Braconidae), parasitoïde larvaire de Maruca vitrata Fabricius, (Lepidoptera: Crambidae), foreuse des fleurs et des gousses du niébé (Vigna unguiculata). Pan-African Grain Legume & World Cowpea Conference, Livingstone, Zambia, 28 February – 4 March, 2016. Poster Number 334.

Dannon, E., B. Datinon, R. Srinivasan, J. Toffa, D. Arodokoun, B.R. Pittendrigh, and M. Tamò. 2016. Biological control: anon-obvious option for managing insect pests in cowpea. Invited Paper, International Congress of Entomology, Orlando, Florida, 24–28 Sept 2016. Abstract 0774: doi: 10.1603/ICE.2016.106004.

Pittendrigh, B.R., M. Tamò, J. Bello-Bravo, E. Dannon, I. Baoua, H. Braimah, S. Asante, C. Dabire, E. Biaou, and A. Laouali. 2016. West Africa Integrated Pest Management (IPM) Cowpea Program: Discovery pipeline to scaling. Invited paper, The World Food Price, USDA-USAID 2016 International Food Assistance and Security Conference, Des Moines, 11 Oct 2016.

Tamò, M. et al., 2016. Biological control of cowpea insect pests: progress, challenges and opportunities. Keynote presentation. Pan-African Grain Legume & World Cowpea Conference, Livingstone, Zambia, 28 February – 4 March, 2016. Paper Number: 1299.

Tamò, M., B.R. Pittendrigh, S. Miresmailli, V. Font, B. Blalock, , E. Dannon, B. Datinon, M. Agyekum, C. Donovan, and E. Biaou. 2016. From biocontrol to precision-IPM in Africa: Challenges and opportunities. Keynote paper, International Congress of Entomology, Orlando, Florida, 24–28 Sept, 2016. Abstract 0644: doi: 10.1603/ICE.2016.95128

Publications

Agunbiade, T.A., B. R. Pittendrigh, M. Tamò, W. Sun, B. S. Coates, F. Traore, J. A. Ojo, A. N. Lutomia, J. B. Bravo, S. Miresmailli. Cowpea Field Insect Pests and Integrated Pest Management Techniques for Cowpea Cultivation in West Africa. Francis Dodds ed, legume book chapter (submitted)

Bello-Bravo et al., An Assessment of Learning Gains from Educational Animations versus Traditional Extension Presentations among Farmers in Benin, submitted.

Ihm, J., M. Pena-Y-Lillo, K. R. Cooper, Y. Atouba, M. Shumate, J. Bello-Bravo, N. M. Ba, C. L. Dabire-Binso and B. R. Pittendrigh (2015). "The Case for a Two-Step Approach to Agricultural Campaign Design." Journal of Agricultural & Food Information 16(3): 203-220.

Ihm, J., M. Shumate, J. Bello-Bravo, Y. Atouba, N. M. Ba, C. L. Dabire-Binso and B. R. Pittendrigh (2015). "How do Service Providers and Clients Perceive Interorganizational Networks?" VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations 26(5): 1769-1785.

Oigiangbe, O.N., Tamò, M., Igbinosa, I.B. 2016. Bioactivity of Alstonia boonei De Wild leaf alkaloid on the growth and development of Maruca vitrata Fabricius pp. 117-122 In: Sahayaraj and Selvaraj (eds.). Biopestides: Innovations and Practices. Smith and Franklin Academic Publishing Corporation, Ash Vale, UK.

Rabé Moctar et al., Champ école paysan un processus participatif pour l’amélioration de rendement du niébé : résultats des expériences pilotes conduites dans les régions de Maradi and Zinder. Submitted to Agronomie Tropicale.

Sokame, B. M., A. K. Tounou, B. Datinon, E. A. Dannon, C. Agboton, R. Srinivasan, B. R. Pittendrigh and M. Tamò (2015). "Combined activity of Maruca vitrata multi-nucleopolyhedrovirus, MaviMNPV, and oil from neem, Azadirachta indica Juss and Jatropha curcas L., for the control of cowpea pests." Crop Protection 72: 150-157.

Progress in Implementing Impact Pathway Action Plan

Objective 1

In terms of “Program Logic” we worked on Step 4.3 for this section.

Objective 2

In terms of “Program Logic” we worked on Step 4.3 for this section.

Objective 3

In terms of Program Logic, step 4.3. As reported on our performance indicator pathway we documented 10,000+ people receiving the educational content, however, this is inclusive of other groups using our materials in their educational programs.

Milestones

October 1, 2015 – March 31, 2016

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: Oct 1, 2015 -- March 31, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by April 1, 2016

Project Title: **SO1.B1 IPM-omics: Scalable and sustainable biological solutions for pest management of insect pests of cowpea in**

	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	**4/1/16**	**Y**	**N***	**4/1/16**	**Y**	**N***	**4/1/16**	**Y**	**N***	**4/1/16**	**Y**	**N***	**4/1/16**	**Y**	**N***	**4/1/16**	**Y**	**N***	**4/1/16**	**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 Educationa	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							

cont.

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		X	X										
4.3 Technicican training				X	X		X	X		X	X										
4.4 ICT Training	X	X																			
4.5 Farmer Field Flora/Farmer Training/Training of trainers							X	X		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	3/28/2016 **Date**	3/28/2016 **Date**

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

April 1, 2016 – September 30, 2016

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Report on the Achievement of "Milestones of Progress"

(For the Period: April 1, 2016 -- Sept 31, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2016

Project Title: **SO1.B1 IPM-omics: Scalable and sustainable biological solutions for pest management of insect pests of cowpea in**

	Abbreviated name of institutions																				
	UIUC/MSU			IITA			INERA			INRAN			INRAB			CRI			SARI		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Milestones by Objectives	**9/31/2016**	**Y**	**N***	**9/31/2016**	**Y**	**N***	**9/31/2016**	**Y**	**N***	**9/31/2016**	**Y**	**N***	**9/31/2016**	**Y**	**N***	**9/31/2016**	**Y**	**N***	**9/31/2016**	**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																			

cont.

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										
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 Educationa	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							
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		X	X										
4.3 Technicican training				X	X		X	X		X	X										
4.4 ICT Training	X	X																			
4.5 Farmer Field Flora/Farmer Training/Training of trainers							X	X		X	X					X	X		X	X	

Name of the PI reporting on milestones by institution	Pittendrigh/Ken Paige	Manuele Tamò	Clementine Dabire/ Fousseni Traore	Laouali Amadou/Baoua	Eustache Biaou	Haruna Braimah/ Moses Mochaih	Stephen Asante
Signature/Initials:	Ken Paige						

Name of the U.S. Lead PI submitting this report to the MO	Barry Robert Pittendrigh		
		9/31/2016	9/31/2016
	Signature	**Date**	**Date**

Performance Indicators

Overall Indicators

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

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	22	29	17	22	0
	Total number by Sex	13	0	0	15	0	1	16	31	31	17	19	31	19	24	0
	Number of women	7	0	0	9	0	0	9	18	18	9	11	19	9	10	0
	Number of men	6	0	0	6	0	1	7	13	13	8	8	12	10	14	0
	Numbers by New/Continuing	0	0	0	0	0	0	16	31	31	17	19	31	16	24	0
	New	0	0	0	0	0	0	6	16	16	4	4	6	0	3	0
	Number of women										0	1	4	0	1	0
	Number of men										0	2	3	0	2	0
	Continuing	0	0	0	0	0	0	10	15	15	13	15	25	16	21	0
	Number of women										1	3	15	4	9	0
	Number of men										0	2	9	4	12	0
2	term training															
	Total number	219	0	0	5444	0	0	11354	11349	11349	11356	11481	11974	100356	100481	0
	Number of women	77	0	0	2692	0	0	5691	5696	5697	5693	5756	5946	50193	50259	0
	Number of men	142	0	0	2752	0	0	5663	5653	5652	5663	5725	6028	50163	50222	0
	Numbers by Type of individual	221	0	0	5444	0	0	11354	11381	11388	11356	11356	11974	100354	100481	0
	Producers	122	0	0	5134	0	0	10694	10773	10774	10695	10695	11318	10695	10817	0
	Number of women										1	0	5617	5250	5398	0
	Number of men										1	0	5701	5250	5419	0
	People in government	35	0	0	58	0	0	153	120	120	155	155	152	155	156	0
	Number of women										1	0	74	50	79	0
	Number of men										0	0	78	50	77	0
	People in private sector firms	18	0	0	34	0	0	144	125	125	145	145	139	145	148	0
	Number of women										1	0	70	50	76	0
	Number of men										0	0	69	50	73	0
	People in civil society	46	0	0	218	0	0	363	363	369	361	361	365	89359	89360	0
	Number of women										1	0	185	44650	44681	0
	Number of men										1	0	180	44650	44679	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	36	37	39	37	39	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	14	15	17	15	17	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	15	15	15	15	15	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	7	7	7	7	7	0

Notes:

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UIUC

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 pests

UIUC

Indic. number	Output Indicators	FY 13 Target	FY 13 Revised	FY 13 Actual	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
		(only April 1, 2013 - September 30, 2013)			(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															
	Total number by Sex	1	0	0	1	0	0	1	1	1	1	2	2	2	2	0
	Number of women	**1**			**1**			**1**	**1**	1	**1**	**1**	1	**1**	**1**	
	Number of men	**0**			**0**			**0**	**0**	0	**0**	**1**	1	**1**	**1**	
	Numbers by New/continuing	0	0	0	0	0	0	1	1	1	1	0	2	0	2	0
	New							**0**	**0**	0		**0**			**0**	
	Number of women															
	Number of men															
	Continuing							**1**	**1**	1	**1**	**0**	2		**2**	
	Number of women											**1**	1	**1**	**1**	
	Number of men											**1**	1	**1**	**1**	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training															
	Total number	28	0	0	5200	0	0	11000	11000	11000	11000	11000	11000	11000	100000	0
	Number of women	**14**			2600			5500	5500	5500	5500	5500	5500	5500	50000	
	Number of men	**14**			2600			5500	5500	5500	5500	5500	5500	5500	50000	
	Numbers by Type of individual	30	0	0	5200	0	0	11000	11000	11000	11000	11000	11000	11000	100000	0
	Producers				5000			10500	10500	10500	10500	10500	10500	10500	10500	
	Number of women												5250	5250	5250	
	Number of men												5250	5250	5250	
	People in government	**4**			25			100	100	100	100	100	100	100	100	
	Number of women												50	50	50	
	Number of men												50	50	50	
	People in private sector firms	**4**			5			100	100	100	100	100	100	100	100	
	Number of women												50	50	50	
	Number of men												50	50	50	
	People in civil society	**22**			170			300	300	300	300	300	300	300	89300	
	Number of women												150	150	44650	
	Number of men												150	150	44650	
3	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	5	0	0	5	0	0	6	6	6	6	6	6	6	6	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	3			2			2	2	2	2	2	2	2	2	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	1			2			2	2	2	2	2	2	2	2	
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	1			1			2	2	2	2	2	2	2	2	

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IITA

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 pests of cowpea in Africa

IITA

Indic. number	Output Indicators	FY 13 Target	FY 13 Revised	FY 13 Actual	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
		(only April 1, 2013 - September 30, 2013)			(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 tr	0	0	0	0	0	0	10	15	15	10	7	12	10	10	0
	Total number by Sex	10	0	0	10	0	0	10	15	15	10	7	12	10	10	0
	Number of women	**5**			5			5	7	7	5	4	7	5	5	
	Number of men	**5**			5			5	8	8	5	3	5	5	5	
	Numbers by New/Continuing	0	0	0	0	0	0	10	15	15	10	7	12	10	10	0
	New							**6**	**9**	9	**4**	**3**	6	**0**	**0**	
	Number of women												4			
	Number of men												2			
	Continuing							**4**	**6**	6	**6**	**4**	6	**10**	**10**	
	Number of women												3		**5**	
	Number of men												3		**5**	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training															
	Total number	10	0	0	10	0	0	10	50	64	10	10	32	10	10	0
	Number of women	**5**			5			5	25	24	5	5	25	5	5	
	Number of men	**5**			5			5	25	26	5	5	7	5	5	
	Numbers by Type of individual	10	0	0	10	0	0	10	50	57	10	10	32	8	10	0
	Producers								10	11			17		2	
	Number of women												15		1	
	Number of men												2		1	
	People in government	**1**			1			1	2	2	1	1	2	1	1	
	Number of women												1		1	
	Number of men												1		0	
	People in private sector firms	**1**			2			2	2	2	2	2	3	2	2	
	Number of women												1		1	
	Number of men												2		1	
	People in civil society	**8**			7			7	36	42	7	7	10	5	5	
	Number of women												8		3	
	Number of men												2		2	
7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	5	0	0	5	0	0	5	5	5	5	5	5	5	5	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	4			2			1	1	1	1	1	1	1	1	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	1			2			2	2	2	1	1	1	1	1	
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance				1			2	2	2	3	3	3	3	3	

Notes:

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INERA

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 pes

INERA

Indic. number	Output Indicators	FY 13 Target	FY 13 Revised	FY 13 Actual	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
		(only April 1, 2013 - September 30, 2013)			(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 individu	0	0	0	1	0	0	1	4	4	1	2	5	0	5	0
	Total number by Sex	0	0	0	1	0	0	1	4	4	1	2	5	0	5	0
	Number of women	**0**			**1**			**1**	**3**	3	**1**	**1**	1		1	
	Number of men	**0**			**0**			**0**	**1**	1	**0**	**1**	4		4	
	Total number by new and continuing	0	0	0	0	0	0	1	4	4	1	2	5	0	5	0
	New							0	0	0			3		3	
	Number of women												1		1	
	Number of men												2		2	
	Continuing							1	4	4	1	2	2		2	
	Number of women												0		0	
	Number of men												2		2	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training															
	Total number	75	0	0	120	0	0	180	120	120	180	180	225	180	180	0
	Number of women	**25**			50			80	50	52	80	80	100	80	80	
	Number of men	**50**			70			100	70	68	100	100	125	100	100	
	Numbers by Type of individual	75	0	0	120	0	0	180	120	120	180	180	225	180	180	0
	Producers	**50**			60			90	100	100	90	90	150	90	90	
	Number of women												70		45	
	Number of men												80		45	
	People in government	**14**			15			30	10	10	30	30	25	30	30	
	Number of women												10		15	
	Number of men												15		15	
	People in private sector firms	6			20			30	10	10	30	30	20	30	30	
	Number of women												10		15	
	Number of men												10		15	
	People in civil society	5			25			30	0	0	30	30	30	30	30	
	Number of women												15		15	
	Number of men												15		15	
7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	16	0	0	18	0	0	18	18	18	18	18	18	18	18	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	10			10			10	10	10	10	10	10	10	10	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	6			8			8	8	8	8	8	8	8	8	
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance															

Notes:
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INRAN

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 pests

INRAN

Indic. number	Output Indicators	FY 13 Target	FY 13 Revised	FY 13 Actual	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
		(only April 1, 2013 - September 30, 2013)			(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 tr	0	0	0	0	0	0	1	8	8	2	6	6	2	2	0
	Total number by sex	0	0	0	1	0	0	1	8	8	2	6	6	2	2	0
	Number of women	0			1			1	6	6	1	4	4	1	1	
	Number of men	0			0			0	2	2	1	2	2	1	1	
	Numbers by New/Continuing	0	0	0	0	0	0	1	8	8	2	6	6	2	2	0
	New							0	7	7			0	0	0	
	Number of women												0	0	0	
	Number of men												0	0	0	
	Continuing							1	1	1	2	6	6	2	2	
	Number of women												4	1	1	
	Number of men												2	1	1	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training															
	Total number	100	0	0	100	0	0	150	165	165	150	150	576	150	150	0
	Number of women	30			30			100	115	115	100	100	247	100	100	
	Number of men	70			70			50	50	50	50	50	329	50	50	
	Numbers by Type of individual	100	0	0	100	0	0	150	197	197	150	150	576	150	150	0
	Producers	70			70			100	159	159	100	100	526	100	100	
	Number of women												230		50	
	Number of men												296		50	
	People in government	15			15			20	6	6	20	20	20	20	20	
	Number of women												10		10	
	Number of men												10		10	
	People in private sector firms	5			5			10	11	11	10	10	10	10	10	
	Number of women												5		5	
	Number of men												5		5	
	People in civil society	10			10			20	21	21	20	20	20	20	20	
	Number of women												10		10	
	Number of men												10		10	
3	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	4	0	0	4	0	0	3	4	4	5	5	5	5	5	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	2			3			2	3	3	1	1	1	1	1	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	2			1			1	3	3	3	3	3	3	3	
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	0							1	1	1	1	1	1	1	

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INRAB

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 pests

INRAB

Indic. number	Output Indicators	FY 13 Target	FY 13 Revised	FY 13 Actual	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
		(only April 1, 2013 - September 30, 2013)			(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 tr	0	0	0	0	0	0	1	1	1	1	3	3	1	3	0
	Total number by Sex	0	0	0	1	0	0	1	1	1	1	0	3	1	3	0
	Number of women	0			0			0	0	0			2		2	
	Number of men	0			1			1	1	1	1	0	1	1	1	
	Numbers by New/Continuing	0	0	0	0	0	0	1	1	1	1	1	3		3	0
	New							0	0	0			0		0	
	Number of women											1	0		0	
	Number of men											1	0		0	
	Continuing							1	1	1	1	1	3		3	
	Number of women										1	1	2		2	
	Number of men												1		1	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training															
	Total number	0	0	0	2	0	0	2	2	2	2	127	127	2	127	0
	Number of women	0			1			1	1	1	1	64	67	1	67	
	Number of men	0			1			1	1	1	1	63	60	1	60	
	Numbers by Type of individual	0	0	0	2	0	0	2	2	2	2	2	127	2	127	0
	Producers	0			0			0	0	0	0	0	120	0	120	
	Number of women												50		50	
	Number of men												70		70	
	People in government	0			1			1	1	1	1	1	2	1	2	
	Number of women												1		1	
	Number of men												1		1	
	People in private sector firms	0			0			0	0	0	0	0	3	0	3	
	Number of women												2		2	
	Number of men												1		1	
	People in civil society	0			1			1	1	1	1	1	2	1	2	
	Number of women												1		1	
	Number of men												1		1	
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	0	0	2	0	0	2	2	2	2	2	3	2	3	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	1			0			0	0	0	0	0	1	0	1	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	1			1			1	1	1	1	1	1	1	1	
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance				1			1	1	1	1	1	1	1	1	

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CRI

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 pests

CRI

Indic. number	Output Indicators	FY 13 Target	FY 13 Revised	FY 13 Actual	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
		(only April 1, 2013 - September 30, 2013)			(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 tr	0	0	0	0	0	0	1	1	1	2	2	2	2	2	0
	Total number by Sex	0	0	0	1	0	0	1	1	1	2	2	2	2	2	0
	Number of women	0			1			1	1	1	1	1	1	1	1	
	Number of men	0			0			0	0	0	1	1	1	1	1	
	Numbers by New/continuing	0	0	0	0	0	0	1	1	1	2	2	2	2	2	0
	New							0	0	0			0	0	0	
	Number of women												0	0	0	
	Number of men												0	0	0	
	Continuing							1	1	1	2	2	2	2	2	
	Number of women											1	1	1	1	
	Number of men											1	1	1	1	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training															
	Total number	4	0	0	6	0	0	6	6	6	8	8	8	8	8	0
	Number of women	2			4			3	3	3	5	5	5	5	5	
	Number of men	2			2			3	3	3	3	3	3	3	3	
	Numbers by Type of individual	4	0	0	6	0	0	6	6	6	8	8	8	8	8	0
	Producers	2			2			2	2	2	3	3	3	3	3	
	Number of women												1		1	
	Number of men												2		2	
	People in government	0			0			0	0	0	2	2	2	2	2	
	Number of women												1		1	
	Number of men												1		1	
	People in private sector firms	1			1			1	1	1	2	2	2	2	2	
	Number of women												1		1	
	Number of men												1		1	
	People in civil society	1			3			3	3	3	1	1	1	1	1	
	Number of women												0		1	
	Number of men												1		0	
7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	2	0	0	2	0	0	1	1	1	0	1	1	1	1	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	1			1							1	1	1	1	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	1			1								0	0	0	
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance							1	1	1			0	0	0	

Notes:

These indicators are developed under the Feed the Future Monitoring System. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

SARI

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 pests of cowpea in Africa

SARI

Indic. number	Output Indicators	FY 13 Target	FY 13 Revised	FY 13 Actual	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
		(only April 1, 2013 - September 30, 2013)			(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 tr	0	0	0	0	0	0	1	1	1	0	2	2	2	2	0
	Total number by Sex	2	0	0	0	0	1	1	1	1	0	0	2	2	2	
	Number of women	**1**						**0**	0	**0**	**0**	0	**1**	**1**	**1**	
	Number of men	**1**					**1**	**1**	1	**1**	**0**	0	**1**	**1**	**1**	
	Numbers by New/Continuing	0	0	0	0	0	0	1	1	1	0	1	2	2	2	0
	New							**0**	**0**	0		**1**	0	**0**	0	
	Number of women												0	**0**	0	
	Number of men											**1**	0	**0**	0	
	Continuing							**1**	**1**	1	**0**	**0**	2	**2**	2	
	Number of women												1	**1**	1	
	Number of men												1	**1**	1	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training															
	Total number	2	0	0	6	0	0	6	6	6	6	6	6	6	6	0
	Number of women	**1**			2			2	2	2	2	2	2	2	2	
	Number of men	**1**			4			4	4	4	4	4	4	4	4	
	Numbers by Type of individual	2	0	0	6	0	0	6	6	6	6	6	6	6	6	0
	Producers				2			2	2	2	2	2	2	2	2	
	Number of women										1		1		1	
	Number of men										1		1		1	
	People in government	**1**			1			1	1	1	1	1	1	1	1	
	Number of women										1		1		1	
	Number of men										0		0		0	
	People in private sector firms	**1**			1			1	1	1	1	1	1	1	1	
	Number of women										1		1		1	
	Number of men										0		0		0	
	People in civil society				2			2	2	2	2	2	2	2	2	
	Number of women										1		1		1	
	Number of men										1		1		1	
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	0	0	2	0	0	1	1	1	0	0	1	0	1	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	1			1								1	0	1	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	1			1								0	0	0	
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance							1	1	1			0	0	0	

Notes:

These indicators are developed under the Feed the Future Monitoring System. 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, leave it blank.

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Farmer Decision Making Strategies for Improved Soil Fertility (SO2.1)

Lead U.S. Principal Investigator and University

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Collaborating Host Country and U.S. PIs and Institutions

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Abstract of Research and Capacity Strengthening Achievements

Researcher-led field experiments are successfully completed in Uganda, with a third season of community-based field trials underway to enable farmers to learn about and test improved management practices and technologies, then evaluate, discuss and decide together. Two multistakeholder bean Innovation Platforms in Masaka and Rakai continue developing in membership size, diversity, enthusiasm and capability, with 10+ value chain member organizations and 400+ farmers. Field experiments in Mozambique will be completed by mid-2017. The project team (led by IIAM), is collaborating with the SEMEAR project (led by IITA) and with CLUSA for community-based field trials. Fifteen project team members presented papers/posters at the Joint 2016 PanAfrican Grain Legume and World Cowpea Conference. Three M.S. students graduated from ISU, with M.S. students at collaborating institutions on track to graduate. Research results are being prepared for publication in peer-reviewed journals and dissemination in regional/national practitioner and policy outlets in Africa. Effective and efficient methods and media (animated video, etc.) for information dissemination to intermediate and end users have been developed and assessed in a participatory manner, and are being refined. Capacity strengthening through applied research-based training has been successfully conducted.

Project Problem Statement and Justification

Sustainable intensification of smallholder cropping systems requires improved soil fertility management in which legumes play an integral role, and enhanced capabilities among farmers to diagnose and find solutions to important soil and other production constraints. Project research activities focus on predominant soil types in key common bean production regions in Masaka and Rakai districts south-central Uganda and Gurúè district, northern Mozambique. To understand potentially limiting soil characteristics and nutrient deficiencies, relevant analyses include soil, physical and chemical properties, nutrient omission studies, and researcher-managed field experiments. It is also valuable for researchers to understand local/indigenous criteria and systems for characterizing soils, particularly those reflecting fertility vs. deficiencies and crops that are appropriate. The combination of scientific and local criteria will enhance understanding and sustainable implementation of recommended cropping system improvements.

Following availability of field experiment results, community-based field trials and demonstration sites facilitate engagement of farmers in understanding key management practices and technologies (MPT) recommended by researchers. Farmer field days stimulate interest through direct observation, participation, and comparison of site-specific MPT. These activities engage producers and other stakeholders in social learning, stimulate interest in the demonstrations and trials, and foster widespread use of MPT that are proven successful in local conditions. The MPT include field preparation and measurement, seed selection, plant spacing, application of organic and inorganic fertilizers, weeding, post-harvest handling, and farm business economic analysis.

An innovative communication and dissemination strategy integrates the use of radio, video animations delivered via smartphones, and print materials delivered through networks of partner organizations supplemented by field demonstrations and other participatory activities. These will engage farmers with diverse backgrounds, characteristics, and other key stakeholders in widespread dissemination and adoption of appropriate diagnostic and decision support aids.

Technical Research Progress

Objective 1. Characterize Smallholder Farmers' Motivations, Current Knowledge and Practices

In Gurúè, smallholder farmers produce their crops on a number of small plots of approximately the same size in different locations as a way to maximize their overall yield as well as assess soil fertility status. Their method involves planting the same crop and seed in two or more locations and comparing yield. Typically, they compare summit land farmed during the rainy season and bottom land farmed, usually flood plain, during dry season.

They have actively participated in project field experiments which have served as the basis for farmer field days to stimulate widespread interest through direct observation and comparison of site-specific management practices and technologies (MPT). Farmers have clearly indicated interest in trying new MPT that can improve their crop yields. Most farmers involved in project activities are willing to buy improved seeds, plant in rows and apply fertilizer to their fields; most are already familiar with urea fertilizer. They cited constraints of access to extension services and capital, and labor if they increase the area devoted to bean production. Farmers are reluctant to make significant changes in their production system unless it results in reliable yield increases and they have access to reliable markets so that they can increase net revenues and improve their livelihoods.

Objective 2. Develop and Refine Models about Smallholder Bean Farmers' Decision Making

Smallholder farmers — women and men — growing beans in Masaka and Rakai districts use their livelihood resources (natural, physical, human, social and financial) to increase productivity, income and natural resource integrity. Collective action and social learning are key elements. The two multistakeholder innovation platforms (IPs) established in Masaka and Rakai districts with project assistance have been very active in promoting improved bean production. Researchers from Makerere University and NARL continue to develop IP groups of farmers across the bean production value chain, including post-harvest handling, marketing, and farmer organization skills. IPs are comprised of farmers, extension, a quality bean seed producer, input sellers, microfinance, and bean buyers. Members share interests, concerns and strategies to address bean productivity and marketing constraints. IP farmer representatives pass on information to member farmers in their respective groups. Field trials and demonstrations, accompanied by hands-on trainings by resource persons have strengthened human and social capital through experimental/experiential learning and peer-to-peer learning based on field observations to increase bean productivity and improve soil fertility. For example, following community-based training and experimentation in 2015, some farmers have invested in triple bags and jerricans for storing their harvested beans. Open discussions are encouraged, joint planning and collaborations is achieved, and new networks and partnerships formed.

In season 2016A, IP members in Masaka and Rakai hosted 18 field trials to demonstrate improved management practices and technologies (MPTs) for bean production and assess the results. Having a full acre to demonstrate the various soil amendment field trials has proven very effective in attracting the interest of other farmers to raise questions and learn. Additional field trials are currently being conducted in Masaka and Rakai during the 2016B season. Competitions organized by the project highlight the most effectively managed field trial and demonstration, and the one that has attracted the most new learners to stimulate interest in improved management practices and technologies.

In 2016, 27 IP farmers received bean seeds under a contract farming arrangement for bean cultivation under CEDO (Community Enterprise Development Organization — a bean seed producing cooperative); this is a 50% increase from 2015. Due to unusually low rains and high temperatures during the first season of 2016, more farmers began contract farming. Many farmers (400+) opened accounts with IP partner MAMEDICOT (Masaka Microfinance and Development Cooperative Trust) to access loans to grow and market beans. Thus, a major benefit of the IP approach is that farmers gain access to information, quality seed, inputs and credit needed to produce beans. The partnership with CEDO has been especially important in making quality seed available to farmers in the area.

Several organizations have initiated activities with the IPs, and some have expressed interest in joining as IP members. These have included Kilimo Trust for marketing beans, African Forum for Agricultural Advisory Services (AFAAS) and Uganda Forum for Agricultural Advisory Services (UFAAS), m-Omulimisa — a mobile phone based extension service, Solar Now (SNV) — an environmental organization which plans to supply solar powered irrigation pumps to farmers to address drought challenges, and Nsanja Agro Dealer and Bukola Agro Chemicals which are major suppliers. IP members have received training about the Kakasa (E-Verification) system designed to decrease the prevalence of counterfeit seeds and pesticides and increase agricultural yields. Supported by USAID's Feed the Future Uganda Agricultural Inputs Activity, Kakasa involves scratch code packaging labels containing a 14 or 16 digit verification number. Marketing agents explained their quantity and quality requirements. Major buyers include CEDO, Kasuja Produce Stores and Yash Commodities (from Kenya). The CIAT 'pre-cooked' bean project is also arranging a bean grain market for farmers, and will use radio to sensitize farmers about the program. The challenge is to fine tune the extension arrangements to support the farmers and the marketing strategies to efficiently reach the farmers with competitive price offers. Because all participants in the IPs have something to gain (farmers get more production, marketers get more quality beans to sell, dealers sell more inputs, CEDO contracts with farmers to get the quality seed it needs), the system is becoming self-sustaining.

In Gurúè, IIAM (on behalf of the project team), has established a collaborative relationship with the SEMEAR program (Improved Seeds for Better Agriculture, 2015-2019), led by IITA (with CIAT, ICRISAT and IIAM). SEMEAR uses a public-private partnership approach to disseminate improved legume seeds and complementary crop management practices already developed in Mozambique through the PARTI (Platform for Agriculture Research and Technology Innovation). The goals are to (1) increase the production and supply of breeder, pre-basic, basic, and certified seeds; (2) increase adoption of improved technologies, income, and food security of 100,000+ smallholder farm households in Zambézia, Nampula, Manica and Tete provinces; and (3) enhance national policy dialog on seed and fertilizer supply. The collaboration involves coordination of field trial and demonstration activities and communication materials and activities.

Mapping indigenous soil classification with the scientific process has been initiated, and included farmers and extension worker field based classifications. Soil typologies are being documented and matched with scientific classification and commensurate management practices for bean production. The three predominant soils on the Buganda catena have differences and similarities in physical, chemical, and biological properties. However, sometimes apparently conflicting properties are cited within a given soil or horizon. This dichotomy can occur due to management induced soil changes that increased or decreased erosion or deposition or mining of soil nutrients (table1). Additional verification of properties will occur in 2016-2017.

- **Table 1. Soils and Prevalent Properties given Cropping Histories, Buganda Catena near Masaka, Uganda.**

Soil fertility improvement is a function of soil fertility status, crop nutrient requirements and available resources. Smallholder farmers and extension workers have had limited capacity to determine which nutrients to apply when and where based on indigenous soil types and existing soil maps. Under the project, two approaches have been taken to improve farmer decision making in choice of nutrient amendments: (1) refining farmers' indigenous soil classification system and (2) refining existing scientific soil maps. The farmers' indigenous soil classification system has been improved by making it hierarchical and more elaborate. Results from the field experimentation can be more precisely applied to these soils. Regarding refining of scientific soil maps, we are in advanced stages of deriving a Digital Elevation Model based on catenary sequencing of hierarchical indigenous soil types to refine the scientific soil maps. This will reduce cost, time and resources in determining appropriate soil amendments by using results from field trials and tests of soils on a few farmers' fields using soil test kits.

To promote adoption and use of recommendations, field trials/demonstrations are set up in strategic locations and farmer field days are organized in Uganda and Mozambique. Field days are important methods of sensitization and demonstration of management practices and technologies, attracting new farmers to try out project recommendations for improved bean production and soil productivity. Training materials on management practices and technologies are being developed for various stakeholders, including extension services.

Farmer's decisions to adopt or adapt new management practices and technologies is influenced by awareness, availability, access and affordability, and by their perceptions of key attributes.

Significant attributes include relative advantage of a practice (locally available materials, multifunctionality of the practice and relatively low cost of investment), ability to observe success of the practice before adoption (from fellow smallholders or through experimentation), and compatibility with existing farm operations and less complexity (less labor intensiveness and smaller package sizes). The influence of these attributes varies among farmers due to heterogeneity in household wealth, land tenure, social networks, access to input-produce markets and extension services. Extension agents and farmer-to-farmer interactions are the most trusted information sources for improved soil fertility management.

More broadly, farmers' decisions are shaped by opportunities and incentives, and moderated by the level of resource ownership and access, labor hiring practices, market sales, and social and economic networks. Our analyses concerning land revealed many significant differences related to the manner by which households acquired their fields. Households with a larger number of adult laborers are significantly more likely to have purchased land which, in turn, is associated with application of manure. Those with livestock have more fields and are more likely to use fertilizer (inorganic). Further analysis found that most households have so few livestock of any type that it's difficult or impossible for them to have a meaningful impact from application of manure only from their livestock. Availability of manure seems rather limited, so farmers default to purchasing fertilizer.

Households that hire labor are significantly more likely to use manure, fertilizer, as well as pesticides and herbicides. They have more resources for a full range of inputs to intensify their efforts and achieve higher yields. Examination of economic variables showed that those who purchase inorganic fertilizers have income from non-agricultural sources, have savings, can get credit when needed, and have borrowed in the preceding year. Those who can readily access credit also apply (generally purchased) manure, pesticides and herbicides. Households with savings also are more likely to apply manure and pesticides. Households that expressed concern over security of land ownership or use rights for bean and other crop production – approximately one-fourth in study communities in each country — were more likely to apply herbicides, reflecting a strategy to ensure a good harvest for the current season.

Objective 3. Develop and Validate Diagnostic and Decision Support Aids

Soils in nearly all common bean fields in Masaka and Rakai are nutrient deficient. Field experiments conducted by Lance Goettsch (ISU M.S. student) documented that comparatively small additions of fertilizer P, K, Ca, Mg, and Zn resulted in more than doubling common bean yield on black soil. Utilizing small amounts of N and P fertilizer with chicken manure, Stewart Kyebologa (Makerere M.S. masters student) documented similar increases in common bean yield. Although data are lacking on elemental and nutrient composition of Ugandan chicken manure, it is well documented in other countries that chicken manure typically has good concentrations of P, K, Ca, Mg, and micronutrients when properly stored before use as a source of plant nutrients. Through field research, preliminary fertilizer recommendations were developed for beans on different soils in Masaka and Rakai as follows: 7.5 kg N ha^{-1} + 7.5 kg P ha^{-1} + 2.5 t ha^{-1} chicken manure for black soil (*Cambic Luvic Phaeozem*), 15 kg N ha^{-1} + 15 kg P ha^{-1} + 2.5 t ha^{-1} chicken manure for red soil (*Eutric Sideralic Cambisol*) and 7.5 kg N ha^{-1} + 15 kg P ha^{-1} + 2.5 t ha^{-1} chicken manure for gravelley soil (*Skeletic Lixic Mollic Umbrisol*).

As farmers begin to consider adopting some of the fertilizer recommendations from field research, it is equally important that they gain an understanding of the economics of bean production. Project research has revealed that most smallholder farmers rarely keep accurate written records of inputs and other costs associated with their farming enterprises or track costs for use of family land and labor Further, farmers are not getting the best possible market prices for their beans, yet bean price is a key factor that influences their net economic return. Comparison of data from our household survey, graduate student research, District Production Officers, and other sources linked to our research (e.g., CEDO), will guide efforts to understand price dynamics in order to educate farmers on the importance of tracking price and using that information to decide when and where to sell their beans.

Farmers have identified the three major activities associated with bean production to be *labor costs* (for land preparation, ploughing, planting, weeding, input application and spraying), *input costs* (seed, fertilizer/manure, pesticides and herbicides) and *post-harvest handling* (threshing, winnowing, drying, bagging and storage). Input costs, especially directs costs, are the easiest to ascertain whereas labor and land are only accounted for if hired or rented.

Triangulation of cost data from scientist-led field experiments, community-based field trials, and individual farmers' plots, combined with the household survey, will be used to obtain a more accurate estimate of costs. In Uganda, farmers planted up to 10 different varieties of beans yet the price received doesn't seem to vary much by variety. In Mozambique, fewer varieties are planted (approximately 4), with price/kg for only one variety slightly higher than the other varieties. The market data collected for Uganda thus far one bean type commanding a much higher price, most likely due to high demand and low supply.

A model budget has been developed summarizing costs associated with one acre of bean production. Since the majority of farmers in our study intercrop, and beans are not necessarily the highest value crop, we have accounted for the value of other crops. We are working on a similar study for Mozambique. Preliminary results suggest farmers in some cases are realizing negative returns if all costs, including land and labor, are included. In 2017, three other data sets from a Makerere graduate student, District Production Officers, and other sources linked to our research (e.g., CEDO), will be used to refine the budget model.

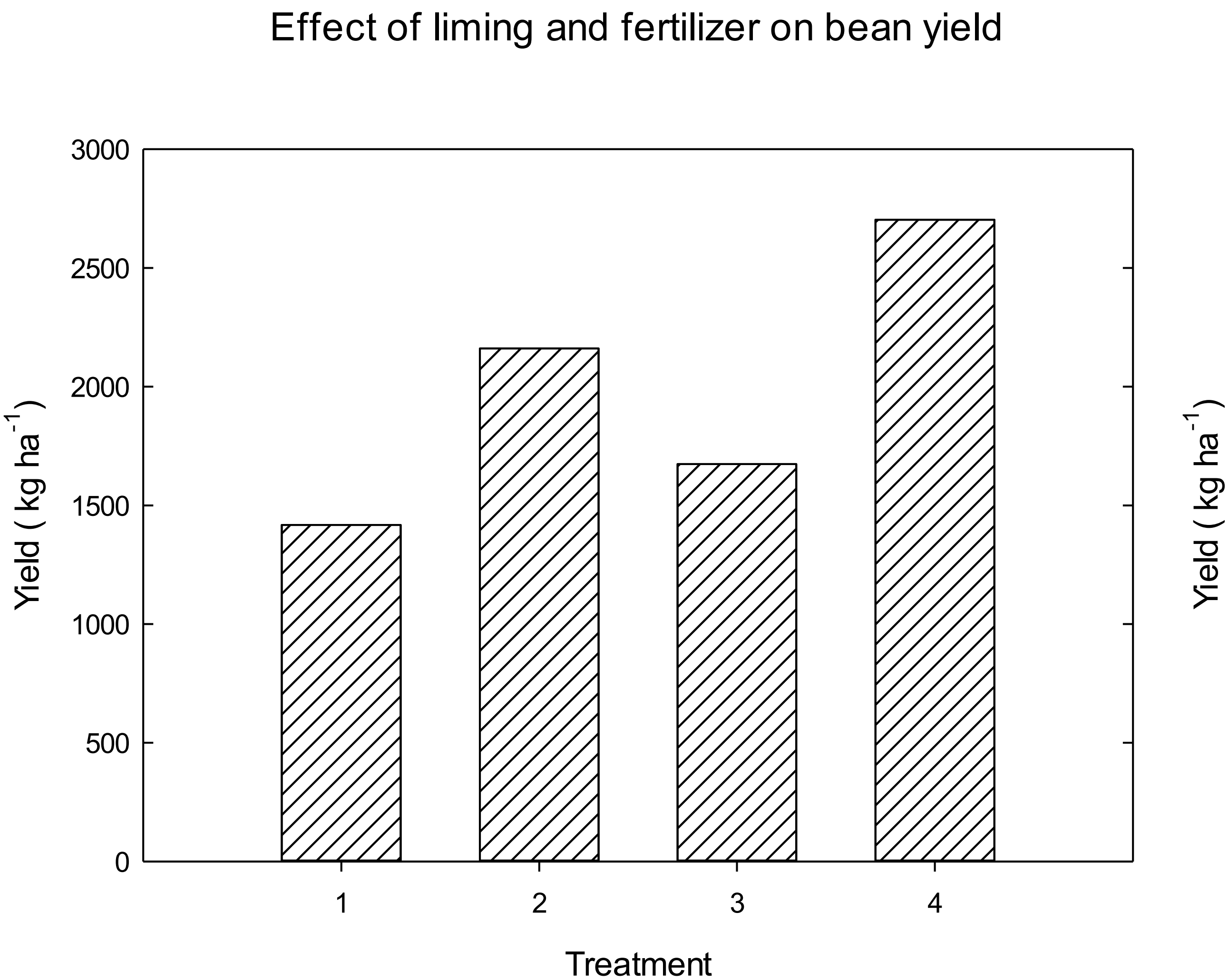
Following completion of researcher-managed field experiments in Uganda, community-based field trials were initiated in early 2016 in Masaka and Rakai. Treatments included a control, organic only (chicken manure), inorganic only (DAP+Urea) and a combination of organic with inorganic fertilizer. These were applied on the black, red, and gravelly soils following the recommendation for each type of soil. Results from 2016A (first) season showed that mean bean grain yields for the three soils were not significantly different. Fertilizer application significantly increased bean yield over the control (i.e., 1136, 1818, 1681 and 1733 kg ha^{-1} for the control, organic, inorganic and combination, respectively; $p<0.05$, $LSD_{0.05}=370$). Mean grain yields for the organic, inorganic or combination were not significantly different. Considering that 2016A was a moisture stressed season, these results show that manure application on the three soils was as good as the inorganic, or a combination. Under such conditions, farmers can apply chicken manure (which is more readily available in their locality compared to inorganic fertilizers) at the recommended rate to improve bean yields. Field trials and demonstrations during the 2016B (August to December) season are further testing these recommendations, as well as examining band vs. broadcast application of fertilizer.

Planting common beans in rows, as done by Goettsch in Masaka, impressed cooperating and other nearby farmers leading them to immediately adopt the practice in their own bean fields. These farmers have continued to plant all of their common beans in rows. Studies done by Kyebogola had all common bean plots planted in rows; cooperating and other nearby farmers also have adopted this practice. All common bean field trial plots planted in collaboration with the Bean Innovation Platforms in Masaka and Rakai have been planted in rows. Farmers noted that although planting in rows required more time than their traditional 'scatter' planting method, the time, effort, and efficacy of weeding, pest and disease monitoring and control, and harvest made their farming bean much more efficient overall. Common bean stand density typically was about 10 plants m^{-2} in traditional scatter planting systems. Research by Goettsch documented that stand densities approaching 20 plants m^{-2} also improved yield. Planting in rows and at a higher density adoption has occurred on both black and red soils, an important improvement for farmers. However, many farmers have adopted even greater seeding rates that, when combined with high quality seed, are less efficient for seed cost and resource use. The research team has noted that many farmers don't have an accurate understanding of the size of their fields, which can make calculation and application of the recommended amount of manure and fertilizer problematic. Researchers and collaborators are exploring methods to effectively address this situation.

Soil acidity is a major factor limiting bean production in the highly weathered red soils of Mepuagíua, Gurúè district. Soil tested by our project and CLUSA revealed potential soil acidity problems, with significant variation of soil pH among communities and within sites (4.4-5.7 with median 5.0) measured in 1:2.5 soil KCl ratio. Our lime incubation study, carried out at the IMAPEG chemistry lab in Gurúè with four rates of fine calcite liming material (0, 0.5, 1.0, 3, 5), generated an estimate of 3-3.5 Mg/ha of limestone needed to ameliorate the pH level for beans.

Soil pH in some paddy-rice production systems of Mepuagíua precludes good growth and yield of common bean. To assess bean response to limestone and fertilizer on paddy rice soil, we conducted an experiment with four treatments: (1) control (no limestone or fertilizer added), (2) limestone at 3 ton ha^{-1}, (3) fertilizer (20 kg N ha^{-1}, 35 kg P_2O_5 ha^{-1}, 12 kg K_2O ha^{-1}, 10 kg S ha^{-1} and 0.5 B + 2.5 Zn kg ha^{-1}) and (4) fertilizer as per (3) and limestone as per (2). Use of limestone alone significantly increased bean grain yield from 1420 kg ha^{-1} (control) to 2160 kg ha^{-1} with lime. The combination of limestone and fertilizer NPKSZnB provided mean bean yield above 2700 kg ha^{-1}, nearly double the yield of the control. Bean yield response was greater for limestone alone than for the fertilizer treatment alone.

Figure 1 — Bean (*Phaseolus vulgaris*, L.) Yields influence by Limestone and Fertilizer

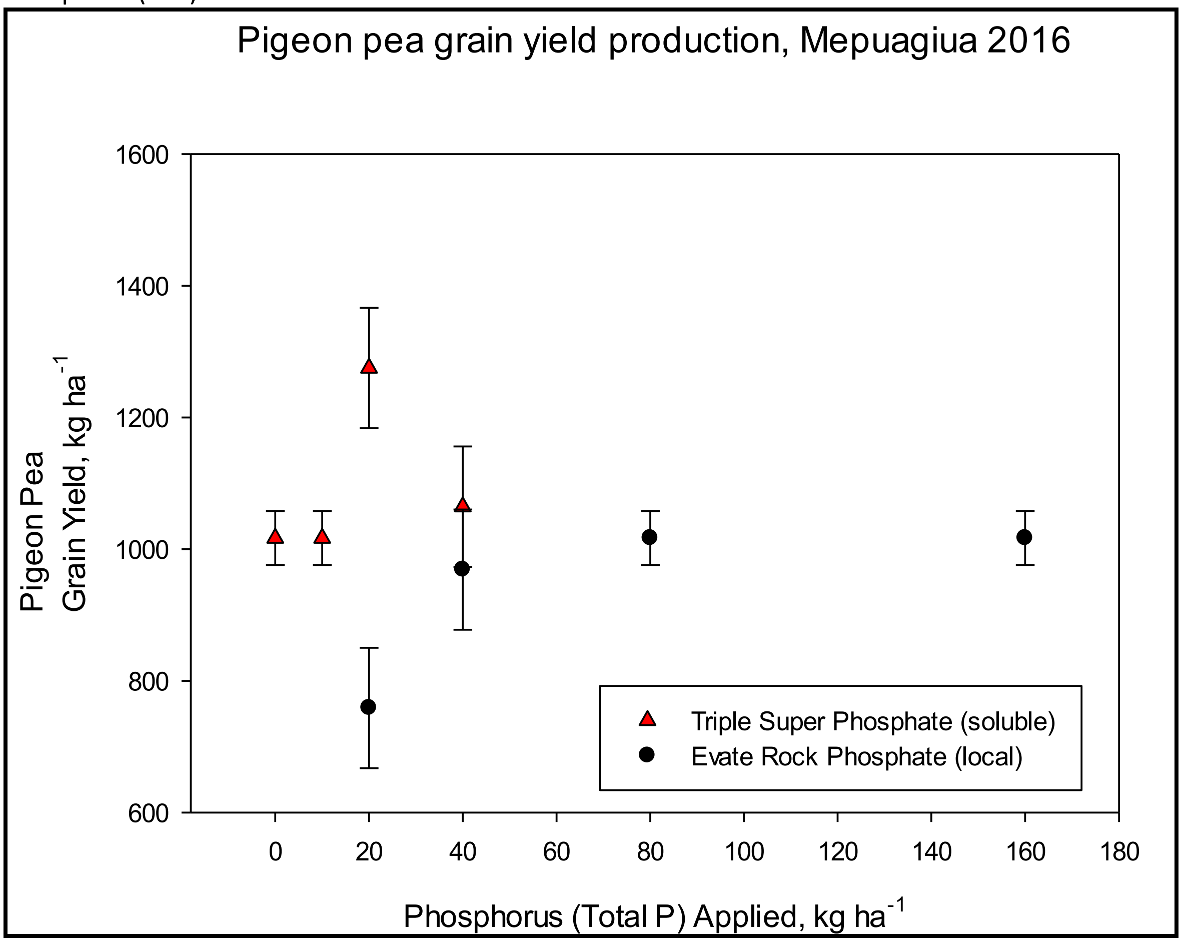


Treatments: (1) control (no limestone or fertilizer added), (2) limestone at 3 ton ha^{-1}, (3) fertilizer (20 kg N ha^{-1}, 35 kg P_2O_5 ha^{-1}, 12 kg K_2O ha^{-1}, 10 kg S ha^{-1} and (0.5 B + 2.5 Zn kg ha^{-1})) and (4) fertilizer as per (3) and limestone as per (2).

During the 2016 rainy season in Mozambique, we conducted an experiment on soils of the upper topographic position in Mepuagíua to (1) improve soil phosphorus availability with locally available rock phosphate and nitrogen availability through the use of pigeonpea (*Cajanus cajan*, L.) before planting bean, and (2) expand the bean growing area by increasing productivity on soils previously not considered suitable for bean. Available P levels are exceptionally low in soils of Mepuagíua. The use of pigeonpea in the season before planting bean rotation provided an opportunity to test the recently characterized Evate rock phosphate of Nampula province while also providing increased N availability for the subsequent bean crop. Triple super phosphate (TSP) was included as a comparison with the Evate rock phosphate.

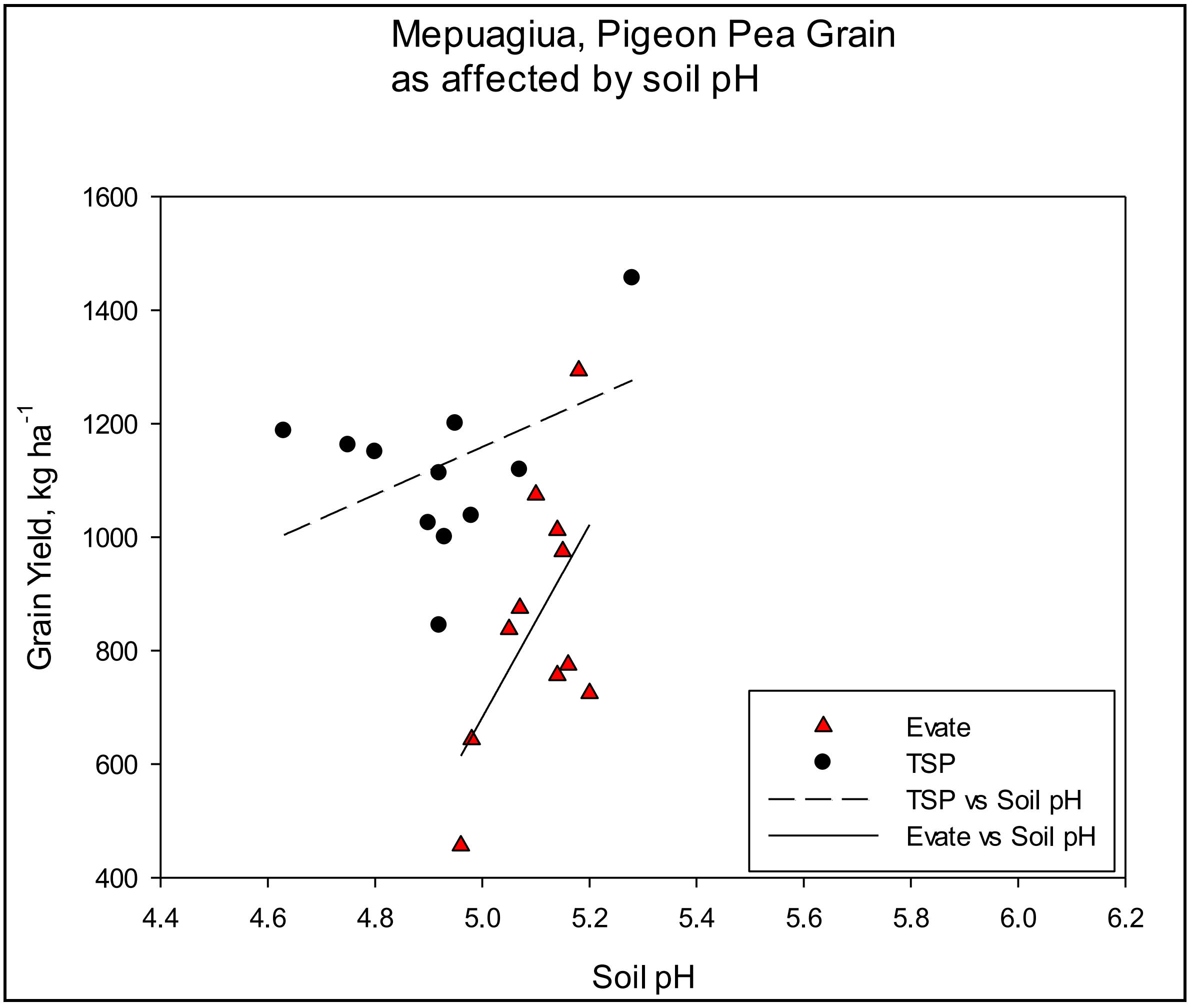
Results confirm the need for phosphate inputs for pigeonpea and indicate that the phosphate needs were substantial (Figure 3), requiring approximately 20 kg P ha^{-1} as TSP to reach maximum yield. Figure 2 also indicates that the Evate rock phosphate, in this specific crop – soil combination was surprisingly effective providing a maximum yield of approximately 1000 kg pigeonpea grain ha^{-1}, with an application of 80 kg ha^{-1} of total P added as Evate rock phosphate. The maximum yield with the addition of soluble phosphate was about 1200 kg pigeonpea grain ha^{-1}. Given the low NAC (neutral ammonium citrate) solubility of the Evate rock phosphate, this effectiveness of the rock phosphate was much higher than expected. This may be due to several factors, including low soil pH and the 6-8 month pigeonpea growing cycle. Common bean will be planted on these plots in January 2017.

Figure 2 — Response of Pigeonpea Grain Yield to Evate Rock Phosphate and Soluble Fertilizer Phosphate (TSP)



There was a clear grain yield increase with increased soil pH (Figure 3). Increased soil pH resulted from previous burning of residue and the consequent liming effect of plant biomass ash (soil pH ranged from 4.6 to 6.0), so improved calcium and magnesium availability may also have improved yields. The yields of 1200 kg ha^{-1} of pigeonpea during this unusually dry year document an excellent potential for pigeonpea to provide grain and a crop for future study.

Figure 3 — Increase in Pigeonpea Grain Yield where Soil pH Increased, Mepuagíua 2016



Consistent with AGRA's suggested protocol for identifying nutrient response, an 8-treatment experiment (randomized complete block with three replications) was conducted to identify critical nutrients for varieties recently released by IIAM's breeding program (NUA 45 and VTTT). These red clay (*Ekotxokwa*) and black with high clay content *(Intxokwa*) soils proved responsive to N, P, K and S fertilizers. Mean yield for NUA 45 was 180-940 kg ha^{-1} (median 570). For VTTT, average yield was significantly lower ($p<0.05$); mean yield was 140-1120 kg ha^{-1} (median 370). The highest yield for NUA 45 had N, P, K, S and Zn added, and for VTTT it was for NPKS (no Zn). Lack of rain in the dry season significantly impacted nutrient uptake and bean yield.

Soils in Gurúè vary over space and time. Good soil management strategies for maintaining soil productivity require understanding physical, chemical and biological properties, soil clustering (classification) criteria and key farmer's indicators of soil quality. An intensive training workshop was conducted to strengthen skills of Mozambican research and extension personnel in Gurúè in spatial data collection, conducting interviews to determine farmer knowledge of soils, soil classification and management, soil sampling and soil profile description. The workshop included use of spatial tools (GPS, GIS and remote sensing). Farmers from Invacula, Hulane and

Mepuagíua-Sede villages discussed soil classification. After discussion, a transect walk along catenae was taken to assess soil and other physical features and infrastructure.

Soils were sampled along a toposequence by individual farmers for focus group discussions about their properties, suitability for crops, and risk management strategies. Three soil profiles 150 cm along the toposequence were described and soil samples from different horizons were collected for laboratory analyses and soil classification. Farmers' perceptions revealed three different observable transition models along toposequence in Mepuagia: (1) Ekotxokwa, Epupo, Intxokwa; (2) Epupo, Ehava, Intxokwa and (3) Epupo, Epupo, Intxokwa (Figure 4).

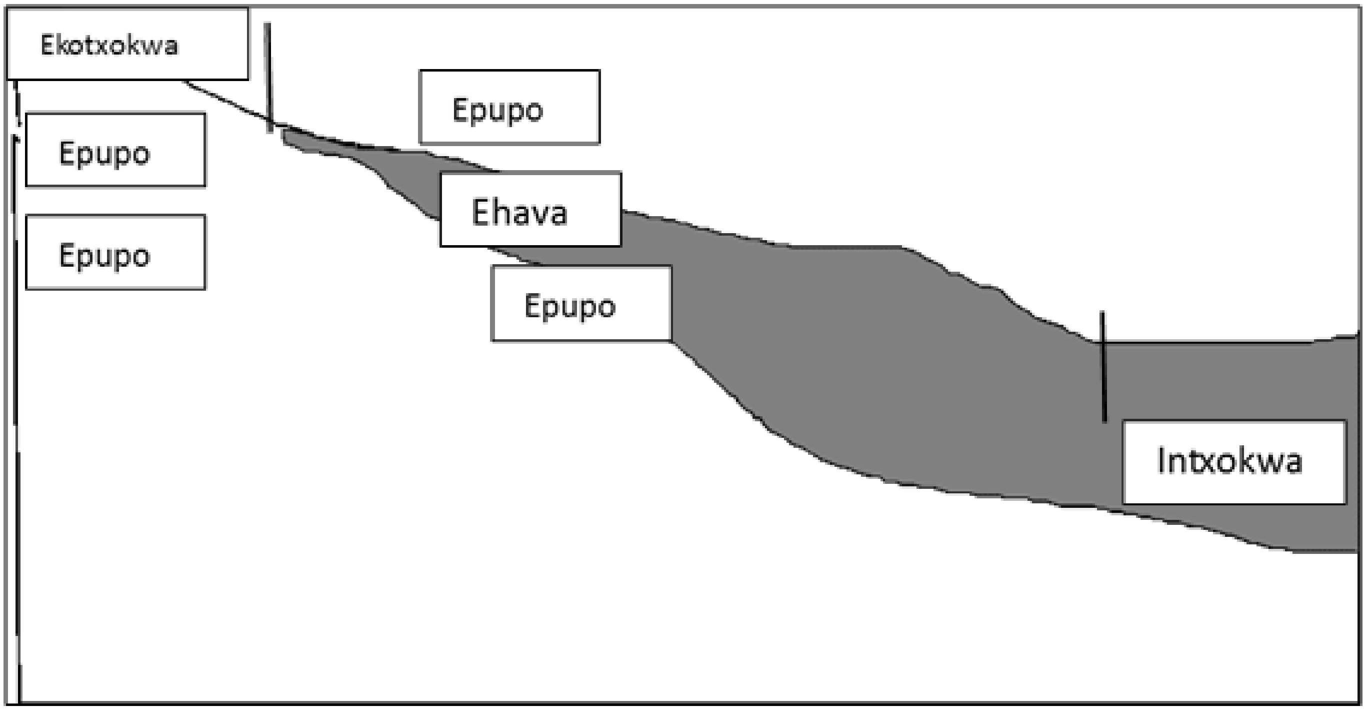
Table 2. Soil Types, Char. & Predom. Crops, & Approx. Planting Times along Catenae at Mepuagíua

	Characteristics			
Soil types	**Soil color, texture**	**Topographic position[1]**	**Soil fertility (common bean yield)**	**Predominant crop (month often planted)**
Ehava	**Reddish-brownish, sandy**	**Summit, Back slope**	**Low**	**Cassava, pineapple and sorghum, banana, and fava beans (Feb.-Mar.)[2]**
Epupu	**Medium black soil, less moist and less clay than Intxokwa**	**Summit, Back slope**	**Medium**	**Cassava (Jun.-Jul.), pineapple, sorghum, pigeon pea (Dec.), maize, common bean (Jan.)**
Ekotxokwa	**Reddish soil**	**Back slope, Foot slope**	**Low**	**Cassava, sorghum (Dec.), fava bean, maize (Nov.) and pineapple (Jul.)**
Intxokwa	**Dark black, always moist, high level of clay**	**Toe slope and flood plain (next to river streams)**	**High**	**Rice (Nov.-Dec.), beans(Jun.-Jul.) and sugar cane, vegetables (Feb.)**

[1] Topographic Position: Upper - highest position is summit, then back slope, foot slope, toeslope is lowest position.

[2] The rainy season typically begins in the month of October and ends in March. August and September are typically dry (burning occurs).

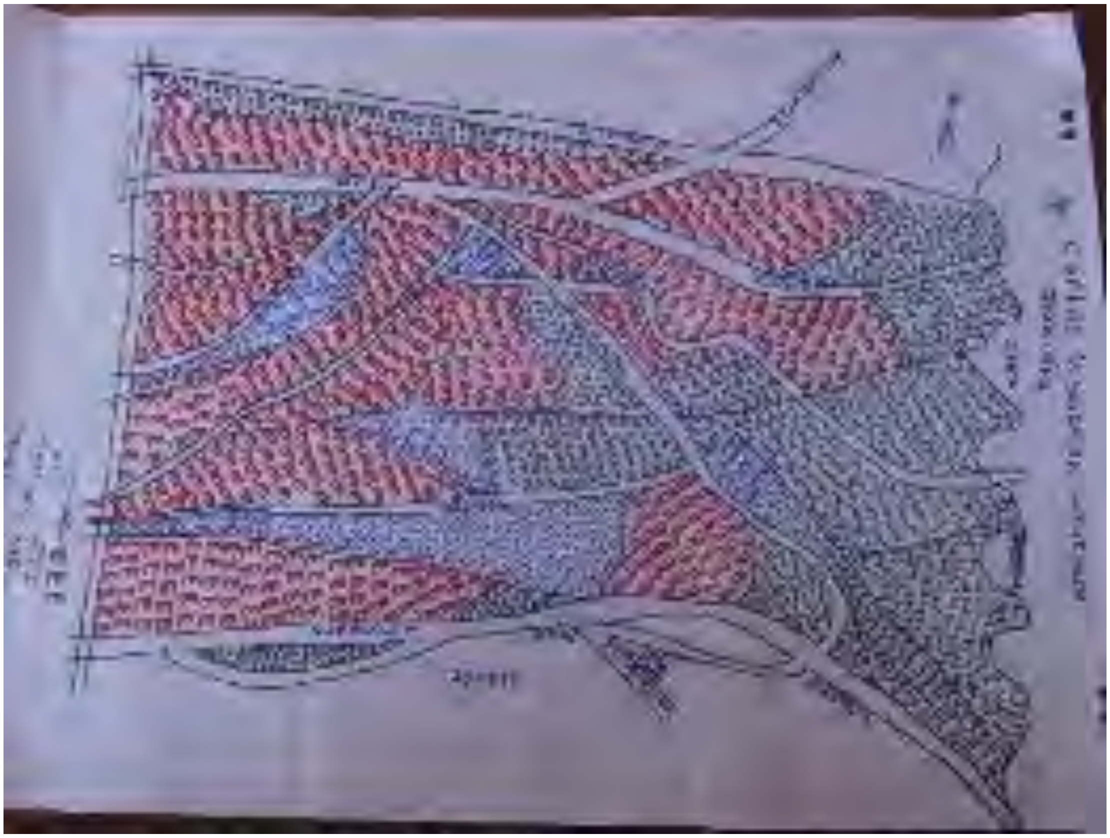
Figure 4. Dominant Soil along a Toposequence in Mepuagíua



Note: Ekotxokwa = red clay; Epupo = black with low clay content; Intxokwa = black with high clay content; Ehava = sandy, light color;

Photo 1. Focus Group Discussion about Major Soil Types in Mepuagíua

Photo 2. Soil Map Developed by the Community in Mepuagíua



Farmers in Gurúè distinguish different soil types (color, texture, stoniness) and their relationship with the toposequence (Figures 5 and 6). Their experiential knowledge enables them to match crops with soils, taking into account fertility and water demands of crops. In *Intxokwa* soil (black with relatively high clay content), major crops are rice, beans, maize, vegetables, and sugarcane. In the top slope, the dominant soil is *Ekotxokwa* (red with clay) for which major crops are sorghum, pigeonpea, cowpea, bambara nut, cassava, sweet potato, sesame, soybean and maize. Farmers share knowledge about variety, adaptability and soil suitability for a given crop.

Objective 4. Develop and Assess Effectiveness of Innovative Approaches for Dissemination

The lack of effective channels for delivering quality information about legume production to farmers and for gathering feedback for researchers and policymakers creates a serious constraint to enhancing bean production and improving soil quality in both Uganda and Mozambique. Researchers are identifying and testing innovative methods for making farmers aware of project-based recommendations to improve their soils and increase bean production, and ways that farmers can actively become involved in the process so that their knowledge and insights are integrated into project-based recommendations.

One innovative method tested used animated video messages delivered by smartphones to farmers. In July 2015, Sostino Mocumbe, (ISU M.S. student) carried out a field experiment in project areas of Mozambique that evaluated the effectiveness of delivery of animated video educational messages via smartphones to small groups of farmers. The topic was post-harvest storage of beans using sealed airtight jerry cans, to address a problem of insect damage reported by many farmers during earlier interviews. Results show that farmers learned more from the animated video, or a combination of animated video and traditional extension lecture/demonstration, than they did from the traditional extension lecture/demonstration alone. Farmers viewed the animated video in small groups, and were permitted to view it multiple times. Women learned at least as much as men from viewing the video. The animated video was produced by SAWBO and was presented in the local language. Results of Mocumbe's research have been presented to IIAM in Mozambique as well as two international conferences. Animated video messages were also shown to groups of farmers in both Masaka and Rakai in Uganda, and were evaluated positively by farmers. In Mozambique, at the time of training, farmers were asked about each step of the recommended process – would they do it? Do they think it would work? Are insect pests a post-harvest problem for them? A follow-up event six months after the training again gathered those who participated to ask if they had actually begun using the jerry can storage method.

In addition to development and testing of the use of animated videos, a second innovative method has been the use of Innovation Platform (IP) groups to both provide information and actual inputs/support. Innovation Platforms developed and supported by Makerere University and NARL in Masaka and Rakai in Uganda have been utilized extensively to assess farmer reactions to messages about bean production. More important, the IP farmers themselves, with guidance from project staff, have conducted their own farmer-managed field trials in multiple locations. Based upon these results, the IP farmers themselves have reached decisions about which new methods of bean production are appropriate and most valuable for them.

For 2017, an animated video message is being developed by SAWBO as a result of project activities focuses on research-based recommendations for growing beans. Principal recommendations include (1) soil testing for acidic soils; (2) use of quality seed; (3) increased density of planting; (4) use of a single seed per hole if seed is quality assured or certified; (5) row planting; (6) three weedings; and (7) use of chicken manure as fertilizer. This animation will also be in the local languages of farmers in both Uganda and Mozambique.

In both Uganda and Mozambique, NGO partners have been recruited to help evaluate the effectiveness of this SAWBO animated video. In Uganda, CEDO has agreed to help the project evaluate the video by showing it through CEDO's network of farmer-trainers. This will reach thousands of farmers in the area, and the CEDO training system gathers evaluation feedback using mobile devices. In Mozambique, CLUSA has agreed to show the SAWBO animated videos to its bean producing farmers in a similar way to gather their reactions and input. Additional participatory sharing and feedback is being developed with IITA and other projects in the area.

Soil analysis indicates that acid soils are a major limiting factor for bean production in both Uganda and Mozambique. Makerere University has developed a soil testing kit that can quickly assess soil acidity and a number of other soil factors limiting bean production. Through the IPs, farmers will gain access to soil testing kits, and printed materials/guides/posters explaining how and why to test soils will be produced. Printed decision guides and other materials will be produced based upon research-based findings and farmer participation in field demonstrations. Photos from the project's archive will be used to document key decision steps.

Because research has indicated the importance of support and 'buy-ins' from the entire value chain and information network, a launch event will be scheduled in 2017 in Uganda featuring a key radio station one-hour public event, the official launch of the smartphone animated videos, and testimonials by key local leaders/vendors/marketers/farmers/extension. While the IPs in Masaka and Rakai have played a major role in strengthening the entire value chain for bean production, this public event will alert many other farmers about the possibilities for bean production and collaboration with the IP.

Major Achievements

- Our researcher-led field experiments in Uganda have been successfully completed, and we are guiding the third season of community-based field trials (n=27) that enable farmers to learn about and test improved management practices and technologies, and discuss together.
- Our two multistakeholder bean Innovation Platforms in Masaka and Rakai continue to develop in membership size, diversity, enthusiasm and capability and as formal organizations, with a growing list of value chain member organizations (10+) and farmers (400+).
- Our researcher-led field experiments in Mozambique are progressing well, and will be completed by mid-2017. The project team (led by IIAM), has established a working relationship with the SEMEAR project (led by IITA) and CLUSA to collaborate in community-based field trials that will enable farmers to learn about and test improved management practices and technologies, and discuss together.
- Fifteen project team members presented papers and posters at the Joint 2016 PanAfrican Grain Legume and World Cowpea Conference, Livingstone, Zambia, 28th Feb. to 4th Mar.
- Three M.S. students have graduated from ISU, with M.S. students at other research institutions on track to complete their programs of study and research, and graduate on schedule.
- Research results are being prepared for publication in peer-reviewed journals and dissemination in regional/national practitioner and policy outlets in Africa
- Our analyses of weekly market prices and patterns, along with detailed costs of inputs, is contributing to refined development of decision support aids and training.
- Effective and efficient methods and media for information dissemination to intermediate and end users have been developed and assessed in a participatory manner, and are being refined.
- Capacity strengthening through applied research-based training has been successfully conducted.

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, interpretation and action. 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 graduated in December 2015. Thesis title: “Farmers’ Knowledge, Perceptions, and Socioeconomic Factors Influencing Decision Making for Integrated Soil Fertility Management Practices in Masaka and Rakai Districts, Central Uganda.” He is preparing on a paper for publication.
- Naboth Bwambale, Ph.D. student in Sustainable Agriculture and Sociology at Iowa State University, is planning his research. Dissertation title: “Influence of Social Structure and Power on social Learning and Adoption of Soil Fertility Management Practices.”
- Lance Goettsch completed requirements and graduated with an M.S. in Crop Production & Physiology, Iowa State University, in May 2016. Thesis title: “Improved Production Systems for Common Bean in South-Central Uganda. I. Liddugavu soil II. Limyufumyufu soil.”
- A manuscript was accepted for publication in African Journal of Agricultural Research, “Improved production systems for common bean on Phaeozem soil in south-central Uganda”, authored by L.H. Goettsch, A.W. Lenssen, R.S. Yost, E.S. Luvaga, O. Semalulu, M. Tenywa, and R.E. Mazur.
- Prossy Kyomuhendo, M.Sc. student in Soil Science at Makerere U., completed research in limiting nutrients and lime requirements for bean production in Leptosols and Luvisols. She defended her thesis, is preparing a paper for publication, and will graduate in January 2017.
- Stewart Kyebogola, M.Sc. student in Soil Science at Makerere U., completed research on the effect of integrating organic with inorganic fertilizers on bean yield on three contrasting soils in Masaka district. He submitted his thesis for examination and is preparing a paper for publication.
- Sostino Mocumbe, M.S. student in Communications at ISU, completed research, defended his thesis and graduated in August 2016. Thesis title: “Use of Animated Videos through Mobile Phones to Enhance Agricultural Knowledge and Adoption among Bean Farmers in Gúruè District, Mozambique.” He is preparing on a paper for publication.
- 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 Gurúè.
- 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, completed 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 Institutional Capacity

Strengthening grants which involved close collaboration among Makerere University, Uganda's National Agricultural Research Laboratories, the University of Hawaii, Iowa State University, and the Institute of Agriculture Research of Mozambique. They focused on combining indigenous and scientific knowledge of soils and recording, analyzing and interpreting GIS associated data with biophysical, economic, and social data. They also involved training scientists, technicians, students and district staff in GIS and geo-spatial skills for distinguishing toposequencing, chronosequencing and lithosequencing of soil catena. Through this field and lab-based activities, trainees acquired practical skills and detailed understanding of soil variability along selected landscapes of the catena using characteristics identified locally by farmers and related it to modern scientific approaches (GIS, geo-statistics 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. This activity assists in understanding and documenting the importance of geomorphology and topography of soils and their importance in farmers' classification of soils in project villages. Some relevant details are shown in Tables 1 and 2, and the discussion there. In August 2016, António Rocha (M.S. student at University of Hawaii) traveled from Mozambique to Uganda to discuss project research experiences with Ugandan project colleagues, to learn about differences in project implementation, results, and implications. He participated in interviews with innovative farmers to understand their knowledge of soils and crop management practices and outcomes. He is comparing these findings with the Mozambique experience.

Human Resource and Institution Capacity Development

Short-Term Training

Innovation Platform

Purposes of Training – IP strengthening, agronomic practices, marketing

Type of training. Soil classification; Planting of beans; Disseminate soil characterization and beans research findings; formation of primary cooperatives; Results from economic analysis of triple bagging; experiences from farmers hosting the 2015B bean trials; Review IP constitution; results from the bean trials & contract farmers 2015; plan activities for 2016; Harvesting of beans; Organize bean farmers for contract farming with CEDO for 2016A season; introduce crop insurance; Introduction to biogas use; Pesticide use training; External evaluation of the beans project & the IP process; introduce the pre-cooked beans project; agro-chemical handling; Seed selection and processing, pest and disease identification; Strategic planning meeting between Yash commodities Ltd and farmer business organizations over finding market for the beans produced by farmers; Post-harvest handling and beans marketing; Harvesting of beans; Preparation of farmers for planting of beans for the 2016B season trials.

Country Benefiting: Uganda
Location and dates of training: 37 events in Masaka and Rakai, 10/2015–09/2106
Number receiving training (by gender): – 1,088 females, 863 males
Home institution(s): – Makerere University and National Agric. Research Lab.
Institution providing training – MAK, NARL, CEDO, MAMEDICOT, Agro-dealers, ISU, U. Illinois, MSU, UC-Davis, Kilimo Trust

Training on Agro-Technology of Bean Production and Post-Harvest Handling
Purpose of Training: strengthen farmer's knowledge on best agronomic practices, including soil

and pest management
Type of training: Extension demonstration, farmer discussion, PowerPoint and animated video presentation
Country Benefiting: Mozambique
Location and dates of training: Gurúè, Mozambique
Number receiving training (by gender): men 57, women 21
Home institution(s): – Institute of Agricultural Research of Mozambique
Institution providing training: Institute of Agricultural Research of Mozambique in partnership with Center for Interdisciplinary Studies and Development (CEID)

Promotion of Soil Fertility Management: Summary of Soil Health Research Findings
Purpose of Training: Create awareness about soil fertility problems and build broader partnership among agricultural practitioners
Type of training: Class presentation of major research achievements, fertilizer use computation and communication strategy for farmers
Country Benefiting: Mozambique
Location and dates of training: Gurúè, Mozambique
Number receiving training (by gender): – men 47, women 23
Home institution(s): – Institute of Agricultural Research of Mozambique
Institution providing training – Institute of Agricultural Research of Mozambique in partnership with Center for Interdisciplinary Studies and Development (CEID)

D. Training on Soil Profile Description, Interview Technique for Capturing Soil Information, Soil Sampling Strategies and Coding
Purpose of Training: Building skills among collaborating partners on soil data gathering and record keeping for soils description and classification
Type of training: Class presentation and field exercise
Country Benefiting: Mozambique
Location and dates of training: Gurúè, Mozambique
Number receiving training (by gender): – men 6, women 3
Home institution(s): –
Institution providing training – Institute of Agricultural Research of Mozambique

<u>**Degree Training**</u>
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: Ph.D.
Program Areas or Discipline: Graduate Program in Sustainable Agriculture *and* Sociology
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Host Country Institution Benefitting from Training: Makerere University
Thesis Title/Research Area: Farmers' Perceptions, Knowledge and Socioeconomic Factors

Influencing Decision Making for Integrated Soil Fertility Management
Start Date: August 2016 (following M.S. program Jan. 2014 – Dec. 2015)
Projected Completion Date: May 2019
Training Status: (active, completed, pending, discontinued or delayed): Active

Trainee #2
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
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Host Country Institution Benefitting from Training: Makerere University
Thesis Title/Research Area: Limiting Nutrients and Lime Requirements for Bean Production
Start Date: January 2014
Projected Completion Date: January 2017
Training Status: (active, completed, pending, discontinued or delayed): Active

Trainee #3
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
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Host Country Institution Benefitting 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: January 2017
Training Status: (active, completed, pending, discontinued or delayed): Active

Trainee #4
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
Is trainee a USAID Participant Trainee and registered on TraiNet? No

Host Country Institution Benefitting 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 2017
Training Status: (active, completed, pending, discontinued or delayed): Active

Trainee #5
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
Is trainee a USAID Participant Trainee and registered on TraiNet? Yes
Host Country Institution Benefitting from Training: 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: August 2017
Training Status: (active, completed, pending, discontinued or delayed): Active

Trainee #6
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
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Host Country Institution to Benefit from Training: Makerere University
Thesis Title/Research Area: Improved production systems for common bean in south-central Uganda. I. Liddugavu soil II. Limyufumyufu soil.
Start Date: August 2013
Projected Completion Date: May 2016
Training Status: (active, completed, pending, discontinued or delayed): Completed

Trainee #7
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
Is trainee a USAID Participant Trainee and registered on TraiNet? Yes (was)
Host Country Institution to Benefit: Institute of Agricultural Research of Mozambique (IIAM)
Thesis Title/Research Area: Socio-technical 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): Completed

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, 1135 women and 973 men have benefited and one woman is benefitting from long-term training.

Explanation for Changes

We significantly exceeded the planned number of short-term training participants/beneficiaries in demand-driven activities.

Self-Evaluation and Lessons-Learned

Our collegial multidisciplinary multi-country team is responsive in multi-way 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 supporting the important partnership opportunities provided by Bean Innovation Platforms in Uganda and SEMEAR project in Mozambique to advance our work and long term positive impacts.

Scholarly Accomplishments

<u>Theses completed, publications prepared or submitted for peer review:</u>

Bwambale, Naboth. 2015. “Farmers’ Knowledge, Perceptions, and Socioeconomic Factors Influencing Decision Making for Integrated Soil Fertility Management Practices in Uganda.” (M.S. thesis, Iowa State University)

Goettsch, Lance. 2016. “Improved Production Systems for Common Bean in South-Central Uganda. I. Liddugavu soil II. Limyufumyufu soil.” (M.S. thesis, Iowa State University)

Goettsch L.H., A.W. Lenssen, R.S. Yost, E.S. Luvaga, O. Semalulu, M. Tenywa, and R.E. Mazur. “Improved production systems for common bean on Phaeozem soil in south-central Uganda” (accepted for publication in *African Journal of Agricultural Research*)

Sostino Mocumbe. 2016. “Use of Animated Videos through Mobile Phones to Enhance Agricultural Knowledge and Adoption among Bean Farmers in Gúruè District, Mozambique.” (M.S. thesis, Iowa State University)

Scientific papers and posters also prepared and presented at the Joint 2016 PanAfrican Grain Legume and World Cowpea Conference, AVANI Victoria Falls Resort and Conference Center. Livingstone, Zambia, 28th February to 4th March 2016 (in alphabetical order by lead author):

Bulyaba R & Lenssen A. "Nutritional Composition of Pulse Legume Crops and the Impact of Leaf Removal on Yield"

Bwambale N, Mazur R, & Abbott E. "Adoption of Integrated Soil Fertility Management in Central Uganda: Influence of perceived practice characteristics and socioeconomic factors"

Goettsch L, Lenssen A, Mazur R, Yost R, Semalulu O, & Tenywa M. "Improved Production Systems for Common Bean in South Central Uganda"

Kyebogola S, Semalulu O, Tenywa M, Lenssen A & Mazur R. "Effect of integrating organic with inorganic fertilizers on bean yield on three contrasting soils"

Kyomuhendo P, Lenssen A, Tenywa M, Semalulu O & Mazur R. "Improving rapid assessment of production constraints for common bean: results from a biweekly survey in Masaka, Uganda"

Kyomuhendo P, Tenywa M, Semalulu O, Lenssen A, Yost R and Mazur R. "Limiting nutrients for bean production on three contrasting soils in Uganda."

Luvaga E, Mazur R, Semalulu O, Tenywa M, & Salegua V. "Determinants of Smallholder Participation in Common Bean Markets in Uganda and Mozambique"

Maria R, Mazur R, Americano J, Yost R, Waite U, Salegua V. "Participatory Action Research to Improve Farmer Decision Making in Integrated Soil Fertility Management in Mozambique"

Mazur R, Miiro R, Salegua V, Abbott E & Luvaga E. "Farmer Decision Making Strategies for Improved Soil Fertility Management in Uganda and Mozambique"

Miiro R, Tenywa M, Mazur R, Semalulu O, Matege J, Kyebogola S, Kyomuwendo P, Kabango F, Kasujja M, Katabalwa C, Mugagga K, Luswata C & Kyambadde T, Lutaya Y, Nkonge J. "Private Sector Led Agricultural Innovation Platforms: Lessons in Formation and Operationalization"

Mocumbe S, Abbott E, Mazur R, Bello Bravo J, & Pittendrigh B. "Animated Videos on Smartphones for Training Farmers to Improve Bean Storage Practices: A Field Experiment in Gurúè, Mozambique"

Semalulu O, Tenywa M, Yost R, Mazur R, Luswata C, Kyebogola S, Kabango F & Smith C. "Comparison of the Indigenous Soil Classification System with the FAO and Soil Taxonomy Systems"

Tenywa M, Kyomuhendo P, Semalulu O, Zebosi B, Lenssen A, Kyebogola S, Yost R & Mazur R. "Liming Requirements for Two Contrasting Soils in the Lake Victoria Crescent"

Progress in Implementing Impact Pathway Action Plan

The project team has made excellent progress in implementing the impact pathway action plan: (1) project research activities have largely determined soil and crop system improvements to recommend, and refined appropriate models of farmer decision making strategies; (2) we have been compiling materials for development of diagnostic and decision support aids using observable characteristics that enable farmers to make site-specific management decisions; and (3) we have been assessing the appropriateness of existing methods and media for information

Milestones

October 1, 2015 – March 31, 2016

Feed the Future Innovation Lab for Collaborative Researchon Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: October 1, 2015-- March 31, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by April 1, 2016

Project Title: **SO2.1 - Farmer Decision Making Strategies for Improved Soil Fertility Management in Maize-Bean Production 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	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**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 Reports farmers' partic. in field experiments-Gurue	**X**	**X**		**X**	**X**		**0**			**0**			**0**			**X**	**X**	
1.2 Reports farmers' knowledge, attitudes, practices-Guru	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 2:	**Develop and Refine Models about Smallholder Bean Farmers' Decision Making**																	
2.1 Reports on farmers' resources & actions	**X**	**X**		**0**			**0**			**X**	**X**		**0**			**X**	**X**	
2.2 Reports on activities & successes of IPs	**0**			**0**			**0**			**X**	**X**		**X**	**X**		**0**		
2.3 Models of farmer decision making	**0**			**0**			**0**			**0**			**0**			**0**		
2.4 Recommendations for training & support	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 3:	**Develop and Validate Diagnostic and Decision Support Aids**																	
3.1 Completed field studies bean crop mgmt.	**0**			**0**			**0**			**X**	**X**		**X**	**X**		**X**	**X**	
3.2 Recommendations for bean crop mgmt. systems	**X**	**X**		**0**			**0**			**X**	**X**		**X**	**X**		**X**	**X**	
3.3 Participatory assessment of preliminary DDSA	**0**			**0**			**0**			**0**			**0**			**0**		
3.4 Refined & field tested DDSA	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 4:	**Develop and Assess Effectiveness of Innovative Approaches for Dissemination**																	
4.1 Analyses effectiveness media & training	**X**	**X**		**0**			**X**	**X**		**0**			**0**			**0**		
4.2 Message & media for dissem. 1st DDSA	**X**	**X**		**0**			**X**	**X**		**0**			**0**			**0**		
4.3 Particip. assess. message & media 1st DDSA	**0**			**0**			**0**			**X**	**X**		**0**			**0**		
4.4 Foci & strategy dev. messages/media more DDSA	**0**			**X**	**X**		**0**			**X**	**X**		**0**			**0**		
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.*

April 1, 2016 – September 30, 2016

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: April 1, 2016 -- September 30, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2016

Project Title: **SO2.1 - Farmer Decision Making Strategies for Improved Soil Fertility Management in Maize-Bean Production 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	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**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 Reports farmers' partic. in field experiments-Gurue	**0**			**0**			**0**			**0**			**0**			**0**		
1.2 Reports farmers' knowledge, attitudes, practices-Gur	**X**	**X**		**X**	**X**		**0**			**0**			**0**			**X**	**X**	
1.3	**0**			**0**			**0**			**0**			**0**			**0**		
1.4	**0**			**0**			**0**			**0**			**0**			**0**		
1.5	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 2:	**Develop and Refine Models about Smallholder Bean Farmers' Decision Making**																	
2.1 Reports on farmers' resources & actions	**0**			**0**			**0**			**0**			**0**			**0**		
2.2 Reports on activities & successes of IPs	**0**			**0**			**0**			**0**			**0**			**0**		
2.3 Models of farmer decision making	**X**	**X**		**0**			**0**			**X**	**X**		**0**			**X**	**X**	
2.4 Recommendations for training & support	**X**	**X**		**X**	**X**		**0**			**X**	**X**		**X**	**X**		**X**	**X**	
2.5	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 3:	**Develop and Validate Diagnostic and Decision Support Aids**																	
3.1 Completed field studies bean crop mgmt.	**0**			**0**			**0**			**0**			**0**			**0**		
3.2 Recommendations for bean crop mgmt. systems	**0**			**0**			**0**			**0**			**0**			**0**		
3.3 Participatory assessment of preliminary DDSA	**0**			**0**			**0**			**X**	**X**		**X**	**X**		**X**	**X**	
3.4 Refined & field tested DDSA	**X**	**X**		**X**	**X**		**0**			**X**	**X**		**X**	**X**		**X**	**X**	
3.5	**0**			**0**			**0**			**0**			**0**			**0**		

Objective 4:	**Develop and Assess Effectiveness of Innovative Approaches for Dissemination**																	
4.1 Analyses effectiveness media & training	**0**			**0**			**0**			**0**			**0**			**0**		
4.2 Message & media for dissem. 1st DDSA	**0**			**0**			**0**			**0**			**0**			**0**		
4.3 Particip. assess. message & media 1st DDSA	**X**	**X**		**0**			**X**	**X**		**X**	**X**		**X**	**X**		**X**	**X**	
4.4 Foci & strategy dev. messages/media more DDSA	**X**	**X**		**X**	**X**		**X**	**X**		**X**	**X**		**X**	**X**		**X**	**X**	
4.5	**0**			**0**			**0**			**0**			**0**			**0**		

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

Overall 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. number	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	8	4	6	0
	Total number by sex	5	5	5	7	6	6	8	0	8	4	6	0
	Number of women	1	1	1	1	1	1	1	0	1	0	1	0
	Number of men	4	4	4	6	5	5	7	0	7	4	5	0
	Total number by New/continuing	0	0	0	7	6	6	8	0	8	4	6	0
	New	0	0	0	1	1	1	0	0	0	0	0	0
	Number of women	0	0	0	0	0	0	0	0	0	0	0	0
	Number of men	0	0	0	0	0	0	0	0	0	0	0	0
	Continuing	0	0	0	6	5	5	8	0	8	4	6	0
	Number of women	0	0	0	0	0	0	0	0	1	0	1	0
	Number of men	0	0	0	0	0	0	0	0	7	0	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	0	0	0	0	0	0	0	0	0
	Total number	7	5	5	8	8	172	71	0	2138	43	235	0
	Number of women	2	2	2	3	3	64	26	0	1141	21	121	0
	Number of men	5	3	3	5	5	108	45	0	997	22	114	0
	Numbers by Type of individual	7	5	5	8	8	172	71	0	2138	43	235	0
	Producers	0	0	0	0	0	57	14	0	2008	14	170	0
	Number of women	0	0	0	0	0	0	0	0	1084	0	100	0
	Number of men	0	0	0	0	0	0	0	0	924	0	70	0
	People in government	7	5	5	8	8	78	43	0	60	15	28	0
	Number of women	0	0	0	0	0	0	0	0	26	0	8	0
	Number of men	0	0	0	0	0	0	0	0	34	0	20	0
	People in private sector firms	0	0	0	0	0	17	6	0	40	6	17	0
	Number of women	0	0	0	0	0	0	0	0	20	0	6	0
	Number of men	0	0	0	0	0	0	0	0	20	0	11	0
	People in civil society	0	0	0	0	0	20	8	0	30	8	20	0
	Number of women	0	0	0	0	0	0	0	0	11	0	6	0
	Number of men	0	0	0	0	0	0	0	0	19	0	14	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	2	2	7	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	1	0	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	1	0	1	2	4	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	1	0

Notes:

These indicators are developed under the Feed the Future Monitoring System. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

ISU

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**

Institution 1: **Iowa State University**

Indic. number	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	2	2	2	2	0	2	1	1	0
	Total number by sex	2	2	2	2	2	2	2	0	2	1	1	0
	Female												
	Male	2	2	2	2	2	2	2		2	1	1	
	Total number by New/continuing	0	0	0	2	2	2	2	0	2	1	1	0
	New												
	Number of women												
	Number of men												
	Continuing				2	2	2	2		2	1	1	
	Number of women												
	Number of men									2		1	
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	0	0	0	0	0	0	0
	Number of women												
	Number of men												
	Numbers by Type of individual	0	0	0	0	0	0	0	0	0	0	0	0
	Producers												
	Number of women												
	Number of men												
	People in government												
	Number of women												
	Number of men												
	People in private sector firms												
	Number of women												
	Number of men												
	People in civil society												
	Number of women												
	Number of men												
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. Disaggregate where applicable. Just providing 'totals' will not be approved.

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Hawaii

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

Institution 2: University of Hawaii

Indic. number	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 tr	0	0	0	1	1	1	1	0	1	1	1	0
	Numbers by Sex	1	0	0	1	1	1	1	0	1	1	1	0
	Number of women												
	Number of men	1	0	0	1	1	1	1		1	1	1	
	Numbers by New/Continuing									1		1	
	New				1	1	1						
	Number of women												
	Number of men												
	Continuing							1		1	1	1	
	Number of women												
	Number of men									1		1	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Numbers by Sex	0	0	0	0	0	2	0	0	0	0	0	0
	Number of women												
	Number of men						2						
	Numbers by Type of individual	0	0	0	0	0	2	0	0	0	0	0	0
	Producers												
	Number of women												
	Number of men												
	People in government						2						
	Number of women												
	Number of men												
	People in private sector firms												
	Number of women												
	Number of men												
	People in civil society												
	Number of women												
	Number of men												
7	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:
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Illinois

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**

Institution 3: **University of Illinois**

Indic. number	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 tr	0	0	0	0	0	0	0	0	0	0	0	0
	Total number by sex	0	0	0	0	0	0	0	0	0	0	0	0
	Female												
	Male												
	Total number by New/continuing	0	0	0	0	0	0	0	0	0	0	0	0
	New												
	Number of women												
	Number of men												
	Continuing												
	Number of women												
	Number of men												
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Total number	0	0	0	0	0	1	1	0	0	0	0	0
	Number of women												
	Number of men						1	1					
	Numbers by Type of individual	0	0	0	0	0	1	1	0	0	0	0	0
	Producers												
	Number of women												
	Number of men												
	People in government						1	1					
	Number of women												
	Number of men												
	People in private sector firms												
	Number of women												
	Number of men												
	People in civil society												
	Number of women												
	Number of men												
7	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:
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Makerere

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

Institution 4: Makerere University

Indic. number	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 tr	0	0	0	3	3	3	4	0	4	2	3	0
	Total number by sex	2	2	2	3	3	3	4	0	4	2	3	0
	Number of women	1	1	1	1	1	1	1		1		1	
	Number of men	1	1	1	2	2	2	3		3	2	2	
	Total number by New/continuing	0	0	0	3	3	3	4	0	4	2	3	0
	New												
	Number of women												
	Number of men												
	Continuing				3	3	3	4		4	2	3	
	Number of women									1		1	
	Number of men									3		2	
2	term training												
	Total number	3	3	3	3	3	68	20	0	975	20	202	0
	Number of women	1	1	1	1	1	29	10		544	10	105	
	Number of men	2	2	2	2	2	39	10		431	10	97	
	Numbers by Type of individual	3	3	3	3	3	68	20	0	975	20	202	0
	Producers						29	4		930	4	150	
	Number of women									520		90	
	Number of men									410		60	
	People in government	3	3	3	3	3	21	6		15	6	19	
	Number of women									10		5	
	Number of men									5		14	
	People in private sector firms						8	4		20	4	15	
	Number of women									10		5	
	Number of men									10		10	
	People in civil society						10	6		10	6	18	
	Number of women									4		5	
	Number of men									6		13	
7	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	4	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance											1	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance											2	
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance											1	

Notes:

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NARL

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**

Institution 5: **National Agricultural Research Laboratories**

Indic. number	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 tr	0	0	0	1	0	0	1	0	1	0	1	0
	Total number by sex	0	1	1	1	0	0	1	0	1	0	1	0
	Female												
	Male		1	1	1			1		1		1	
	Total number by New/continuing	0	0	0	1	0	0	1	0	1	0	1	0
	New												
	Number of women												
	Number of men												
	Continuing				1			1		1		1	
	Number of women												
	Number of men									1		1	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Total number	1	2	2	2	2	69	20	0	976	20	30	0
	Number of women		1	1	1	1	29	10		544	10	15	
	Number of men	1	1	1	1	1	40	10		432	10	15	
	Numbers by Type of individual	1	2	2	2	2	69	20	0	976	20	30	0
	Producers						28	10		930	10	20	
	Number of women									520		10	
	Number of men									410		10	
	People in government	1	2	2	2	2	22	6		15	6	6	
	Number of women									10		2	
	Number of men									5		4	
	People in private sector firms						9	2		20	2	2	
	Number of women									10		1	
	Number of men									10		1	
	People in civil society						10	2		11	2	2	
	Number of women									4		1	
	Number of men									7		1	
7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	1	1	1	1	1	0	1	0	1	1	1	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	1	1	1	1	1							
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance							1		1	1	1	
	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. Disaggregate where applicable. Just providing 'totals' will not be approved.

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IIAM

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**

Institution 6: **Institute of Agricultural Research of Mozambique**

Indic. number	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 tr	0	0	0	0	0	0	0	0	0	0	0	0
	Total number by sex	0	0	0	0	0	0	0	0	0	0	0	0
	Female												
	Male												
	Total number by New/continuing	0	0	0	0	0	0	0	0	0	0	0	0
	New												
	Number of women												
	Number of men												
	Continuing												
	Number of women												
	Number of men												
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Total number	3	0	0	3	3	32	30	0	187	3	3	0
	Number of women	1	0	0	1	1	6	6		53	1	1	
	Number of men	2	0	0	2	2	26	24		134	2	2	
	Numbers by Type of individual	3	0	0	3	3	32	30	0	187	3	3	0
	Producers									148			
	Number of women									44			
	Number of men									104			
	People in government	3	0	0	3	3	32	30		30	3	3	
	Number of women									6		1	
	Number of men									24		2	
	People in private sector firms												
	Number of women												
	Number of men												
	People in civil society									9			
	Number of women									3			
	Number of men									6			
7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	1	0	0	1	1	1	1	0	1	1	2	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	1	0	0	1	1	1	1		1		1	
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance										1	1	
	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. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

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

Short Title: Grain Legume Value Chain Initiative

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

Abstract of Research and Capacity Strengthening Achievements

The third year of the project has been trying in scheduling events to accomplish project training sessions and research dissemination meetings. Five undergraduate students from Zambia and two Masters students from Malawi have completed their programs. One of the Masters' thesis from Malawi focused on the industry situation of common beans in Malawi and the other Masters' thesis used the data from the project's bean consumption survey to examine consumer choice of dry common beans. MAB students have been recruited for all three host countries and the last cohort will start the MAB program in January 2017. We have successfully managed relationships with principal leaders of the grain legume industry in Malawi, specifically the Grain and Legume Association and Women in Agribusiness in Sub-Saharan Africa, to work on improving understanding and operation of the grain legume value chain. An industry training workshop was held in Malawi in April 2016 to discuss strategies for improving relationships along the chain. We have started planning for the First Malawi Bean Recipe Contest, which will be held in early FY2017, and similar contests are expected to follow in Tanzania and Zambia. The fourth year of the program is dedicated to completing the research component of the project objectives, disseminating those research findings, and building capacity among legume chain members.

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 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 the factors and their extent of shaping consumer choices to engage industry stakeholders and public institutions 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 the 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: 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.

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:

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

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:

$$u_{ji} = V_{ji} + \varepsilon_{ji} \tag{2}$$

Results, Achievements and Outputs of Research

- To help facilitate these analyses, computers with analytical software installed on them were sent to all new students.
- All countries have access to the survey data and are starting to analyze the data.
- A Masters student from Malawi has completed her thesis "Consumer Choice of Dry Common Beans in Malawi: Case of Lilongwe City" using the primary survey data. A policy brief from this thesis has been drafted and will be published on the project website in FY2017.
- The Kansas State University (K-State) research team has conducted a study on the cross country differences in factors influencing bean consumption. Report and policy briefs based on this research study will be posted on the website in FY2017.

<u>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.</u>

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

- Malawi and Tanzania have completed drafts for their situational analyses and prepared policy briefs on these analyses. These reports and briefs will be posted on our project website in early FY2017.
- The recruited students and research team in Zambia have drafted a research report on the following research project, "Situation Analysis of Bean Consumers in Zambia"
  - The report has been shared with researchers at K-State and the report will be finalized by the K-State team
- A draft of this final Zambia report is expected by the end of December 2016.

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

No change in proposed methods and approaches in technical report

Results, Achievements and Outputs of Research

- Each Host Country has recruited at least one male and one female student from each of the focus countries
    - Zambia experienced some difficultly recruited Master level students but were very successful in recruited senior level undergraduate students, who are each responsible for completing an honors research study to graduate. These undergraduate students will be using data from the bean consumption survey to achieve some of the project objectives. All five undergraduate students have successfully completed their programs in September 2016.
- Each country has recruited one student for the Master of Agribusiness program with Zambia and Malawi each recruiting two students.
- An industry training workshop was held in Malawi in April 2016, in which the structure and governance of the legume supply chain were discussed. This workshop lead to the idea generation and planning of the First Malawi Bean Recipe Contest, which makes beans center of plate.
    - K-State PI in collaboration with key groups in Malawi's legume industry has started the planning process for this contest. The purpose of this contest is to discover creative recipes that positions beans as center of plate, easy to cook, and fits nicely into the urban resident's meal structure. Meeting this contest objective would increase the consumptions of beans and improve market conditions for producers and the bean supply chain. The contest is scheduled to occur in the first half of 2017 and similar contests are expected to follow in Tanzania and Zambia.

Major Achievements

- Strengthened the relationship with key industry groups in Malawi. Our relationship with these groups is vital to the success of our outreach programs in Malawi, since they have a wealth of knowledge and expertise in the legume industry and have deep networks within and outside the country to legume chain members, stakeholders and consumers. These groups provide us with advice, guidance, and insights into the industry's challenges and opportunities. They help support us in delivering effective and relevant programs that will improve value chain alliances and wealth distribution along the chain. These groups play an important role in how the results from the consumer bean survey will impact or benefit the supply chain partners and they will help us to develop specific markets for the bean varieties that meet consumer preferences.
- Planned the First Malawi Bean Recipe Contest for 2017. The purpose of the contest is to create recipes that shift beans to the center of the plate instead of being a relish or sauce

but are easy to incorporate into Malawian's lifestyles particularly urban residents, who are looking for convenience in their diet. K-State PI is collaborating with industry leaders in Malawi to plan and execute the contest in the early half of 2017. Similar contests will be planned for Zambia and Tanzania.

- Delivered a 2-day industry training workshop for bean producers and traders in Malawi. The main outcome of the workshop was developing a collaborative mindset that everyone providing a valuable service along the chain deserves to be rewarded and it is everyone's responsibility to find the information they need to enhance their transactional success. Other topics discussed during this session were the difficulty in acquiring improved seed and the importance of accurate recording keeping for individual member and organization performance.
- Conducted a cross-country analysis of the factors influencing bean consumption in the three host countries. Differences exist between the three countries but gravy quality and cultural beliefs are important factors in bean consumption for all three countries. Price and bean size are factors influencing bean consumption in Zambia.

Research Capacity Strengthening

- Scientific Research and Publication Training. This training session was specifically developed for faculty and graduate students at Lilongwe University of Agriculture and Natural Resources (LUANR). K-State PIs lead the 3-day training session, which focused on research ethics and the publication process. Space was limited to 60 participants for the training, although 75 people expressed interest in the training. Of the 60 participants (44 males and 16 females), the majority were graduate students since faculty were involved in student exams. Overall, participants considered the workshop relevant to their professional development and approach to research. The main comments received from the participants was the desire to increase the duration of the training and have more hands-on activities. Participants also expressed an interest to have more faculty members present at the training because they believed faculty would benefit from the mentoring sections of the training program.

Human Resource and Institution Capacity Development

<u>Training Activity #1</u>

Purpose of Training: This training program is designed to enhance legume industry stakeholder's capacity in the development and management of their supply chain relationships.
Type of training: Supply Chain Management
Country Benefiting: Malawi
Location and dates of training: Lilongwe, Malawi, April 28-29, 2016
Number receiving training: 43 participants (21 males and 22 females)
Institution providing training or mechanism: K-State

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 2016/2017. The support provided will be partial of the total cost of their training cost.

	Student	Student
First and Other Given Names	Wupe	Dinah Tuwanje
Last Name	Msukwa	Banda
Citizenship	Malawian	Malawian
Gender	Male	Female
Training Institution	Lilongwe University of Agriculture and Natural Resources (LUANAR)	Lilongwe University of Agriculture and Natural Resources (LUANAR)
Supervising CRSP PI	Dr. Lawrence D. Mapemba	Dr. Lawrence D. Mapemba
Degree Program for training	Masters	Masters
Program Areas or Discipline	Agricultural Economics	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	N/A
Host Country Institution to Benefit from Training	LUANAR	LUANAR
Thesis Title/Research Area	Household Demand for Common Beans in Lilongwe District of Malawi: A Censored Regression Approach	Assessing the importance of common bean attributes in determining market price in Lilongwe district

Start Date	2015	2015
Projected Completion Date	December 2016	December 2016
Training status (Active, completed, pending, discontinued or delayed)	Active	Active
Type of Legume Innovation Lab Support for training activity	Partial	Partial

	Student	Student
First and Other Given Names	Billy Mark	Moses
Last Name	Dzimbiri	Chitete
Citizenship	Malawian	Malawian
Gender	Male	Male
Training Institution	LUANAR	LUANAR
Supervising CRSP PI	Dr. Lawrence D. Mapemba	Dr. Lawrence D. Mapemba
Degree Program for training	MASTERS	MASTERS
Program Areas or Discipline	Agribusiness Management	Agricultural 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	N/A
Host Country Institution to Benefit from Training	LUANAR	LUANAR

Thesis Title/Research Area	Do commodity exchanges improve efficiency of bean markets in Malawi: A case of AHLCX and ACE	Market Structure, Conduct and Performance of Beans Marketing System in Malawi
Start Date	2016	2016
Projected Completion Date	September 2017	September 2017
Training status	Active	Active
Type of Legume Innovation Lab Support for training activity	Partial	Partial
	Student	Student
First and Other Given Names	Dorothy	Yanjanani
Last Name	Chisusu	Lifeyo
Citizenship	Malawian	Malawian
Gender	Female	Male
Training Institution	LUANAR	LUANAR
Supervising CRSP PI	Dr. Lawrence D. Mapemba	Dr. Lawrence D. Mapemba
Degree Program for training	MASTERS	MASTERS
Program Areas or Discipline	Agribusiness Management	Agribusiness Management
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID and included in Trainet?	N/A	N/A
Host Country Institution to Benefit from Training	LUANAR	LUANAR

Thesis Title/Research Area	Price volatility of common beans in Malawi: A Time series analysis	Market participation of smallholder common bean farmers in Malawi: A Triple Hurdle Approach
And Start Date	2016	2016
Projected Completion Date	September 2017	September 2017
Training status	Active	Active
Type of Legume Innovation Lab Support for training activity	Partial	Partial

	Student	Student
First and Other Given Names	Edwin	Jackson
Last Name	Kenamu	Jaccob
Citizenship	Malawian	Tanzania
Gender	Male	Male
Training Institution	LUANAR	Sokoine University of Agriculture
Supervising CRSP PI	Dr. Lawrence D. Mapemba	Fredy T. M. Kilima
Degree Program for training	MASTERS	M.Sc.
Program Areas or Discipline	Agribusiness Management	Agric. Econ.
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID and included in Trainet?	N/A	N/A

Host Country Institution to Benefit from Training	LUANAR	Sokoine University of Agriculture
Thesis Title/Research Area	Consumers' willingness to pay for bean attributes in Malawi	Analysis of Consumers' Demand for Dry Beans in Tanzania: An almost Ideal Demand System
Start Date	2016	April 2016
Projected Completion Date	September 2017	November 2017
Training status	Active	Active
Type of Legume Innovation Lab Support for training activity	Partial	Partial
	Student	Student
First and Other Given Names	Ocran	Ezekiel
Last Name	Chengula	Swema
Citizenship	Tanzania	Tanzania
Gender	Male	Male
Training Institution	Sokoine University of Agriculture	Sokoine University of Agriculture
Supervising CRSP PI	Fredy T. M. Kilima	Fredy T. M. Kilima
Degree Program for training	M.Sc.	M.Sc.
Program Areas or Discipline	Agric. Econ.	Agric. Econ.
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?	N/A	N/A
HC Institution to Benefit from Training	Ministry of Agric. Food Security and Coop.	Sokoine University of Agriculture
Thesis Title/Research Area	Market Participation Among Smallholder Bean Farmers In Tanzania	Common Beans Attributes and Consumer Preference in Dar Es Salaam, Tanzania
Start Date	September 2013	September 2015
Projected Completion Date	January 2017	April 2017
Training status	Active	Active
Type of Legume Innovation Lab Support for training	Partial	Partial

activity		

	Student	Student
First and Other Given Names	Elizabeth	Rameck
Last Name	Medard	Rwakalaza
Citizenship	Tanzania	Tanzania
Gender	Female	Male
Training Institution	Sokoine University of Agriculture	Sokoine University of Agriculture
Supervising CRSP PI	Fredy T. M. Kilima	Fredy T. M. Kilima
Degree Program for training	M.Sc.	M.Sc.
Program Areas or Discipline	Agric. Econ.	Agric. Econ.
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID?	N/A	N/A
HC Institution to Benefit from Training	Sokoine University of Agriculture	Sokoine University of Agriculture
Thesis Title/Research Area	Factors Influencing Beans Consumption Decisions in Tanzania	Analysis of relative position of beans on consumers’ foods ranking in Tanzania: Revealed preference approach
Start Date	April 2016	April 2016
Projected Completion Date	November 2017	November 2017
Training status	Active	Active
Type of Legume Innovation Lab Support for training activity	Partial	Partial
	Student	**Student**
First and Other Given Names	Mabvuto	Isabel
Last Name	Zulu	Sakala
Citizenship	Zambian	Zambian

Gender	Male	Female
Training Institution	University of Zambia	University of Zambia
Supervising CRSP PI	Dr. Gelson Tembo	Dr. Gelson Tembo
Degree Program for training	Master of Science	Master of Science
Program Areas or Discipline	Agricultural Economics	Agricultural Economics
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?	N/A	N/A
HC Institution to Benefit from Training	University of Zambia	University of Zambia
Thesis Title/Research Area	Consumer Preferences for Common Beans in Lusaka, Zambia. A Stated Preference Approach	Consumer Choices and Consumption of Beans in Zambia: A Double Hurdle Approach
Start Date	April 1, 2015	August 2016
Projected Completion Date	March 31, 2017	September 2017
Training status	Active	Active
Type of Legume Innovation Lab Support for training activity	Partial	Partial

	Student	Student
First and Other Given Names	Nandi Nomsa	Isaac
Last Name	Jama	Sikaaswe

Citizenship	Zambian	Zambian
Gender	Female	Male
Training Institution	University of Zambia	University of Zambia
Supervising CRSP PI	Dr. Gelson Tembo	Dr. Gelson Tembo
Degree Program for training	Master of Science	Bachelors of Science
Program Areas or Discipline	Agricultural Economics	Agricultural Economics
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?	N/A	N/A
HC Institution to Benefit from Training	University of Zambia	University of Zambia
Thesis Title/Research Area	Factors Affecting the Consumption of Cow Peas in Lusaka District	Determinants of Beans Consumptions Among Households in Lusaka District
Start Date	August 2016	October 2015
Projected Completion Date	September 2017	September 2016
Training status	Active	Completed
Type of Legume Innovation Lab Support for training activity	Partial	Partial
	Student	Student
First and Other Given Names	Kabanshi	Astridah
Last Name	Matunga	Munsaka
Citizenship	Zambian	Zambian

Gender	Female	Female
Training Institution	University of Zambia	University of Zambia
Supervising CRSP PI	Dr. Gelson Tembo	Dr. Gelson Tembo
Degree Program for training	Bachelors of Science	Bachelors of Science
Program Areas or Discipline	Agricultural Economics	Agricultural Economics
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?	N/A	N/A
HC Institution to Benefit from Training	University of Zambia	University of Zambia
Thesis Title/Research Area	The Economic Efficiency Of Smallholder Beans Farmers In Zambia	Determinants of Purple Beans (Kablangeti bean variety) Consumption in Lusaka District
Start Date	October 2015	October 2015
Projected Completion Date	September 2016	September 2016
Training status	Completed	Completed
Type of Legume Innovation Lab Support for training activity	Partial	Partial

	Student	Student
First and Other Given Names	Cynthia	Brenda
Last Name	Chibebe	Makayi
Citizenship	Zambian	Zambian

Gender	Female	Female
Training Institution	University of Zambia	University of Zambia
Supervising CRSP PI	Dr. Gelson Tembo	Dr. Gelson Tembo
Degree Program for training	Bachelors of Science	Bachelors of Science
Program Areas or Discipline	Agricultural Economics	Agricultural Economics
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?	N/A	N/A
HC Institution to Benefit from Training	University of Zambia	University of Zambia
Thesis Title/Research Area	Factors Influencing The Price Of Beans Received By Bean Traders.	Impact Of Maize Input Subsidies On The Profitability Of Beans Among Smallholder Farmers In Zambia
Start Date	October 2015	October 2015
Projected Completion Date	September 2016	September 2016
Training status	Completed	Completed
Type of Legume Innovation Lab Support for training activity	Partial	Partial

Students enrolled in the Master of Agribusiness (MAB) program will be supervised by US PI. They will be enrolled in US institution. The support provided will be partial of the total cost of their training cost.

	Student	Student
First and Other Given Names	Ednah	Marvin
Last Name	Kasanda	Mbaso
Citizenship	Zambian	Malawian
Gender	Female	Male
Training Institution	Kansas State University	Kansas State University
Supervising CRSP PI	Vincent Amanor-Boadu	Vincent Amanor-Boadu
Degree Program for training	MAB	MAB
Program Areas or Discipline	Agribusiness	Agribusiness
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID?	No	No
HC Institution to Benefit from Training	University of Zambia	LUANAR
Thesis Title/Research Area	To be Determined	To be Determined
Start Date	January 2015	August 2016
Projected Completion Date	May 15, 2017	
Training status	Active	Active
Type of Legume Innovation Lab Support for training activity	Partial	Partial
	Student	Student
First and Other Given Names	Austin	Furaha
Last Name	Mbamba	Rashid
Citizenship	Malawian	Tanzanian
Gender	Male	Male
Training Institution	Kansas State University	Kansas State University
Supervising CRSP PI	Vincent Amanor-Boadu	Vincent Amanor-Boadu
Degree Program for training	MAB	MAB
Program Areas or Discipline	Agribusiness	Agribusiness
If enrolled at a US university, will Trainee be a	No	No

“Participant Trainee” as defined by USAID?		
HC Institution to Benefit from Training	LUANAR	Sokoine University of Agriculture
Thesis Title/Research Area	To be Determined	To be Determined
Start Date	January 2017	January 2017
Projected Completion Date		
Training status	Pending	Pending
Type of Legume Innovation Lab Support for training activity	Partial	Partial

Achievement of Gender Equity Goals

Of the 22 students supported by the project, 10 were females. The sampling process was specifically weighted to ensure representation of equitable proportion of females in the sample.

Explanation for Changes

The original work plan stipulated that cross country comparisons and situational analyses of chain activities for the three focus countries will be completed in FY 2016. Drafts of policy briefs have been completed by Malawi, Tanzania and Zambia, but they have not been circulated for discussion among stakeholders nor have they been finalized. Also, one-day workshops, i.e., national conference, and regional meetings to disseminate the results from the DCE survey and situational analyses in each country have not been conducted. Industry training workshop addressing knowledge and capacity identified in the industry were also originally scheduled for FY 2016. One workshop was conducted in Malawi in April 2016 but none have been conducted in Zambia or Tanzania. Numerous operational and institutional challenges forced the national conferences, regional meetings, and industry training workshops to be delayed until FY2017 and for the analyses to be completed in FY2017. There were delays in student recruitment for Zambia, which lead to delays in completing the situational analysis and cross country comparisons. K-State PIs are working closely with Zambia PIs to quickly complete these reports. Also Zambia is on track with their student recruitment and has made progress with their research responsibilities in FY 2016 and are expected to continue to make significant progress in FY2017. Scheduling conflicts and time commitments were the main challenges experienced in organizing the national conferences, regional meetings and industry training. We are faced with the challenge that our Host Country PIs' primary responsibility is teaching at their home academic institutions and they receive little incentive from their institution to engage in research projects. Thus, our Host Country PIs have little time and motivation to focus on their research responsibilities associated with this project. We are looking into the possibility of working with Host Country students after they graduate as part of a practical training contract to provide research support to Host Country PIs and help produce key outputs for the project.

Table 1: Revised Time Table for Objectives

Objective	Deliverable	Date	Revised Date
Objective 1	Cross country comparison analyses on legume consumption in the focus countries.	December 2015	January 2017
Objective	Complete draft of policy brief based on consumption report, distribute to collaborators, industry stakeholders, country USAID missions and policymakers for comment, finalization and rollout process discussion.	December 2015	December 2016 – January 2017

Table 1: Revised Time Table for Objectives (cont'd)

Objective	Deliverable	Date	Revised Date
Objective 1	Consumption report distributed to Legume Innovation Lab partners, regional CG partners, country USAID missions and country policy makers.	January 2016	March 2017
Objective 2	Conduct focus interviews in the HC countries (particularly in Tanzania and Zambia).	November - December 2015	February 2017
Objective 2	Situation analysis of primary production for Zambia and complete the country comparison report.	November 2015	February 2017
Objective 2	Complete a draft situation analyses of downstream activities and report on chain activities in the focus countries.	April 2016	April – May 2017
Objective 2	Conduct workshops in each HC country to present lessons learned from Objective 1 and 2 and identify.	May 2016	March – April 2017
Objective 3	Conduct a training workshop in each HC country (particularly in Tanzania and Zambia).	February - September 2016	March – April 2017
Objective 3	Work with local policymakers to undertake public education initiatives about the value for nitration in their respective countries.	October 2015 – September 2016	October 2016 – September 2017

Self-Evaluation and Lessons-Learned

From past experiences, we have realized that progress in achieving the project objectives occurs when the research team, particularly the presence of the K-State team, is together. When the team is not together, the project drops in its priority ranking with the Host Country PIs; *out of sight, out of mind*. K-State has realized that they are competing for the Host Country PIs' time with their significant teaching loads and other organizations such as World Bank and IFPRI, who have also engaged them in research projects. These organizations have the ability to directly pay their host country partners instead of paying them through their institutional channels, and this results in these organizations receiving a higher priority than K-State who send the funds to their Host Country PIs through their academic institutions which can create challenges and funding delays for the Host Country PIs. Host Country PIs participate in projects such as this legume project out of academic curiosity; however, this curiosity does not pay the bills and feed hunger bellies. Thus, Host Country PIs' research academic endeavors become a hobby and receive attention only when time allows and financial obligations have been met. In the future, we need to rethink the model of the Host Country PIs to ensure the successful completion of research projects. One short term solution is to create consulting contracts with former students who were sponsored by the project but have since graduated. As research consultants, these graduates would receive additional practical training, help reduce some of the research burden for the Host Country PIs, and help complete some of the project objectives.

Scholarly Accomplishments

Chengula, O., F. T. M. Kilima, V. Amanor-Boadu and K. Ross. “Commercialization of Bean Production in Tanzania”. Sokoine University of Agriculture, School of Agricultural Economics and Agribusiness Studies, Department of Agricultural Economics and Agribusiness. October 2016.

Chilala C. and G. Tembo. “Factors Affecting Bean Prices Received by Smallholder Farmers in Zambia**”.** University of Zambia, School of Agricultural Sciences, Department of Agricultural Economics and Extension. Policy Brief. October 2016

Mapemba. L., M. Tumeo, and N. Moyo. “Contextual and Factual Analysis of Common Bean Production and Bean Attributes.” Selected posted prepared for presentation at the Pan-Africa Grain Legume and World Cowpea Conference, Livingstone, Lusaka. February 27-March 4, 2016.

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Tumeo, M., L. Mapemba, V. Amanor-Boadu, K. Ross, and A-K. Edriss. “Consumer Choice of Dry Common Beans in Malawi: Case of Lilongwe City”. Lilongwe University of Agriculture and Natural Resources (LUANAR). Policy Brief. October 2016.

Progress in Implementing Impact Pathway Action Plan

We are on track with our project outputs for our educational training impact pathways and the output is still outgoing. We have partially achieved our project outputs for our research objectives and short-term capacity building outreach programs. Our situational analyses for Malawi and Tanzania have been completed but still need to be published and distributed. The timeline for the situation analysis for Zambia has been shifted to Q1 FY2017. Malawi has completed a study on the factors influencing legume consumption using the survey data collected in the project and more consumer studies are expected from the three countries in FY2017. Because of scheduling difficulties, the industry situation reports for all three countries will be completed in FY2017. All of these situational analyses, consumption reports, and industry situation reports will be made available on our project website and press releases were be developed and circulated in FY2017. We have been successful in building strategic alliances with key groups in the legume industry in Malawi and we have made progress in Tanzania and Zambia. Our industry relationships in Malawi have provided support in developing and implementing our outreach programs. We will offer outreach programs in Zambia and Tanzania in FY2017 as well as continue to offer programs in Malawi.

Milestones

October 1, 2015 – March 31, 2016

Feed the Future Innovation Lab for Collaborative Researchon Grain Legumes

Report on the Achievement of "Milestones of Progress"

(For the Period: October 1, 2015-- March 31, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by April 1, 2016

Project Title: **Making**

	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	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***
	(Tick mark the Yes or No column for identified milestones by institution)																	
Objective 1	**Identify and anlayze the principal factors shaping bean/cowpea consumption and their relative positions in consumers' food ranking**																	
1.1 Bean/Cowpea Consumption Factors Report	√			√			√			√			**0**			**0**		
1.2 Policy Briefs to Shape Consumers	√			√			√			√			**0**			**0**		
1.3	**0**			**0**			**0**			**0**			**0**			**0**		
1.4	**0**			**0**			**0**			**0**			**0**			**0**		
1.5	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 2:	**Conduct situational analyses for bean/cowpea production and marketing/distribution systems with a view to identify the gaps in the value chains**																	
2.1 Farm Production Situation Report	√			√			√			√			**0**			**0**		
2.2 Industry Situation Report	**0**			**0**			**0**			**0**			**0**			**0**		
2.3 Policy Solutions	√			√			√			√			**0**			**0**		
2.4 Strategic Options	**0**			**0**			**0**			**0**			**0**			**0**		
2.5	**0**			**0**			**0**			**0**			**0**			**0**		

cont.

Objective 3:	**Formal and Informal Capacity building initiatives to address identified gaps and support value chain management capacity across the legume indu**																	
3.1 Outreach Programs	**0**			**0**			**0**			**0**			**0**			**0**		
3.2 Value Chain Short Course	**0**			**0**			**0**			**0**			**0**			**0**		
3.3 Value Chain Management Support	**0**			**0**			**0**			**0**			**0**			**0**		
3.4 Online Modules	**0**			**0**			**0**			**0**			**0**			**0**		
3.5 Podcasts	**0**			**0**			**0**			**0**			**0**			**0**		
3.6 MS Students	√			√			√			**0**			**0**			**0**		
3.7 MAB Students	√			√			√			**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	V. Amanor-Boadu			G. Tembo			L. Mapemba			F. Kilima			PI name			PI name		
Name of the U.S. Lead PI submitting this Report to the MO	V. Amanor-Boadu																	

Signature **Date**

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

April 1, 2016 – September 30, 2016

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: April 1, 2016 -- September 30, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2016

Project Title: **S02.2 Enhancing Pulse Value-Chain Performance through Improved Understanding of Consuming Behavior and Decision-Making**

	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	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***
	(Tick mark the Yes or No column for identified milestones by institution)																	
Objective 1	**Identify and anlayze the principal factors shaping bean/cowpea consumption and their relative positions in consumers' food ranking**																	
1.1 Bean/Cowpea Consumption Factors Report	**0**			**0**			**0**			**0**			**0**			**0**		
1.2 Policy Briefs to Shape Consumers	**0**			**0**			**0**			**0**			**0**			**0**		
1.3	**0**			**0**			**0**			**0**			**0**			**0**		
1.4	**0**			**0**			**0**			**0**			**0**			**0**		
1.5	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 2:	**Conduct situational analyses for bean/cowpea production and marketing/distribution systems with a view to identify the gaps in the value chains**																	
2.1 Farm Production Situation Report	**0**			**0**			**0**			**0**			**0**			**0**		
2.2 Industry Situation Report	√		X	√		X	√		X	√		X	**0**			**0**		
2.3 Policy Solutions	**0**			**0**			**0**			**0**			**0**			**0**		
2.4 Strategic Options	**0**			**0**			**0**			**0**			**0**			**0**		
2.5	**0**			**0**			**0**			**0**			**0**			**0**		

cont.

Objective 3:	**Formal and Informal Capacity building initiatives to address identified gaps and support value chain management capacity across the legume industry**																	
3.1 Outreach Programs	√		X	√		X	√	X		√		X	**0**			**0**		
3.2 Value Chain Short Course	√		X	√		X	√	X		√		X	**0**			**0**		
3.3 Value Chain Management Support	√		X	√		X	√		X	√		X	**0**			**0**		
3.4 Online Modules	**0**			**0**			**0**			**0**			**0**			**0**		
3.5 Podcasts	**0**			**0**			**0**			**0**			**0**			**0**		
3.6 MS Students	√	X		√	X		√	X		√	X		**0**			**0**		
3.7 MAB Students	√	X		√	X		√	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**		
Name of the PI reporting on milestones by institution	V. Amanor-Boadu			G. Tembo			L. Mapemba			F. Kilima			PI name			PI name		

Name of the U.S. Lead PI submitting this report to the MO: V. Amanor-Boadu

Signature

10/13/2016
Date

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

Explanation for Not Achieving Milesones, October 1, 2016

Milestones	**Explanation for Not Achieving the Milestones (October 1, 2016)**
Objective 1:	
1.1 Bean/Cowpea Consumption Factors Report	
1.2 Policy Briefs to Shape Consumers	
1.3	
1.4	
1.5	
Objective 2:	
2.1 Farm Production Situation Report	
2.2 Industry Situation Report	Due to limited commitment from Host Country PIs, this report has not be completed. We are looking into hiring local support to help complete this report in FY2017 if our Host County PIs are not able to do produce the report.
2.3 Policy Solutions	
2.4 Strategic Options	
2.5	
Objective 3:	
3.1 Outreach Programs	Due to scheduling issues and limited commitment from Host Country PIs, these project activities have not been implemented (except for 2 programs offered in Malawi). We are looking into hiring local support to help complete these activities in FY2017 if our Host County PIs are not able to meet the project committments.
3.2 Value Chain Short Course	Due to scheduling issues and limited commitment from Host Country PIs, these project activities have not been implemented (except for 2 programs offered in Malawi). We are looking into hiring local support to help complete these activities in FY2017 if our Host County PIs are not able to meet the project committments.
3.3 Value Chain Management Support	Due to scheduling issues and limited commitment from Host Country PIs, these project activities have not been implemented. We are looking into hiring local support to help complete these activities in FY2017 if our Host County PIs are not able to meet the project committments.
3.4 Online Modules	
3.5 Podcasts	
3.6 MS Students	In FY2016, Zambian PI recruited both Masters and senior level graduate students to be apart of the project and provide research assistance. The increase in recruited students is expected to get Zambia back on track with respect to their research commitments for this project.
3.7 MAB Students	The MAB student from Tanzania was recruited late and was not able to start the MAB program on schedule in FY2016. The student will be starting the MAB program in January 2017.

Performance Indicators

Overall 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. number	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	38	15	21	0
	Total number by sex	4	0	0	10	0	3	10	0	22	15	19	0
	Number of women	2	0	0	4	0	2	6	0	10	8	6	0
	Number of men	2	0	0	6	0	1	4	0	12	7	13	0
	Total number by New/continuing	0	0	0	10	0	3	10	0	22	15	19	0
	Number of New	0	0	0	10	0	2	8	0	16	6	2	0
	Number of women	0	0	0	0	0	0	0	0	8	0	0	0
	Number of men	0	0	0	0	0	0	0	0	8	0	2	0
	Number of Continuing	0	0	0	0	0	1	2	0	6	9	17	0
	Number of women	0	0	0	0	0	0	0	0	2	0	6	0
	Number of men	0	0	0	0	0	0	0	0	4	0	11	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	103	363	322	0
	Number of women	27	0	0	0	0	86	129	0	38	129	174	0
	Number of men	40	0	0	0	0	156	234	0	65	234	148	0
	Numbers by Type of individual	67	0	0	0	0	242	363	0	103	363	322	0
	Producers	5	0	0	0	0	41	64	0	43	64	139	0
	Number of women	0	0	0	0	0	0	0	0	22	0	83	0
	Number of men	0	0	0	0	0	0	0	0	21	0	56	0
	People in government	30	0	0	0	0	9	20	0	0	20	16	0
	Number of women	0	0	0	0	0	0	0	0	0	0	5	0
	Number of men	0	0	0	0	0	0	0	0	0	0	11	0
	People in private sector firms	9	0	0	0	0	156	217	0	60	217	167	0
	Number of women	0	0	0	0	0	0	0	0	16	0	86	0
	Number of men	0	0	0	0	0	0	0	0	44	0	81	0
	People in civil society	23	0	0	0	0	36	62	0	0	62	0	0
	Number of women	0	0	0	0	0	0	0	0	0	0	0	0
	Number of men	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	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. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

Zambia

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

Institution 1 UNZA Zambia

Indic. number	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	2	0	0	2	0	15	4	3	0
	Total number by sex	4	0	0	2	0	0	2	0	8	4	3	0
	Number of women	**2**			**1**		0	**1**		6	**2**	2	
	Number of men	**2**			**1**		0	**1**		2	**2**	1	
	Total number by New/continuing	0	0	0	2	0	0	2	0	8	4	3	0
	New				**2**		0	**2**		7	**2**	0	
	Number of women									6		0	
	Number of men									1		0	
	Continuing							**0**		1	**2**	3	
	Number of women									0		2	
	Number of men									1		1	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Total number by sex	22	0	0	0	0	46	69	0	0	69	68	0
	Number of women	7					22	33		0	33	33	
	Number of men	15					24	36		0	36	35	
	Numbers by Type of individual	22	0	0	0	0	46	69	0	0	69	68	0
	Producers						10	15		0	15	30	
	Number of women									0		16	
	Number of men									0		14	
	People in government	10					6	9		0	9	5	
	Number of women									0		1	
	Number of men									0		4	
	People in private sector firms	3					22	33		0	33	33	
	Number of women									0		16	
	Number of men									0		17	
	People in civil society	9					8	12		0	12	0	
	Number of women									0		0	
	Number of men									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												
	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. 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, leave it blank.
There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

Malawi

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

Institution 2 Name : LUANAR Malawi

Indic. number	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 tr	0	0	0	4	0	1	3	0	12	4	7	0
	Numbers by Sex	0	0	0	4	0	1	3	0	7	4	7	0
	Number of women				1		0	2		2	2	2	
	Number of men				3		1	1		5	2	5	
	Numbers by New/Continuing	0	0	0	4	0	1	3	0	7	4	7	0
	New				4		1	2		5	2	0	
	Number of women									1		0	
	Number of men									4		0	
	Continuing							1		2	2	7	
	Number of women									1		2	
	Number of men									1		5	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Numbers by Sex	25	0	0	0	0	112	166	0	103	166	126	0
	Number of women	10					44	66		38	66	70	
	Number of men	15					68	100		65	100	56	
	Numbers by Type of individual	25	0	0	0	0	112	166	0	103	166	126	0
	Producers	5					5	10		43	10	60	
	Number of women									22		37	
	Number of men									21		23	
	People in government	10					3	6		0	6	6	
	Number of women									0		3	
	Number of men									0		3	
	People in private sector firms	3					90	120		60	120	60	
	Number of women									16		30	
	Number of men									44		30	
	People in civil society	7					14	30		0	30	0	
	Number of women									0		0	
	Number of men									0		0	
7	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. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

Tanzania

REVISED PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 14, FY 15, FY16, and FY 17

Project Name: SO2.2 Grain Legume Value Chain Initiative

Institution 3 Name (one sheet per instittion): SUA Tanzania

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 tr	0	0	0	4	0	1	3	0	8	4	5	0
	Total number by sex	0	0	0	4	0	1	3	0	5	4	5	0
	Number of women				2		1	2		1	2	1	
	Number of men				2			1		4	2	4	
	Total number by New/continuing	0	0	0	4	0	1	3	0	5	4	5	0
	New				4		1	2		3	2	0	
	Number of women									1		0	
	Number of men									2		0	
	Continuing							1		2	2	5	
	Number of women									0		1	
	Number of men									2		4	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Total number	20	0	0	0	0	84	128	0	0	128	128	0
	Number of women	10					20	30		0	30	71	
	Number of men	10					64	98		0	98	57	
	Numbers by Type of individual	20	0	0	0	0	84	128	0	0	128	128	0
	Producers						26	39		0	39	49	
	Number of women									0		30	
	Number of men									0		19	
	People in government	10					0	5		0	5	5	
	Number of women									0		1	
	Number of men									0		4	
	People in private sector firms	3					44	64		0	64	74	
	Number of women									0		40	
	Number of men									0		34	
	People in civil society	7					14	20		0	20	0	
	Number of women									0		0	
	Number of men									0		0	
7	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. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

KSU

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

Institution 4 Name (one sheet per instittion): KSU

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 tr	0	0	0	0	0	1	2	0	3	3	6	0
	Total number by sex	0	0	0	0	0	1	2	0	2	3	4	0
	Number of women						1	1		1	2	1	
	Number of men							1		1	1	3	
	Total number by New/continuing	0	0	0	0	0	1	2	0	2	3	4	0
	New				0		0	2		1		2	
	Number of women									0		0	
	Number of men									1		2	
	Continuing				0		1			1	3	2	
	Number of women									1		1	
	Number of men									0		1	
2	term training												
	Total number	0	0	0	0	0	0	0	0	0	0	0	0
	Number of women												
	Number of men												
	Numbers by Type of individual	0	0	0	0	0	0	0	0	0	0	0	0
	Producers												
	Number of women												
	Number of men												
	People in government												
	Number of women												
	Number of men												
	People in private sector firms												
	Number of women												
	Number of men												
	People in civil society												
	Number of women												
	Number of men												
7	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. 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, leave it blank.
There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

Legumes, Environmental Enteropathy, the Microbiome and Child Growth in Malawi (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, University of Malawi College of Medicine
Chrissie Thakwalakwa, University of Malawi College of Medicine
Indi Trehan, Washington University School of Medicine in St. Louis

Abstract of Research and Capacity Strengthening Achievements
In FY16, 100% enrollment in Study 1 and complete enrollment and sample collection for Study 2 was accomplished. Final sample collection for Study 1 will take place in December 2016 and samples will be sent to the University of California San Diego for sequencing and analysis. The local team implementing the clinical trial continues ongoing training in the principles of "Good Clinical Practice." Two Malawian PhD students enrolled at the University of Malawi-College of Medicine were identified and began work on the project. The students are currently training at Washington University in lab techniques, attending classes and other training/seminars.

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 antioxidants. 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.

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 and continued to be utilized in FY16.

Objective 2. Develop and test the acceptability of two sets of 3-4 recipes that include either cowpea or common bean 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 were selected and are currently being used in the clinical trials during FY16.

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. The two PhD students recruited at the Malawi College of Medicine are currently in the United States at Washington University attending classes, learning lab techniques and attending other seminars/lectures/conferences to enhance their knowledge base. All local staff continues to undergo extensive training in Clinical Good Practice techniques and data collection methods to properly conduct all enrollment and data collection. The field teams continue to engage the district, local community leaders and health and health centers near Masenjere in Nsanje District and Limela in Machinga District in the current research project. 100% enrollment and over 50% of sample collection in Study 1 and 100% completion of sample collection for Study 2 was achieved in FY16.

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. ALUANAR 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 foods. Two PhD students recruited at the Malawi College of Medicine are currently in the United States at Washington University attending classes, learning lab techniques and attending other seminars/lectures/conferences to enhance their knowledge base. Conducted Food Safety Seminar with speakers from Valid Nutrition Malawi, LUANAR, ICRISAT, MBS, CAMA, NASFAM and the University of Malawi-College of Medicine with 41 attendees from producers and private, government and civil sectors.

Major Achievements

1. 100% enrollment in Study 1 and 100% sample collection 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.
2. Successfully enrolled two Malawian PhD students in classes and taught them dPCR techniques.
3. Conducted a Food Safety Seminar with 10 speakers and 41 attendees from various sectors.

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, 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. One of these students continues to be engaged in by supervising production and quality control of the flours using the food science and safety knowledge she obtained as part of her training. The two Malawian PhD students are attending classes at Washington University that are not offered at the University of Malawi increasing their research knowledge base. These students have also been trained in dPCR lab techniques utilized in Dr. Manary's lab at Washington University.

Human Resource and Institution Capacity Development

Short-Term Training: Staff Field Training

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.

Type of training: Field Training for research activities

Country Benefiting: Malawi

Location and dates of training: Malawi, 2016

Location and dates of training: 6 female nurses, 4 male drivers, 15 village health workers (11

male, 4 female)
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
Institution providing training or mechanism: University of Malawi College of Medicine

Short-Term Training: Food Safety
Purpose of Training: A 1 week training course on food safety, where the key threats to legumes and other Malawian crops are emphasized across the value chain.
Type of training: Food Training
Country Benefiting: Malawi
Location and dates of training: Malawi, 2016
Location and dates of training: 22 males and 19 females.
Home institution(s): (if applicable):
Institution providing training or mechanism: University of Malawi College of Medicine

Degree Training
Name of trainee: Lucy Bollinger
Country of Citizenship: USA
Gender: Female
Host Country Institution Benefitting from Training: University of Malawi College of Medicine
Institution providing training: Washington University
Supervising LIL PI: Mark Manary and Indi Trehan
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): Completed

Degree Training
Name of trainee: William Cheng
Country of Citizenship: USA
Gender: Male
Host Country Institution Benefitting from Training: Washington Unversity
Institution providing training: Washington University
Supervising LIL PI: Mark Manary and Indi Trehan
Degree Program: Masters
Field or Discipline: Biological Sciences
Research Project Title (if applicable): :
Start Date: May 2016
Projected Completion Date: May 2017
Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training status (Active, Completed, Pending, Discontinued, or Delayed): Active

<u>Degree Training</u>
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 LIL 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
Gender: Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training status (Active, completed, pending, discontinued or delayed): Active

<u>Degree Training</u>
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 LIL PI: Ken Maleta
Degree Program: PhD
Field or Discipline: Epidemiology
Research Project Title: N/A
Start Date: August 2015
Projected Completion Date: July 2017
Gender: Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training status (Active, completed, pending, discontinued or delayed): Active

<u>Degree Training</u>
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 LIL 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
Gender: Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training status (Active, completed, pending, discontinued or delayed): Active

Degree Training
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 LIL 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

Degree Training
Name of trainee: Ulemu Chimimba
Country of Citizenship: Malawi
Gender: Female
Host Country Institution Benefitting from Training: LUNAR
Institution providing training: LUNAR
Supervising LIL 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
Gender: Is trainee a USAID Participant Trainee and registered on TraiNet? No
Training status (Active, completed, pending, discontinued or delayed): Complete

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 non-degree American students is female.

Particular care was extended to women for inclusion in the Food Safety training course. With approximately 46% of attendees being female.

Explanation for Changes

We have no significant changes or delays to report.

Self-Evaluation and Lessons-Learned

Project SO3.1 has proceeded very well. Two out of our four Malawian graduate students have successfully completed their training and have graduated. The other two are currently in St. Louis, Missouri, studying at Washington University and receiving laboratory training. Our large number of village health workers have also received significant training in the identification and management of malnutrition, skills that they report they have taken back to their communities to improve nutritional counselling of children, agricultural practices, and the clinical identification of malnourished children.

The clinical trial itself is nearing completion before the end of 2016 with successful recruitment and retention of more than our anticipated sample size. No significant challenges have been encountered during the course of the study; no significant adverse events have occurred and the mothers of children in the trial report great happiness with being involved in such a lengthy study aimed at improving the growth and gut health of their children. Nearly all of the clinical samples have been returned to the United States and analysis of the dual-sugar and microbiome results has begun on a blinded basis. After the clinical trial finishes in December 2016, the study's growth data will be unblinded to see if the legume interventions had any benefit on growth rates.

The collaboration with the University of Malawi and LUANAR has continued successfully and has brought all of our institutions closer together, especially with the recent Food Safety Seminar held in Blantyre. We look forward to nurturing this relationship in the future to work on other projects aimed at improving food security, agricultural output, and the health of women and children in Malawi.

Scholarly Accomplishments

Trehan I, et al. “Common beans and cowpeas as complementary foods to reduce environmental enteric dysfunction and stunting in Malawian children: study protocol for two randomized controlled trials. Trials (2015) 16:520

Progress in Implementing Impact Pathway Action Plan

We remain on track with the Impact Pathway developed during the project planning and workplan 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.

Milestones

October 1, 2015 – March 31, 2016

Feed the Future Innovation Lab for Collaborative Researchon Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: October 1, 2015-- March 31, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by April 1, 2016

Project Title: **S03.1 Legumes and growth**

	Abbreviated name of institutions								
	WUSM			MCM			LUANAR		
	Target	Achieved		Target	Achieved		Target	Achieved	
Milestones by Objectives	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***
	(Tick mark the Yes or No column for identified milestones by institution)								
Objective 1	**Enrollment, Intervention Delivery and Speciman Collection in infant with a dietary legume**								
1.1 50% of Enrollment Complete	1	1		1	1		0		
1.2 100 % of Enrollment Complete	1	1		1	1		0		
1.3 Speciman collection on 25% of participants complete	1	1		1	1		0		
1.4 Sepciman collection on 50% of participants complete	0			0			0		
1.5 Subset for Microbiome Analysis identified	0			0			0		
Objective 2:	**Recipe Development**								
2.1 Development of recipes	1	1		0			1	1	
2.2 Examination of orginal recipes and formulations	1	1		0			1	1	
2.3 Acceptability trial preparations and approval	1	1		1	1		0		
2.4 Conduct filed acceptability trial	1	1		1	1		0		
2.5 Select and finalize food formulations	1	1		1	1		1	1	

cont.

Objective 3:	**Enrollment, intervention delivery and speciman collection in young children with a dietary legu**								
3.1 Staff recruitment	**1**	**1**		**1**	**1**		**0**		
3.2 Staff training	**1**	**1**		**1**	**1**		**0**		
3.3 Secure ethics approvals	**1**	**1**		**1**	**1**		**0**		
3.4 Conduct community engagement programs	**1**	**1**		**1**	**1**		**0**		
Objective 4:	**Increase Capacity, Effectiveness and sustainability of aguriculture research institutions in**								
4.1 Malawian graduate student continued supervision	**0**			**1**	**1**		**0**		
4.2 Training/Support of malawian graduate student on specir	**1**	**1**		**0**			**0**		
4.3 Identification and training of malawian graduate student i	**1**	**1**		**0**			**0**		
4.4 Conduct community engagement activities	**0**			**1**	**1**		**0**		
Name of the PI reporting on milestones by institution	Dr. Mark Manary			Dr. Kenneth Maleta			Dr. Mark Manary		
Name of the U.S. Lead PI submitting this Report to the MO	Dr. Mark Manary								

Signature

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

April 1, 2016 – September 30, 2016

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: April 1, 2016 -- September 30, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2016

Project Title: **S03.1 Legumes and growth**

	Abbreviated name of institutions																	
	WUSM			MCM			LUANAR			Institution 4			Institution 5			Institution 6		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Milestones by Objectives	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***
	(Tick mark the Yes or No column for identified milestones by institution)																	
Objective 1	**Enrollment, Intervention Delivery and Speciman Collection in infant with a dietary legume**																	
1.1 50% of Enrollment Complete	**0**			**0**			**0**			**0**			**0**			**0**		
1.2 100 % of Enrollment Complete	**0**			**0**			**0**			**0**			**0**			**0**		
1.3 Speciman collection on 25% of participants complete	**0**			**0**			**0**			**0**			**0**			**0**		
1.4 Sepciman collection on 50% of participants complete	**1**	**1**		**1**	**1**		**0**			**0**			**0**			**0**		
1.5 Subset for Microbiome Analysis identified	**1**	**1**		**1**	**1**		**0**			**0**			**0**			**0**		
Objective 2:	**Recipe Development**																	
2.1 Development of recipes	**0**			**0**			**0**			**0**			**0**			**0**		
2.2 Examination of orginal recipes and formulations	**0**			**0**			**0**			**0**			**0**			**0**		
2.3 Acceptability trial preparations and approval	**0**			**0**			**0**			**0**			**0**			**0**		
2.4 Conduct filed acceptability trial	**0**			**0**			**0**			**0**			**0**			**0**		
2.5 Select and finalize food formulations	**0**			**0**			**0**			**0**			**0**			**0**		

cont.

Objective 3:	**Enrollment, intervention delivery and speciman collection in young children with a dietary legume**																	
3.1 Staff recruitment	**0**			**0**			**0**			**0**			**0**			**0**		
3.2 Staff training	**0**			**0**			**0**			**0**			**0**			**0**		
3.3 Secure ethics approvals	**0**			**0**			**0**			**0**			**0**			**0**		
3.4 Conduct community engagement programs	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 4:	**Increase Capacity, Effectiveness and sustainability of aguriculture research institutions in Malawi**																	
4.1 Malawian graduate student continued supervision	**1**	1		**1**	1		**1**	1		**0**			**0**			**0**		
4.2 Training/Support of malawian graduate student on specimen processing	**1**	1		**0**			**0**			**0**			**0**			**0**		
4.3 Identification and training of malawian graduate student in young child	**0**			**0**			**0**			**0**			**0**			**0**		
4.4 Conduct community engagement activities	**1**	1		**1**	1		**1**	1		**0**			**0**			**0**		

Name of the PI reporting on milestones by institution	Dr. Mark Manary	Dr. Kenneth Maleta	Dr. Mark Manary	PI name	PI name	PI name

Name of the U.S. Lead PI submitting this report to the MO Dr. Mark Manary

Mark J Manary
Signature

10/14/2016
Date

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

Performance Indicators

Overall Indicators

Project Name: SO3.1 Legumes and Growth

Summary of all institutions

Indic. number	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	0	7	5	4	8	5	5	0
	Total number by sex	0	0	0	7	0	7	5	4	8	5	5	0
	Male	0	0	0	3	0	1	2	1	3	2	2	0
	Female	0	0	0	4	0	6	3	3	5	3	3	0
	Total number by New/continuing	0	0	0	7	0	7	5	4	8	5	5	0
	New	0	0	0	7	0	7	0	0	3	0	0	0
	Male	0	0	0	0	0	0	0	0	2	0	0	0
	Female	0	0	0	0	0	0	0	0	1	0	0	0
	Continuing	0	0	0	0	0	0	5	4	5	5	5	0
	Male	0	0	0	0	0	0	0	0	1	0	2	0
	Female	0	0	0	0	0	0	0	0	4	0	3	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	0	0	0	12	0	12	12	10	66	12	12	0
	Number of men	0	0	0	6	0	7	6	5	37	6	6	0
	Number of women	0	0	0	6	0	5	6	5	29	6	6	0
	Numbers by Type of individual	0	0	0	12	0	15	12	0	66	12	12	0
	Producers	0	0	0	0	0	0	0	0	7	0	0	0
	Number of men	0	0	0	0	0	0	0	0	3	0	0	0
	Number of women	0	0	0	0	0	0	0	0	4	0	0	0
	People in government	0	0	0	12	0	15	12	0	37	12	12	0
	Number of men	0	0	0	0	0	0	0	0	23	0	6	0
	Number of women	0	0	0	0	0	0	0	0	14	0	6	0
	People in private sector firms	0	0	0	0	0	0	0	0	7	0	0	0
	Number of men	0	0	0	0	0	0	0	0	4	0	0	0
	Number of women	0	0	0	0	0	0	0	0	3	0	0	0
	People in civil society	0	0	0	0	0	0	0	0	15	0	0	0
	Number of men	0	0	0	0	0	0	0	0	7	0	0	0
	Number of women	0	0	0	0	0	0	0	0	8	0	0	0

cont.

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	0	2	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	0	2	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:
These indicators are developed under the Feed the Future Monitoring System. 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, leave it blank.
There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

Washington University in St. Louis

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 **SO3.1**
Institutio **Washington University School of Medicine in St Louis**

Indic. number	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	1	0	2	1	0	4	1	1	0
	Total number by sex	0	0	0	1	0	2	1	0	4	1	1	0
	Male									2			
	Female				1		2	1		2	1	1	
	Total number by New/continuing	0	0	0	1	0	2	1	0	4	1	1	0
	New				1		2			3			
	Male									2			
	Female									1			
	Continuing							1		1	1	1	
	Male												
	Female									1		1	
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	0	0	0	0	0	0	0
	Male												
	Female												
	Numbers by Type of individual	0	0	0	0	0	0	0	0	0	0	0	0
	Producers												
	Male												
	Female												
	People in government												
	Male												
	Female												
	People in private sector firms												
	Male												
	Female												
	People in civil society												
	Male												
	Female												

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	0	2	2	2	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance				2		2	2		2	2	2	
	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. 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, leave it blank.

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University of Malawi

REVISED PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 14, FY 15, FY16, and FY 17

Project N SO3.1

Institutio University of Malawi School of Medicine

Indic. number	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 tr	0	0	0	6	0	5	4	4	4	4	4	0
	Numbers by Sex	0	0	0	6	0	5	4	4	4	4	4	0
	Male				3		1	2	1	1	2	2	
	Female				3		4	2	3	3	2	2	
	Numbers by New/Continuing	0	0	0	6	0	5	4	4	4	4	4	0
	New				6		5	0	0	0	0	0	
	Male												
	Female												
	Continuing				0			4	4	4	4	4	
	Male									1		2	
	Female									3		2	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Numbers by Sex	0	0	0	12	0	12	12	10	66	12	12	0
	Male				6		7	6	5	37	6	6	
	Female				6		5	6	5	29	6	6	
	Numbers by Type of individual	0	0	0	12	0	15	12	0	66	12	12	0
	Producers									7			
	Male									3			
	Female									4			
	People in government				12		15	12		37	12	12	
	Male									23		6	
	Female									14		6	
	People in private sector firms									7			
	Male									4			
	Female									3			
	People in civil society									15			
	Male									7			
	Female									8			
7	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. 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, leave it blank.

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

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, Robert Shupp, Nicole Mason and David DeYoung, Agricultural, Food and Resource Economics, Michigan State University; Byron Reyes, formerly at MSU, currently at CIAT; Fulgence Mishili and Paul Kusolwa, SUA; Francis Kusi, SARI; Dieudonne Ilboudo, INERA.

US and HC PIs/collaborators of other Feed the Future Legume Innovation Lab Projects

Abstract of Research Achievements and Impacts

An assessment of the current status of the climbing bean/maize intercropping production system was completed in the highlands of Guatemala in close collaboration with SO1.A1 team. A research activity was initiated using existing data to build an evidence base by exploring pathways through which legumes can potentially enhance agriculture-food security linkages. Analysis using nationally representative data from Zambia suggest consistent positive effects of cereal-legume rotation and other legume technologies on net crop income, calorie and protein production, and months of adequate household food provisioning. Several research studies on the theme of sustainable seed system were initiated or completed in FY 16. This includes two studies on 'willingness to pay' for different types of seeds--one in northern Tanzania (for beans) and the other in northern Ghana (for cowpea). A case study focused on a farmer association in Burkina Faso was completed. The case of ASK provides a good example of how a farmer based local seed entrepreneurship model can be combined with a non-governmental oversight of quality control to produce QDS. But this case study also points to the challenges of small-holder farmers' ability to grow seeds that meet quality standards despite technical training and supervision from ASK. It points to the need for lowering the price of QDS that is still attractive to a seed producer to remain in the seed business but is within the 30-40% range of grain price to remain within the average range of farmers' willingness to pay for seed. The case study and the willingness to pay experiments indicate that increasing the yield of cowpea seed that meets quality standards is key to lowering the price of seed and still make it profitable for seed producers to produce them.

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 Feed the Future Legume Innovation Lab program and its Management Office (MO) to achieve two important goals--accountability and learning. Greater accountability (and strategic validation) is a prerequisite for continued financial support from USAID and better learning 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 Feed the Future Legume Innovation Lab will ultimately help increase the overall impact of such investments.

Technical Research Progress

Objective 1. Provide technical leadership in the design, collection and analysis of data for strategic input and impact evaluation

1a. Analysis of baseline study in Guatemala

Rationale. The indigenous population of mostly Mayan descent living in the western highlands of Guatemala are among the most undernourished in the world. Beans, which are one of the best sources of nutrients, are commonly grown in this region as part of the *Milpa* system, which is a traditional system of intercropping maize and beans (or other crops). The crops are either planted simultaneously, or maize first, and beans a few weeks later. Research indicates that to tackle the problem of undernourishment, household energy consumption from own-produced beans can be significantly enhanced by increasing bean yields. Genetic improvement of climbing beans for the highlands of Central America is thus one of the research activities of the Feed the Future Legume Innovation Lab project (SO1.A1) led by NDSU and ICTA.

To better understand the current status of the climbing bean/maize intercropping production system, and to establish a baseline about production of climbing beans in the highlands of Guatemala, a study was designed by this project team jointly with the SO1.A1 project team (Juan Osorno (NDSU) and 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.

Method. A survey of more than 500 farm households from five FTF Departments in Guatemala representing the highland bean growing regions was conducted in 2015, and data cleaning and analysis was completed in FY 16. 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.

Results. The results indicate the importance of beans in the diets of the indigenous population and confirm the need for increasing productivity to increase 'bean security' in the region. Major findings are summarized below.

Bean Consumption

- Majority of farmers (80%) do not sell beans; only 6% sold more than 50% of their harvest
- Own production covered less than half of annual bean consumption for 23% of farmers; For another 33% of farmers, own production covered between 50-75% of annual

consumption. Once own produced beans were consumed, 50% of farmers purchased beans at least weekly.

- On average, a household cooked beans 2.5 times and consumed a total of 5 cups of (uncooked) beans in the week prior to the survey.
- Households with children (under 14) on average served beans to the children 3 days in the week preceding the interview. On days that children ate beans, more households served beans at breakfast (75%) and dinner (79%) than at lunch (53%)
- Beans are consumed throughout the year; it is highest at or after the harvest –from November to March, and lowest in July and August (Figure 1)

Dietary diversity, culinary preferences and farmers' perceived nutritional value of beans

- On average a household consumed 6 out of 12 diverse food groups in the day prior to the survey; More than 85% reported consuming beans the previous day.
- Frijol negro', 'vulgaris' and 'bolonillo' were among the most preferred bean variety/type for consumption named by farmers (Figure 2)
- Respondents indicated that flavor (76%) was what they like most about a bean variety followed by thickness of bean broth (32%), cooking time (3.2%), expansion of size (1.5%) and color retention during cooking (0.7%).
- On a scale of 0-10, farmers rated beans 8.9 in terms of nutritional value, which was just below the score for maize (9.4), but higher than the perceived nutritional value of rice (8.1), potatoes (7.8), meat (6.9), chayote (5.9) and Coca Cola (1.4).

Bean Productivity and Production Practices

Progress report on publication outputs. A paper summarizing the main results of the survey was presented as a poster paper at the Pan African Legume conference in Zambia early this year, and is planned to be published as an MSU Ag Econ Staff Paper by the end of this year.

1b. Analysis of existing data for strategic insights to guide impactful research on legume based farming systems

Rationale. Legumes impart several agronomic, environmental, and economic benefits to smallholder farm households. As natural nitrogen fixers, legumes reduce the need for inorganic fertilizer and enhance long-term soil fertility and productivity. Due to their high protein, mineral, and fiber content, legumes also carry nutritional benefits. Legumes therefore likely play a positive role in ensuring a household's food security through two pathways:

- The income pathway (i.e. increasing the productivity and income-generating capacity of the production system), and
- The consumption pathway (i.e. increasing the diversity of nutrient-rich food for self-consumption).

In FY 16, this project team undertook a research activity using existing data to build an evidence base by exploring pathways through which legumes can potentially enhance agriculture-food security linkages. Specifically, we examine the links between the various ways in which households incorporate legumes into their cropping activities (namely, cereal-legume rotations, cereal-legume intercropping, and other means such as legume monocropping or intercropping legumes with non-cereal crops) and several indicators of household food security and welfare along the agricultural production and income pathways. The legumes commonly grown in Zambia and included in the study are groundnuts, soybeans, mixed beans, cowpeas, velvet beans, and bambara nuts. The cereals considered for cereal-legume rotation and intercropping are maize, sorghum, and millet.

Data. The data for this study are from the Rural Agricultural Livelihoods Survey (RALS), a two-wave, nationally representative panel survey of Zambian smallholder farm households conducted in June-July 2012 and 2015 by the Indaba Agricultural Policy Research Institute.[1] The RALS data include detailed information on household demographics, crop production (e.g., input use, area planted, and quantities harvested by plot and crop, as well as plot-level information on the use of intercropping and the main crop that was planted on the plot in the previous agricultural year), crop sales, asset holdings, and access and distances to agricultural extension, *inter alia*. From these data, we compute net crop income, defined here as the gross value of crop production minus fertilizer costs. (Insufficient data are available to net out other input costs; however, fertilizer is the major cash input cost incurred by Zambian smallholder farmers.) Both RALS survey waves also capture households' months of adequate household food provisions (MAHFP; Bilinsky and Swindale, 2010), and the 2015 wave included a household dietary diversity score (HDDS) module (Swindale and Bilinsky 2006). These data allow us to analyze the effects of legume technologies on five household-level welfare indicators: net crop income, calories produced/capita/day, protein produced/capita/day (in grams), MAHFP and HDDS.

Because we are interested in how incorporating legumes into their cropping activities affects cereal- (i.e., maize-, sorghum-, or millet-) growing households, our analytical sample consisted of all panel households that grew a cereal crop in both the 2010/2011 and 2013/2014 agricultural seasons (N=6,226).

Empirical strategy. In this study, we relied on observational data on the adoption of legume technologies and household welfare, and thus employed quasi-experimental techniques to identify the welfare effects of cereal-legume intercropping and rotation and other legume combinations. More specifically, we used panel data methods (e.g., the fixed effects estimator and the correlated random effects approach) or two-stage least squares to control/correct for different sources of endogeneity. For the purpose of comparison, we also report OLS estimates for all outcome variables.

For all outcome variables except for HDDS, which is only observed in the 2015 RALS, we estimate household fixed effects (FE) models of the welfare indicators regressed on measures of the household's adoption of the various legume technologies (cereal-legume intercropping, cereal-legume rotation, and other legume technologies), and a vector of control variables. Adoption of the various legume technologies is measured as either (i) a binary 'treatment'

[1] In Zambia, smallholder households are defined as those cultivating less than 20 ha of land. For details on the RALS sample design, see IAPRI (2012, 2015).

variable equal to one if the household practiced the legume technology on at least one plot, and equal to zero otherwise; or (ii) a continuous 'treatment' variable equal to the household's total hectares under the legume technology.

Given the count-variable nature of the MAHFP and HDDS, we also attempted to estimate correlated random effects negative binomial (CRE-NB) models for these outcome variables. But unfortunately, the CRE-NB model did not converge for MAHFP. For HDDS we estimate linear CRE and CRE-NB models in which the RALS 2015 HDDS is regressed on the RALS 2015 levels of the covariates as well as the RALS 2012 and 2015 household time averages of the covariates.

Finally, for all outcome variables, we estimate two-stage least squares (2SLS) regressions in which we instrument for the three main explanatory variables of interest, which we suspect may be endogenous to household welfare: adoption of cereal-legume intercropping, of cereal-legume rotation, and of other legume technologies.

Results. Legume cultivation is fairly common among cereal-growing smallholder households in Zambia. Approximately 64% of such households grow legumes in some way (Figure 3). Among legume crops, groundnuts are the most popular (53% of cereal-growing households grew groundnuts in the 2013/14 agricultural year), followed by mixed beans (about 17% of households), soybeans (8% of households), and Bambara nuts and cowpeas (3% of households each); just 0.1% of households grew velvet beans. The most common way that Zambian smallholders incorporate legumes into their farms is via rotation with cereals – approximately 40-43% of households do this each year (Figure 4). In contrast, cereal-legume intercropping is practiced by less than 5% of households each year. Approximately 22-23% of households grow legumes via other means (e.g., legume monocropping).

The econometric analysis results are summarized in table1 and indicate that cereal-legume intercropping exhibits few statistically significant ($p<0.10$) effects on the outcome variables examined in this study. Only for HDDS do we find statistically significant effects that are retained across multiple non-OLS estimators. The results suggest positive and statistically significant cereal-legume intercropping effects on HDDS in three of eight models.

In contrast to cereal-legume intercropping, cereal-legume rotation has more statistically significant, and generally positive, effects on household welfare (table1). The results are not robust to the choice of estimator for HDDS (although they are positive where statistically significant), but for MAHFP, calorie production, and protein production, the majority of the estimates suggest that cereal-legume rotation positively affects these outcome variables. The fixed effects results, for example, suggest that MAHFP increases by an average of 0.05 units with the use of cereal-legume rotation, and by an average of an additional 0.05 units given a one-hectare increase in cereal-legume rotations, ceteris paribus.

The positive effects of cereal-legume rotation on MAHFP appear to be coming mainly through the food production pathway, as cereal-legume rotation significantly increases both household calorie and protein production but has mixed effects on household crop income (table1). In terms of the magnitudes of the effects, the FE results, for example, suggest that each additional hectare of cereal-legume rotated land increases calorie production by an average of 1,088 calories/capita/day and protein production by an average of 38 grams/capita/day, holding other factors constant. These are substantial increases vis-à-vis the sample means of 5,913 calories/capita/day and 158 grams of protein/capita/day.

In summary, cereal-legume rotation appears to have generally positive effects on household food access (especially MAHFP) and on per capita calorie and protein production. These effects appear to come through both the crop income pathway and the agricultural production pathway. From a policy perspective, the empirical evidence that cereal-legume rotations can improve food production and food access among Zambian smallholder cereal growers, points to the need to promote this practice where it is feasible for farmers to do so. Researchers at the Zambian Agriculture Research Institute together with social scientists could investigate the specific types and lengths of cereal-legume rotations that are the most welfare-enhancing for Zambian smallholders. Further research is also needed to understand the low adoption rates of cereal-legume intercropping among Zambian smallholders, and to identify and promote specific cereal-legume intercrops that meet farmers' needs.

Progress report on publication outputs. A paper summarizing preliminary results of the survey were as a poster paper at the Pan African Legume conference in Zambia in February and as an oral presentation at the AAEA meetings in August. In the coming months we plan to publish this paper as an IAPRI working paper. We also plan to submit a manuscript for consideration in the *Journal of Development Studies*.

<u>Objective 2. Conduct ex ante and ex post impact assessments</u>

2a. Sustainability of legume seed system constraints and opportunities to guide policies and programs:

Motivation. One of the important factors that determine the sustainability of a seed system is the 'effective '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 post-harvest 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. 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

Keeping the genetics constant (i.e., for the same improved variety), the viability of a seed market will depend on the co-existence of the 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.

i. Willingness of small holder farmers to pay for quality seed

This study is conducted in Tanzania for beans in collaboration with SUA and CIAT, and in Ghana for cowpeas in collaboration with SARI. In Ghana all the field work and data collection is completed and data entry and analysis is still ongoing. In Tanzania the study was concluded in FY 16 and we present the main results of this study in this Report.

Rationale. In Tanzania, 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, 1) 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 2) whether that translates into differential price that farmers are willing to pay for these seeds are empirical questions addressed by this study.

Method. A two-step approach was used to address the two research quesitons. First, double-blind field experiments were established in 12 hamlets across two districts 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 first-hand 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 first-hand how different types/grades of seeds of the same improved variety perform in a location that is close to their farm. 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 pre-conceived higher and lower quality seed type (this is called the Hawthorne effect in the economics literature). 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 planted on approximately 100 sq. m. (10m x 10m) sub-plot 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'). 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, first-hand. The first field day was conducted around the flowering stage (or soon after), and the second field day occurred just before or after harvest. Attendees in the first Field Day were given a sheet where they ranked the sub-plots 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 sub-plots and the reason for their ranking.

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 245 farmers participated in the BEA across the 12 villages. Survey data were collected from each farmer that participated in the auction experiment to capture their socio-economic household characteristics, and experience with producing beans, varietal use and prior use of different types of seed.

Results. This study on farmers' willingness to pay for quality seed has generated three interesting results that have implications on designing seed systems for legume crops. First, seed quality matters (not just the genetics)--on average certified seed 1 (Type A) consistently outperformed certified seed 2 (Type B) and quality declared seeds (QDS) (Type D) and QDS outperformed farmer recycled seeds (Type C) of the same variety in field experiments conducted on farmers' fields and farmers perception of these quality difference was highly correlated with the yield performance as reflected in their ratings of different plots during the flowering and harvest stages (Figure 5).

Second, all else equal, farmers are willing to pay premium for quality seeds--the relative difference in Farmers' WTP for different seed types is correlated with the relative difference in their perceived quality differences (Figure 6). Third, results confirm the downward sloping demand curve for quality seed—the number of farmers willing to pay a premium price for quality seed declines as price of seed increases (Figure 7).

The overall implication of these findings is that there is no one-size-fits-all strategy to meet the seed needs of all the farmers. The strategy should be built on multi-pronged approaches based on subsidies to meet the needs of farmers on the lower end of the WTP spectrum, private sector based approaches to meet the needs of farmers on the higher end of the WTP spectrum, and alternative models based on in-kind subsidy and not for profit seed production models (e.g., community based models) for farmers in the middle ranges.

Progress report on publication outputs. A paper summarizing preliminary results of the survey was presented at the Pan African Legume conference in Zambia in February. In the coming months we plan to submit a manuscript for consideration in a development journal.

2a-ii. Case study on community based seed system. The problem of lack of farmer access to legume seed has left millions of smallholder farmers relying on their own or other farmers' harvested 'grain' (accessed from the local market) as the main source for seed. The advantages of this decentralized informal seed system is that it is able to meet diverse needs of farmers at lower cost (i.e., at grain price). However, on the disadvantage side, the informal system is not directly linked with the research system, and thus not able to quickly channel new improved varieties, and produces lower quality 'seed,' which negatively impacts the productivity of food production. In view of these challenges, this project undertook a case study of a farmer association in Burkina Faso called Association-Song-Koaadba (ASK), which is involved in training its members to produce quality declared seeds (QDS) of cowpea for sale to other farmers. The goal of this case study was to investigate whether and how the ASK model builds on the cost advantages of community based seed production, and minimizes the disadvantages of potentially lower seed quality of an informal seed system. This study was conducted in close collaboration with INERA socio-economist (Dieudonne Ilboudo) and host country PIs of other Legume Lab projects (Issa Drabo and Clementine Dabire).

Method.The case study uses a combination of qualitative and quantitative methods comprised of a) Key informant interviews (KII) conducted in 2015 and 2016 with the staff members of the ASK management team, INERA, the National Seed Service (SNS), the Union Nationale des Production Semenciers (UNPS) and other farmer organizations that purchased seeds from ASK; and b) Survey conducted in 2015 of 225 cowpea farmers across 25 villages where ASK is active, including ASK member seed producers (53), non-seed producers (99) and non-members (73).

Results. The Association Song Koaadba (ASK) 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. table2 presents the business model used by ASK based on the key informant interviews and farmer survey in terms of operating costs, types of services offered by ASK, scale of seed production, seed distribution, marketing, cost of seed production, and the requirement vs. reality of seed production system used by ASK. 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 non-member 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.

In terms of the evidence of use of purchased seed, 70% of members and 30% of non-members in the village surveyed had purchased seed from ASK in the past. However, the last time a farmer purchased seed was on average 3 years ago. In terms of the seed source for the 2014 planting season, according to the farmer survey, 77% of cowpea plots had planted seeds from previous harvest, 14% had accessed it from ASK, 6% had purchased as grain and 2% had purchased or received as seed; 35% of cowpea plots surveyed was planted to an improved variety (IV). Thus, despite the presence of ASK, own saved seed remains the major source of planting material. Only 35% of cowpea plots surveyed were reported as planted to an improved variety (IV).

The case of ASK provides a good example of how a farmer based local seed entrepreneurship model can be combined with a non-governmental oversight of quality control to produce QDS. The broad based services provided by ASK to its members is highly valued and is the reason for its long-term operation. But despite their operation, access to new varieties and affordable quality seeds of cowpea in ASK member communities remains a constraint as evidenced by:

- Low adoption of improved varieties: 30-40% of plots planted to IV
- Low cowpea grain and seed yields: average 300 kg/ha
- High rejection rate: 30% seed is rejected (according to farmer survey)
- High price of seed set by ASK: More than double the grain price

Reliance on the subsidized seed distribution channel.More than 1/3 of seed produced by ASK members ends up being sold outside the ASK network, which ends up being distributed as free or highly subsidized QDS (To put this in broader context--95% of certified seed ends up in this channel). The high percentage of seed in the subsidized seed distribution channel undermines the overall sustainability of the model.

In summary, this case study results indicate the challenges of small-holder farmers’ ability to grow seeds that meet quality standards despite technical training and supervision from ASK. It points to the need for lowering the price of QDS that is still attractive to a seed producer to remain in the seed business but is within the 30-50% range of grain price. Increasing the yield of cowpea seed that meets quality standards is key to lowering the price of seed and still make it profitable for small-scale community based seed producers.

Progress report on publication outputs. A paper summarizing preliminary results of the survey was presented as a poster paper at the Pan African Legume conference in Zambia in February. In the coming months we plan to publish this study as an MSU International Development Working Paper.

2b. Adoption 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 FY15-16 workplan of this project and supplemental funding was secured in 2015 under the Strengthening Host Country Institutional Capacity call for proposals.

In collaboration with the SO1.A4 team and based on the feedback received from the Management Office and the USAID, the study design was finalized in May this year and shared with the MO and USAID/Haiti. Specific objectives of this study are:

1. To conduct a survey of bean farmers in Haiti and collect information on farm characteristics, bean area, varieties planted, sources of seed, criteria farmers use in making seed use decisions (type, quantity, source, etc.), varietal trait preferences, and perceptions on seed quality, price, availability, and constraints.
2. To conduct an assessment of the bean seed supply chain to understand the seed system characteristics, supply and demand side constraints, institutional players involved in different nodes of the supply chain (i.e., producers/multipliers of different generation of seeds, distributors, traders, sellers, and buyers), and strategies/approaches used by the seed suppliers and users to meet the country's need for quantity and quality seed
3. To collect bean seed samples throughout the seed supply chain (i.e., seed producers, distributors, traders, seed and grain vendors, agro-dealers, and farmers) and conduct DNA fingerprinting analysis to identify the genetic identity of bean varieties planted by farmers and available in the 'seed system.'
4. To estimate the extent to which bean seeds of improved varieties are used by farmers and are in circulation in the seed system, and identify major constraints and opportunities for increasing the adoption of quality of bean seeds by farmers in Haiti.

The plan was to do the field research in summer 2016. However, due to personnel changes in NSS, which delayed the release of funds and hurricane Mathew, field data collection was postponed. Thus, no activities were undertaken to report in FY 16. The plan is to implement the survey in November-December in 8 Departments not affected by the hurricane and in March-April in the 2 Departments affected by the hurricane. 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, Ghana 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 Feed the Future 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).

Major Achievements

We would like to highlight the following emerging 'messages' based on the research results presented in this report.

- Research conducted in Zambia suggests consistent positive effects of cereal-legume rotation and other legume technologies on net crop income, calorie and protein production, and months of adequate household food provisioning. However, effects of cereal-legume intercropping are mixed for these indicators, and effects of the integration of legume crops in cereal based farming systems on household dietary diversity were inconclusive.
    - All else equal, farmers are willing to pay a premium for quality seed; but the average willingness to pay for highest rated quality seed over the lowest rated quality seed was only 30%. This is less than the price premium charged for certified seeds over the grain price in most developing countries. Secondly, the number of farmers willing to pay a premium price for quality seed declines as price of seed increases (i.e., evidence of a downward sloping demand curve). The implications of these findings are that there is no one-size-fits-all strategy (or business model) to meet the seed needs of all the farmers. Secondly, The importance of private sector, public sector and not-for profit sector in the seed system will depend on at what price the suppliers can produce and sell seeds that are perceived by the farmers to be of better quality than the grain. There is a need for:
    - Lowering the cost of quality seed production by increasing seed yield (i.e., reducing the rejection of seeds that don't meet quality standards)
    - Adopting a flexible seed price system where price of different quality grade seeds are determined by cost of production and not by the government or a seed regulatory agency

Research Capacity Strengthening

Unlike other Feed the Future 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 Feed the Future Legume Innovation Lab.

Human Resource and Institution Capacity Development

Short-term Training

Survey design and implementation training in Haiti (classroom and field testing)

Status: Not completed in FY 2016

Degree Training

First and Other Given Names: Christine
Last Name: Sauer
Citizenship: USA
Gender: Female
Training Institution: Michigan State University
Supervising Innovation Lab PI: Mywish Maredia
Degree Program for training: M.S..
Program Areas or Discipline: Agricultural Economics
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? No
Host Country Institution to Benefit from Training: None
Thesis Title/Research Area: the student assisted in panel data analysis of existing datasets from Zambia
Start Date: Fall 2015
Projected Completion Date: Fall 2017
Training status (Active, completed, pending, discontinued or delayed): Active
Type of Innovation Lab Support (full, partial or indirect) for training activity: Partial (student hourly job; the student had ¼ time assistantship from the Department)

First and Other Given Names: Edward
Last Name: Opoku
Citizenship: Ghana
Gender: Male
Training Institution: Michigan State University
Supervising Innovation Lab PI: Mywish Maredia
Degree Program for training: M.S..
Program Areas or Discipline: Agricultural Economics
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? No
Host Country Institution to Benefit from Training: None
Thesis Title/Research Area: the student assisted in the Ghana study on farmers' willingness to pay for cowpea seed
Start Date: Fall 2015
Projected Completion Date: Fall 2017
Training status (Active, completed, pending, discontinued or delayed): Active
Type of Innovation Lab Support (full, partial or indirect) for training activity: Indirect (the student has funding from the Mastercard Foundation Scholarship program)

Achievement of Gender Equity Goals

This project is designed to assess how the technologies and knowledge generated by the Feed the Future 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 Feed the Future 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.

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 2016 for each output:

Output 1. development of impact pathway analytical tools and guidelines:

1. Transfer of analytical tools to project PIs and research teams. Completed as planned (in FY 14)
2. Input and feedback to research teams on their impact pathway. Completed as planned (in FY 14)
3. 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: four technical reports, one thesis, and three manuscripts for peer reviewed venue have been completed.

Explanation for Changes

The following activities targeted to be achieved by the end of FY 2016 have been delayed:

Haiti impact study and short-term training. As indicated before, due to personnel changes and the hurricane, the field work for this study was delayed and is now being conducted in FY 17.

Self-Evaluation and Lessons-Learned

Challenges

Our project is a collaborative project cutting across all the other projects funded by the Feed the Future 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.

- **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.

Scholarly Accomplishments

Publications and Manuscripts

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. (under review Information Technology for Development)

Reyes, Byron A., Mywish K. Maredia, Richard H. Bernsten, and Juan Carlos Rosas. 2016. Opportunities Seized, Opportunities Missed: Differences in the Economic Impact of Bean Research in Five Latin American Countries. MSU International Development Working Paper 151. East Lansing: Michigan State University.

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 (submitted in December 2015).

Presentations and Posters

DeYoung, D., B. Reyes, J. C. Villatoro, L. Montejo, J. Moscoso, J. M. Osorno and Mywish Maredia. 2016. The Role of Beans in Milpa Production and Dietary Systems of Guatemalan Highlands: Results of a Farm Household Survey. Poster paper presented at the Pan-African Grain legume Conference, Livingston, Zambia, February 28 – March 4, 2016.

DeYoung, D. and M. Maredia. 2016. Can Community Based Seed Growers Produce Quality Seeds and be Sustainable? Evidence from the Community Seed Bank models in Nicaragua. Poster paper presented at the Pan-African Grain legume Conference, Livingston, Zambia, February 28 – March 4, 2016.

Maredia, M., D. Ilboudo and R. Pitoro. 2016. The Economics of Community Based Seed Production: A Case Study of the Association Song Koaadba (ASK), Burkina Faso. Poster paper presented at the Pan-African Grain legume Conference, Livingston, Zambia, February 28 – March 4, 2016.

Maredia, M., B. Reyes and D. DeYoung. 2016. Farmers' Willingness to Pay for Quality Bean Seed: Evidence from Central America. Poster paper presented at the Pan-African Grain legume Conference, Livingston, Zambia, February 28 – March 4, 2016.

Sauer, C., M. Maredia and N. Mason. 2016. Legume Technology and Agricultural Productivity: Evidence from Zambia. Poster paper presented at the Pan-African Grain legume Conference, Livingston, Zambia, February 28 – March 4, 2016.

Oral presentations

DeYoung, D. and M. Maredia. 2016. Determinants of Sustainability of Community Seed Banks in Nicaragua: A Duration Analysis Approach. Selected Paper prepared for presentation at the 2016 Agricultural & Applied Economics Association Annual Meeting, Boston, Massachusetts, July 31-August 2.

Maredia, M., R. Shupp, F. Mishili, B. Reyes and P. Kusolwa. 2016. Farmer willingness to pay for quality bean seed: Experimental evidence from Tanzania. Paper presented at the Pan-African Grain legume Conference, Livingston, Zambia, February 28 – March 4, 2016.

Sauer, C., N. Mason, M. Maredia and R. Mofya-Mukaka. 2016. The role of legume technologies in the agriculture-nutrition-food security nexus: evidence from Zambia. Selected Paper prepared for presentation at the 2016 Agricultural & Applied Economics Association Annual Meeting, Boston, Massachusetts, July 31-August 2.

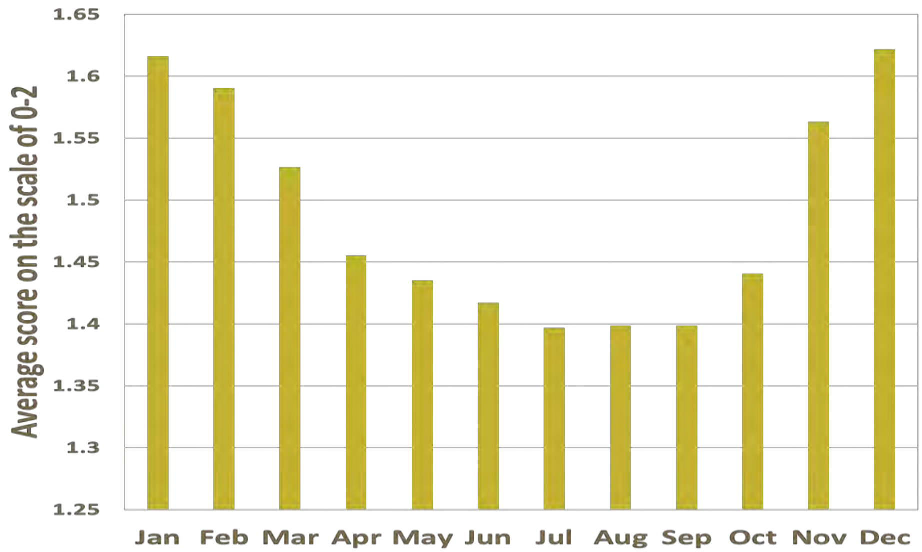
Data Management

The following datasets were submitted to USAID's DDL site in this reporting period (FY 2016).

- Bean Technology Dissemination Project: Beneficiary Survey in Guatemala
- Bean Technology Dissemination Project: Beneficiary Survey in Honduras
- Bean Technology Dissemination Project: Beneficiary Survey in Nicaragua

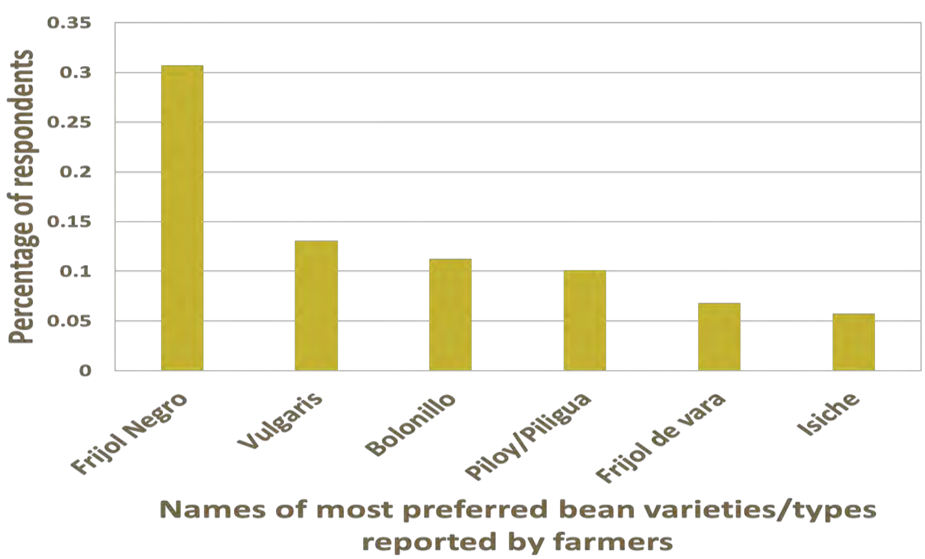
ANNEXES

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



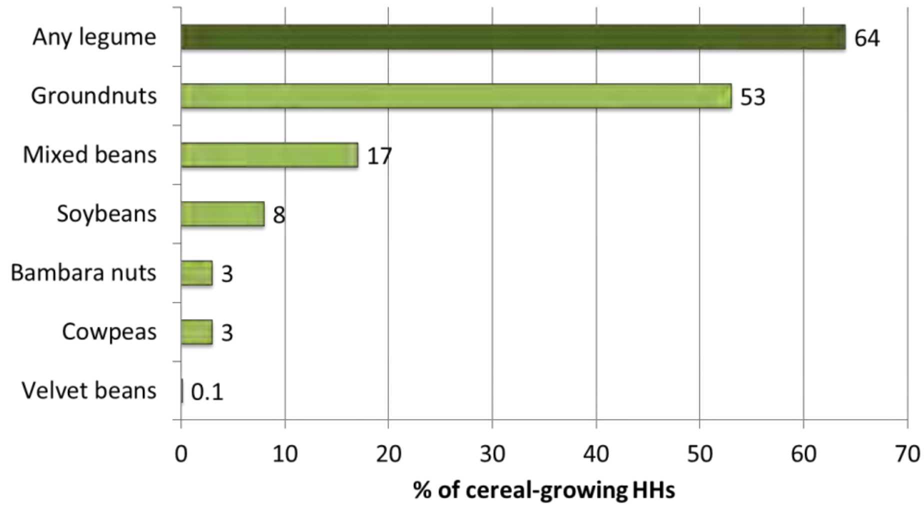
Source: Baseline survey of bean farmers in highlands of Guatemala (2015)

Fig 1. Mean bean consumption score over the past 12 months on a scale of 0 (no consumption) to 2 (relatively more consumption)



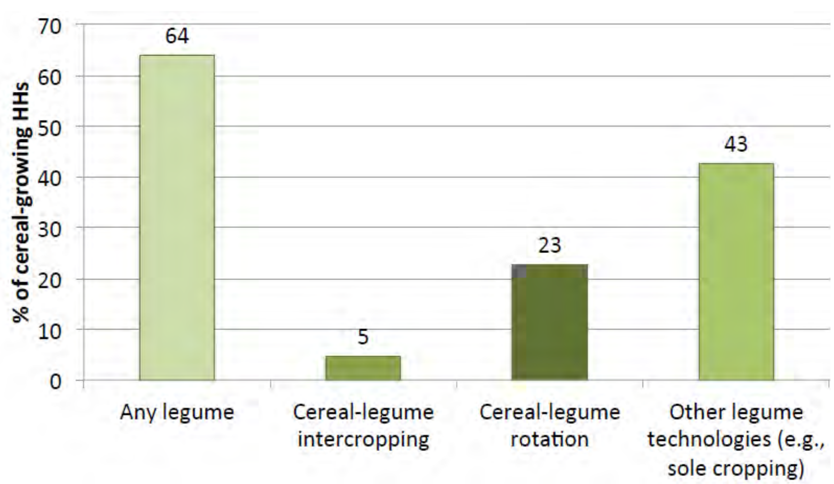
Source: Baseline survey of bean farmers in highlands of Guatemala (2015)

Fig 2. Most preferred bean varieties for consumption as named by farmers in Guatemalan highlands



Source: RALS (2015)

Figure 3. Percentage of cereal-growing HHs in Zambia producing legumes (2013/14 agricultural year)



Source: RALS (2015)

Figure 4. Prevalence of legume technologies among cereal-growing HHs in Zambia (2013/14 agricultural year)

Table 1. Effect of legume technologies on household income, calorie and protein production, Months of Adequate Household Food Provisioning, and Household Dietary Diversity Score: Key findings from Zambia

	Main explanatory variables of interest		
Outcome variables	**Cereal-legume intercropping**	**Cereal-legume rotation**	**Other legume technologies**
Net crop income	• Little evidence of stat. sig. effects once use 2SLS/FE	• Consistent (+) effects for continuous measure of adoption	
Calorie production			
Protein production			
MAHFP			
HDDS	• Some evidence of (+) effect (3/8 models)	• Some evidence of (+) effect (4/8 models)	• (+) in most (6/8) models

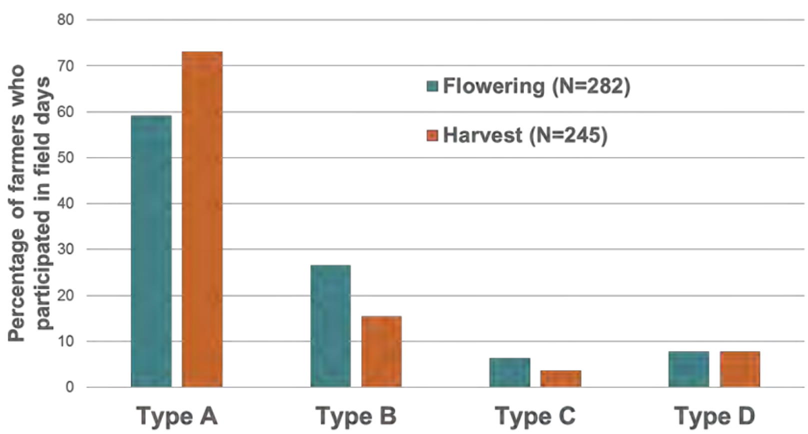


Figure 5. Farmer's rating of the best plot at two stages: Results from Tanzania

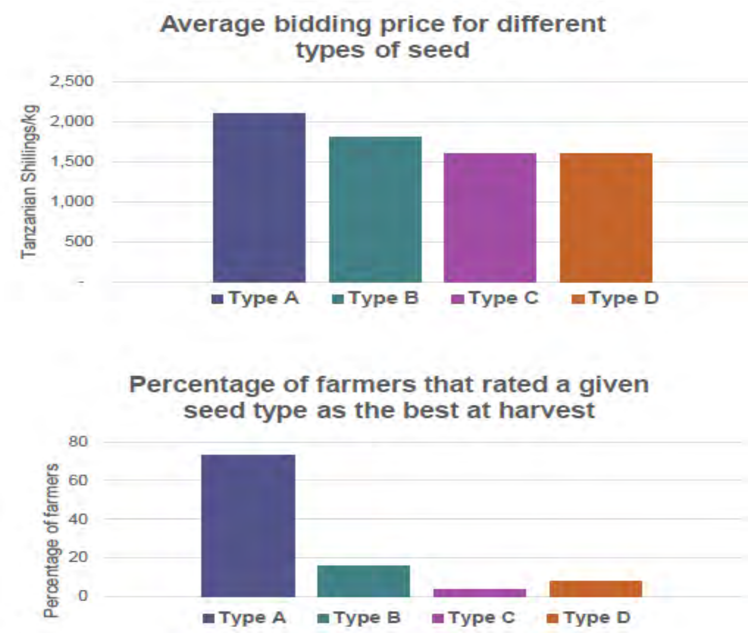


Figure 6. Comparison of farmers willingness to pay with their perceived quality differences (N=247)

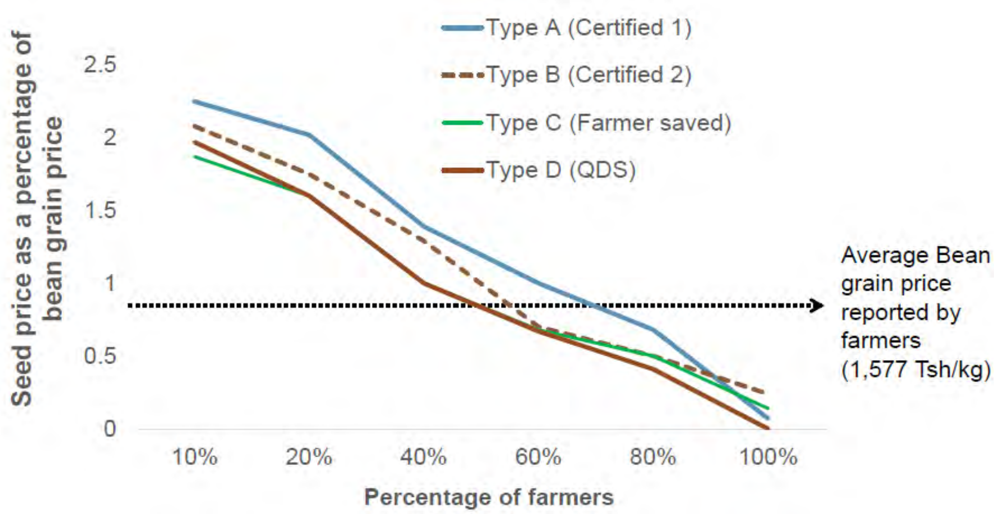


Figure 7. Farmer willingness to pay for seed of different perceived quality as a percentage of bean grain price: Results from Tanzania

Table 2. Business Model of ASK based on key informant interviews and farmers' survey

According to ASK key informant interviews	
Operation cost	30% of operating budget comes from sales of cowpea seeds (20%) membership fees (5%) and renting equipment (5%); The other 70% comes from donor support (NGOs).
Product/ services offered (all free to members)	a) Test, adapt and promote technologies; b) Capacity building (train farmers, trainers, farmer field schools); c) Technical monitoring, inspection and 'certification' of quality declared seeds produced by ASK members; d) Facilitate the purchase and sale of excess seeds produced by members
Scale of cowpea seed production	On average ASK members together produce ~40 tons of cowpea seed per year. In 2014, seed producing members devoted total 80 ha for cowpea seed production and produced 54 t of QDS cowpea seeds (compared to total 300 t of certified seeds produced in the country that year)
Seed distribution	In 2014 (According to ASK): 60% sold by seed producer members directly to other farmers; 30% sold through assistance from ASK; 10% sold or saved as grain by farmers
According to Producer Survey	
Requirement vs. Reality	Must devote 1-3 ha of land for seed production (compared with min 3 ha for certified seed); In practice, only 30% of farmers devoted 1 or more ha for seed production. Must follow technical guidelines: Only 2/3 seed producers received monitoring visits from ASK during seed production. Can sell the harvest as "seed" only if it meets the quality standards set by ASK; Rejected seed can be sold/consumed as grain. On average 31% of harvest is rejected as seed due to quality issues
Cost of seed production	Major costs: Foundation seed (procured by ASK from INERA)--2,500 CFA/kg applied at a rate of 12 kg/ha; labor; purchased inputs (e.g., fertilizer, chemicals); post-harvest handling (drying, sorting, conditioning). On average cowpea QDS seed production costs are ~50% more than cost of grain production (Source: farmer survey)
Quantity	On average a seed producer harvested 200 kg of approved seed
Marketing	36% of seed is sold to others; 34% to ASK and 30% retained; Price of QDS seed is set by ASK--700 CFA/kg for members, 800 CFA/kg for non-members (compare to price of grain-300 CFA/kg, certified seed-850 CFA/kg. A seed producer on avg. sold seed to 13 farmers.

Milestones

October 1, 2015 – March 31, 2016

Feed the Future Innovation Lab for Collaborative Researchon Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: October 1, 2015-- March 31, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by April 1, 2016

Project Title: **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	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**Y**	**N ***	**4/1/16**	**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 A research report summarizing the baseline assessment in Guatemala completed	X		X	0			0			0			0			0		
1.2 Preliminary results from panel data analysis generated for at least one country	X	X		0			0			0			0			0		
1.3 Policy Brief based on Objective 1 activities developed	0			0			0			0			0			0		
1.4 One research paper/manuscript based on objective 1 actiivities developed	0			0			0			0			0			0		
0	0			0			0			0			0			0		
Objective 2:	**Conduct ex ante and ex post impact assessments**																	
2.1 All data collection towards the willingness to pay study in Tanzania completed	X	X	X	0			0			0			0			0		
2.2 Preliminary results of the Tanzania willingness to pay study available for discussi	X	X		0			0			0			0			0		
2.3 decision made on extend in the field experiments to other countries	X	X		0			0			0			0			0		
2.4 Study design for Haiti impact study completed	X		X	0			0			0			0			0		
2.5 Field work for Haiti study completed	0			0			0			0			0			0		
Objective 3:	**Build institutional capacity and develop human resources in the area of impact assessment research**																	
3.1 HC collaborators participating in Haiti study trained	0			0			0			0			0			0		
3.2 Graduate student enrolled in degree program in AFRE	X	X		0			0			0			0			0		
3.3	0			0			0			0			0			0		
3.4	0			0			0			0			0			0		
3.5	0			0			0			0			0			0		

cont.

Objective 4:	**write objective here**																	
4.1	**0**			**0**			**0**			**0**			**0**			**0**		
4.2	**0**			**0**			**0**			**0**			**0**			**0**		
4.3	**0**			**0**			**0**			**0**			**0**			**0**		
4.4	**0**			**0**			**0**			**0**			**0**			**0**		
4.5	**0**			**0**			**0**			**0**			**0**			**0**		
Name of the PI reporting on milestones by institution	Mywish Maredia			PI name			PI name			PI name			PI name			PI name		
Name of the U.S. Lead PI submitting this Report to the MO	Mywish Maredia																	
	Signature															**Date**		

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

April 1, 2016 – September 30, 2016

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: April 1, 2016 -- September 30, 2016)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2016

Project Title: **SO4.1 Impact Assessment of Dry Grain Pulses CRSP investments in research, institutional capacity building and**

	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	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**Y**	**N***	**10/1/16**	**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 A research report summarizing the baseline assessment in Guatemala comp	**0**			**0**			**0**			**0**			**0**			**0**		
1.2 Preliminary results from panel data analysis generated for at least one coun	**0**			**0**			**0**			**0**			**0**			**0**		
1.3 Policy Brief based on Objective 1 activities developed	**X**	**X**		**0**			**0**			**0**			**0**			**0**		
1.4 One research paper/manuscript based on objective 1 actiivities developed	**X**	**X**		**0**			**0**			**0**			**0**			**0**		
0	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 2:	**Conduct ex ante and ex post impact assessments**																	
2.1 All data collection towards the willingness to pay study in Tanzania complete	**0**			**0**			**0**			**0**			**0**			**0**		
2.2 Preliminary results of the Tanzania willingness to pay study available for dis	**0**			**0**			**0**			**0**			**0**			**0**		
2.3 decision made on extend in the field experiments to other countries	**0**			**0**			**0**			**0**			**0**			**0**		
2.4 Study design for Haiti impact study completed	**0**			**0**			**0**			**0**			**0**			**0**		
2.5 Field work for Haiti study completed	**X**		**X**	**0**			**0**			**0**			**0**			**0**		

cont.

Objective 3:	**Build institutional capacity and develop human resources in the area of impact assessment research**																	
3.1 HC collaborators participating in Haiti study trained	**X**		X	**0**			**0**			**0**			**0**			**0**		
3.2 Graduate student enrolled in degree program in AFRE	**0**			**0**			**0**			**0**			**0**			**0**		
3.3	**0**			**0**			**0**			**0**			**0**			**0**		
3.4	**0**			**0**			**0**			**0**			**0**			**0**		
3.5	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 4:	**write objective here**																	
4.1	**0**			**0**			**0**			**0**			**0**			**0**		
4.2	**0**			**0**			**0**			**0**			**0**			**0**		
4.3	**0**			**0**			**0**			**0**			**0**			**0**		
4.4	**0**			**0**			**0**			**0**			**0**			**0**		
4.5	**0**			**0**			**0**			**0**			**0**			**0**		
Name of the PI reporting on milestones by institution	Mywish Maredia			PI name			PI name			PI name			PI name			PI name		
Name of the U.S. Lead PI submitting this report to the MO	Mywish Maredia																	

Mywish Maredia

Signature **Date**

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

Field work for Haiti study is significantly delayed because of: 1) funds not available to local partners to do the training and data collection. This was a result of the unexpected and abrupt change in the leadership at SNS; 2) contract

Performance Indicators

Overall Indicators 1

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

Summary of all institutions

Indic. number	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	0	0	0	1	1	2	0	1	0
	Total number by sex	0	0	0	0	0	0	1	1	2	0	1	0
	Number of women	0	0	0	0	0	0	1	1	1	0	0	0
	Number of men	0	0	0	0	0	0	0	0	1	0	1	0
	Total number by New/continuing	0	0	0	0	0	0	1	1	0	0	0	0
	New	0	0	0	0	0	0	1	1	0	0	0	0
	Number of women							0	0	1	0	0	0
	Number of men							0	0	1	0	0	0
	Continuing	0	0	0	0	0	0	0	0	0	0	0	0
	Number of women							0	0	0	0	0	0
	Number of men							0	0	0	0	1	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	0	0	0	55	0	16	15	15	0	0	15	0
	Number of women	0	0	0	15	0	4	5	5	0	0	5	0
	Number of men	0	0	0	40	0	12	10	10	0	0	10	0
	Numbers by Type of individual	0	0	0	55	0	16	15	15	0	0	0	0
	Producers	0	0	0	0	0	0	0	0	0	0	0	0
	Number of women							0	0	0	0	0	0
	Number of men							0	0	0	0	0	0
	People in government	0	0	0	55	0	16	15	15	0	0	0	0
	Number of women							0	0	0	0	5	0
	Number of men							0	0	0	0	10	0
	People in private sector firms	0	0	0	0	0	0	0	0	0	0	0	0
	Number of women							0	0	0	0	0	0
	Number of men							0	0	0	0	0	0
	People in civil society	0	0	0	0	0	0	0	0	0	0	0	0
	Number of women							0	0	0	0	0	0
	Number of men							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	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. 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, leave it blank.

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf

Overall Indicators 2

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 instittition): Michigan State University

Indic. number	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	1	2	0	1	0
	Total number by sex	0	0	0	0	0	0	1	1	2	0	1	0
	Number of women							1	1	1			
	Number of men									1		1	
	Total number by New/continuing	0	0	0	0	0	0	1	1	2	0	1	0
	New							1	1				
	Number of women									1			
	Number of men									1			
	Continuing												
	Number of women												
	Number of men											1	
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training												
	Total number by sex	0	0	0	55	0	16	15	15	0	0	15	0
	Number of women				15		4	5	5	0		5	
	Number of men				40		12	10	10	0		10	
	Numbers by Type of individual												
	Producers						0						
	Number of women												
	Number of men												
	People in government				55		16	15	15				
	Number of women									0		5	
	Number of men									0		10	
	People in private sector firms												
	Number of women												
	Number of men												
	People in civil society												
	Number of women												
	Number of men												
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. Disaggregate where applicable. Just providing 'totals' will not be approved.

** Short term training targets not achieved because of significant delays in m

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

There is additional guidance on the USAID website: https://feedthefuture.gov/sites/default/files/resource/files/Feed_the_Future_Indicator_Handbook_Sept2016.pdf