

**LEGUME INNOVATION LAB FOR COLLABORATIVE RESEARCH
ON GRAIN LEGUMES**

FY 2017 WORKPLAN FORMAT

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

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

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

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

Phil McClean, Dept. of Plant Sciences, North Dakota State University. Fargo-ND 58108

Julio C. Villatoro, ICTA-Guatemala

Angela Miranda, ICTA-Guatemala

Jessica Moscoso, ICTA-Guatemala

I. Project Problem Statement and Justification:

II. Planned Project Activities for the Workplan Period (October 1, 2016 – September 30, 2017)

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.

Approaches and Methods:

1.1: Validation plots and release of at least 1 climbing bean cultivar (ICTA): After 3 years of farmer's field testing (see previous annual reports), a selected group of 2-3 breeding lines will be grown in what ICTA calls validation plots across 10-15 locations in the western highlands of Guatemala. Each field consist of ~400 m² planted with one of the selected lines and growth next to or near the variety or varieties the grower normally uses. Some lines such as Bolonillo-Textel have been already in validation plots during the 2015 and 2016 growing seasons. Seed yield and other traits will be compared with common varieties and landraces grown in the vicinity of the testing fields (similar to sentinel plots).

The resulting information coming from multiple locations will allow understanding if only 1 line should be released or recommended for the entire highland ecosystem or if specific lines seem to be more adapted to specific regions and/or ecosystems better than others. This validation step (locally known as "Ensayos de Validacion"), is crucial for the approval of a new variety under the ICTA-Guatemala seed system. The releasing of an improved variety of climbing bean in 4 years of this project is possible thanks to the previous efforts made by the ICTA bean breeding project. In addition, we'll keep monitoring the phenotypic heterogeneity of the lines tested (objective 1.3).

1.2: Breeding pipeline (ICTA/NDSU): Approximately 97 advanced lines obtained from individual plant selections and purifications made during the last 2 years (objective 1.3) will be evaluated in replicated field trials at the ICTA stations in Chimaltenango and Quetzaltenango. This number includes individual plant selections made within heterogeneous lines (based on overall disease resistance/tolerance, pod load, color, and seed type). An average of 3 individual plants was selected within lines of interest. This material was planted again in 2016 at ICTA-Quetzaltenango for field evaluation under trellis conditions (Monoculture instead of intercropping to facilitate visual selection). Phenotypic selection will be practiced again. Selected advanced lines will be given to ICTA to continue field testing in subsequent years beyond FY2017 if additional funding is available after this 4-year cycle.

1.3: Genetic purification of selected advanced lines (ICTA/NDSU): A final effort to purify the advanced lines will be made if genetic heterogeneity is visually detected. During the 2016 growing season, plants with apparent superior performance (e.g. disease resistance, seed yield, pod distribution, seed quality, climbing aggressiveness, earliness, etc.) were tagged and individually harvested as a single plant selections. The seed from each individual plant selected will be in the off-season nursery at San Jeronimo in FY2017 for: i) seed increase, and ii) further evaluations.

1.4: Third crossing block (ICTA/NDSU): Another set of crosses will be attempted in FY2017 at the ICTA-Chimaltenango station in order to keep feeding the breeding pipeline (Objective 1.2). At least 40 new parental combinations will be made in order to create new segregant populations that can be used for selection in later generations. All this material contributes to the breeding pipeline (objective 1.2) that will

help to establish a long-term breeding program that will continue developing improved climbing beans adapted to the region in the future. It is important to note that besides the breeding efforts made by CIAT on climbing beans, this is the second breeding program focused on climbing beans in the western hemisphere.

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.

Approaches and Methods:

2.1 Evaluation of core collection with the 6k SNP chip (NDSU): Genotyping of the climbing bean germplasm collection has been completed by running the 6k chip in ~400 accessions. SNP data was recently received from Hudson Alpha Institute and it is currently being processed for analysis as it is usually done in Phil McClean's lab. Gene call and identification of heterozygotes is one of the first main steps in order to control for data quality. We are nearing the completion of the SNP calling step. This has required us to evaluate several SNP calling software for our purposes. These include GATK and VarScan. That final SNP data set will be used for multiple GWAS analysis using data collected at ICTA and data collected by LIL project participants.

Monomorphic markers as well as markers with more than 50% of missing information will be discarded. Several parameters of population diversity and structure will be used to assess the organization of the genetic diversity in this group of germplasm. An attempt to do comparisons with other genetic groups/races previously analyzed by the BeanCAP project and others, will also allow having a better understanding of where this group of germplasm could fit into what is known about bean genetic diversity (gene pools and race organization). As suggested in several previous studies, the climbing beans from Guatemala tend to cluster as a separate race (labeled as "Guatemala race") within the Mesoamerican gene pool.

The genotyping and analyses will be part of the research topic for one of the M.S. students coming to NDSU from ICTA. The NDSU bean genomics lab under the direction of Phil McClean has a lot of expertise in this area and will be in charge of these analyses. Some of the results found in this study will aid in the planning and designing of the crossing block during FY2017. This core 300 collection could be used as a diversity panel that could be used for Genome Wide Association Studies (GWAS). This will allow identifying genomic regions associated with traits of agronomic/economic importance within this unique group of germplasm. This approach has been successful already in common bean, identifying regions associated with growth habit,

seed color, seed size, days to flowering, among others. A similar approach is being used as a thesis topic for two more M.S. students from ICTA to identify candidate regions associated with disease resistance genes (rust and anthracnose). GWAS analysis will be made by using the GAPIT software/pipeline commonly used in the lab. The analysis will consist of four models: naïve (no population structure or relatedness control); general linear model (structure control); mixed linear model (relatedness control); and mixed linear model (population and relatedness control). The output from the analyses will be compared, and the model that best fit the expected distribution will be selected. The p-value distribution will be bootstrapped, and the SNPs at the 0.1% and 0.01% lower tail of the distribution will be considered significant. This project has pre-release access to version 2 of the annotation of common bean genome. The release will be used to selected candidate genes. Genes within 50kb up- and down-stream of the most significant SNP peak will be selected as potential candidate genes that control a specific trait.

Other members of the project will also use the SNP data during the upcoming year. The original ICTA population is being screened for response to local bean rust and anthracnose isolates collected in Guatemala as part of this project. That data will be subjected to GWAS will use the same protocol just described above. This approach will provide a unique opportunity to confirm the results obtained by the evaluation of the bean rust and anthracnose isolates. Disease resistance genes are well-known to cluster in common bean. The specific disease resistance specificities have been localized within these clusters. Therefore, the location of the GWAS peak will correspond to a unique resistance specificity. If the peak does not fall within the location of a known resistance specificity, then we will know that we are observing a new race of the pathogen and a new resistance locus. Those lines expressing resistance will then be useful parents for further genetic studies to identify the resistance gene and to introgress that resistance into the Guatemalan bean improvement program.

2.2 SNP Evaluation of the new Guatemalan collection (NDSU): A total of 452 samples of beans were donated by local farmers as part of the grower's survey made during FY2015 (Objective 3). This came in the form of donations from 1-2 seeds to several dozen seeds. These are seeds represent the beans that are currently being grown throughout the highlands of Guatemala, the target region of the project. This is a major new resource that needs full characterization both phenotypically and genotypically. In addition, an additional 48 samples were provided by an additional ICTA collection made during 2014. Of the 500 samples, 420 contained only a single seedtype (black, red, white). Sequence-based SNP data from this new collection will be compared with the SNP data from the original collection housed at ICTA. A major advantage of this newer collection is that passport data (GPS coordinates, location, altitude, etc.) is available while this was lost for the original collection as mentioned in previous documents. We will attempt to do a geographical correlation between both collections using the genotypic data obtained from both groups.

This 500-entry collection consists of black, red, and white seeded beans, and 420 of the donations contain only a single seed type. Those donations with mixed seed types were split into two subsamples based on seed type. All totaled, 580 sample will be characterized. Plants for all of the samples will be grown

in the greenhouse until the initial trifoliolate leaves emerge. Leaf samples will be collected on a single plant. DNA will then be isolated from all of the samples. We will then develop five or six (depending on final number of lines) pooled, low-pass sequencing libraries, and DNA sequence data will be collected from 230 base pair reads. The reads will be processed using the GATK software from The Broad Institute, MIT. The final SNP collection will be imputed to develop the final SNP set to be used for analysis.

The SNP data from this population will be merged with the SNP data for ICTA population. A STRUCTURE analysis will be performed that will provide a characterization of the subpopulation structure of the original and new populations. We will be looking to determine if members of the new population are distributed across the subpopulations of the original populations, or whether they represent a new distinct population. The results of this analysis will inform choices for parents in new crosses for Guatemalan bean improvement.

2.3 Field evaluation of the newer ICTA collection of climbing beans (ICTA/NDSU): A final evaluation of the new germplasm collection obtained from the grower survey (see objective 3.2) will be made at the ICTA station in Chimaltenango during the growing season of 2017 to allow a re-evaluation of the material and also the production of a newer batch of seed. Approximately 490 accessions were obtained during the grower survey. In addition, 100 accessions have been obtained from the genetic resources group at ICTA which were collected during 2014. Each accession is planted in short rows (~2 m) in a trellis system mostly for phenotypic observation. The following traits are recorded: disease reaction under natural conditions (Ascochyta, Rust, Anthracnose), earliness, biomass/climbing aggressiveness, seed yield potential, and pod distribution (upper vs. homogeneous distribution). Selected germplasm will be used in future crosses.

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: Julio Cesar Villatoro, Jessica Moscoso, Angela Miranda.

MSU: Mywish Maredia and David DeYoung.

Approaches and Methods:

3.1 Final statistical analyses of survey data and publication of results (ICTA/MSU/NDSU): Final statistical analyses and publication of results are the remaining activities of this objective. 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. In the same way Gustavo Mejia, a social economist at ICTA-Quetzaltenango was of key importance in

coordinating this activity. Results of this survey will be shared not only within the project but with other projects currently working in Guatemala (e.g. Masfrijol) and government agencies interested. No field activities are planned for this objective during FY17.

3.2 Conditioning and storage of seed samples collected during the survey (ICTA): During the deployment of the survey during FY2015, growers were asked to provide a small seed sample of the variety or varieties they commonly grow in their farms. Once the seed increase of these germplasm is completed during FY2016, seed will be conditioned and stored at the cold seed room available at the ICTA-Chimaltenango station.

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 (NDSU): The 2 students recruited from ICTA for M.S. degrees at NDSU continue to make progress towards their degree. We expect they will be able to complete their programs by the end of FY2017. Funds are needed to pay for their assistantship as well as research supplies so they can successfully complete their degrees.

4.2. Long-term breeding plan (ICTA/NDSU): A final document describing a long term plan to continue breeding activities for climbing beans will be developed. This document will help to be a future roadmap regardless of the availability of funds in the future. If future funding opportunities arise, this document will facilitate the writing of a new project that will keep the momentum gained during these 4 year cycle.

4.3. Plant Breeding workshop (ICTA/NDSU): A 2-day workshop will be held during the summer 2017 at ICTA-Guatemala focused on plant breeding theory and techniques. All ICTA personnel currently doing work related to plant breeding in any crop will be invited. In addition, faculty/students from local universities as well as national programs from the Central American region will be invited to participate but they will have to cover their travel expenses.

III. Contribution of Project to USAID Feed the Future Performance Indicators:

See attached table with Future Performance Indicators.

IV. Outputs:

- 1. Objective 1:**
 - 1.1. Validation plots and release of at least 1 climbing bean cultivar (ICTA)**
 - 1.2. Breeding pipeline (ICTA/NDSU)**
 - 1.3. Genetic purification of selected advanced lines (ICTA/NDSU)**
 - 1.4. Third crossing block (ICTA/NDSU)**

- 2. Objective 2:**
 - 2.1. SNP evaluation of core collection with the 6k SNP chip (NDSU).**
 - 2.2. SNP evaluation of the new Guatemalan collection (NDSU).**
 - 2.3. Field evaluation of the new collection of climbing beans (ICTA/NDSU)**

- 3. Objective 3:**
 - 3.1. Final statistical analyses of survey data and publication of results (ICTA/MSU/NDSU).**
 - 3.2. Conditioning and storage of seed samples collected during the survey (ICTA)**

- 4. Objective 4:**
 - 4.1. Two graduate students at NDSU (ICTA/NDSU).**
 - 4.2. Long-term breeding plan (ICTA/NDSU).**
 - 4.3. Plant Breeding workshop (ICTA/NDSU).**

V. Engagement of USAID Field Mission(s)

Local USAID Mission in Guatemala is always contacted when U.S. scientists visit. In most cases, briefing meetings are held in their offices. Host country scientists are also responsible of informing local USAID Missions about progress of the Legume Innovation Lab project toward research and training objectives. Opportunities will be sought to obtain USAID Mission support to expand activities in host countries.

VI. Partnering and Networking Activities:

The NDSU scientists responsible for this project (Osorno and McClean) are also involved in other projects from the Legume Innovation Lab (e.g. SO.A4). Therefore, some collaboration among projects is expected. The personnel from EAP-Honduras (J.C. Rosas) have also shared germplasm and expertise to help in any way possible. Efforts will be made to travel around the same dates to the region in order to discuss the project's evolution. Close collaboration with project SO4.1 (Mywish Maredia) has been crucial for the success of the survey activities. In addition, P. McClean is directly involved with the project lead by Penn State (J. Lynch) on climate-resilient beans and also funded by USAID.

Several Legume Innovation Laboratory scientists participate in Regional Hatch Project W-3150 which is a multi-disciplinary network of U.S. bean researchers. The NDSU dry bean breeding program at NDSU conducts winter nurseries at Puerto Rico and this will allow for further discussion of the projects on a person-to-person base. In addition, most scientists involved in the project will meet every other year at the Bean Improvement Cooperative (BIC) meetings and other scientific meetings. Researchers in Central America and the Caribbean often make scientific presentations at the annual meeting of the PCCMCA. The meeting provides an opportunity for the Central American/Caribbean research network which includes national programs, CIAT and the Legume Innovation Laboratory scientists to meet to exchange results from research and plan activities for the upcoming year. Efforts will be made to participate at these meetings in Central America and share the project developments.

Last but not least, efforts will be made to have close collaboration with the Masfrijol project funded by the USAID Guatemala mission and lead by Luis Flores from Michigan State Univ. Advanced genetic material developed by our project will be shared with them for field testing and studies on consumer preferences. Efforts will be made to meet with members of this group whenever possible to keep both project updated on the current activities.

VII. Leveraging of CRSP Resources:

Germplasm exchange is still a common activity among dry bean breeders and even boosted up by some of the networks previously mentioned. The germplasm developed in this project could be useful in other regions growing climbing beans. In addition, the genetic material could have unique genes/sources of resistance/tolerance to production problems also present in the United States.

Some of the genomic resources and tools developed by the BeanCAP project funded by USDA-NIFA will be of great help to start these breeding platforms in Guatemala and other developing countries.

Legume Innovation Lab breeders and pathologists (Kelly, Steadman, Urrea, Osorno, Beaver, Estevez, and Porch) have an opportunity to meet at least once a year in Puerto Rico. This facilitates communication between the Legume Innovation Lab bean breeding projects. In addition, close collaboration with CIAT breeders will allow germplasm exchange and sharing of the scientific knowledge.

VIII. Timeline for Achievement of Milestones of Technical Progress:

See attached file with project Milestones.

XI. Training/Capacity Building Workplan for FY 2016 – 2017 (use format below)

Degree Training:

Degree Training:

First and Other Given Names: Maria Gabriela

Last Name: Tobar Piñon

Citizenship: Guatemalan

Gender: Female

Training Institution: NDSU

Supervising CRSP PI: Phil McClean

Degree Program for training: M.S. in Plant Sciences

Program Areas or Discipline: Plant breeding/genomics

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? Yes

Host Country Institution to Benefit from Training: ICTA

Thesis Title/Research Area: Molecular characterization of germplasm collection of Guatemalan climbing beans.

Start Date: August 2015

Projected Completion Date: December 2017

Training status (Active, completed, pending, discontinued or delayed): Active

Type of CRSP Support (full, partial or indirect) g for training activity: Full

Degree Training:

First and Other Given Names: Luz de Maria

Last Name: Montejo

Citizenship: Guatemalan

Gender: Female

Training Institution: NDSU

Supervising CRSP PI: Juan M. Osorno

Degree Program for training: M.S. in Plant Sciences

Program Areas or Discipline: Plant breeding/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: Disease resistance (rust) 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 CRSP Support (full, partial or indirect) g for training activity: Full

Short term training:

Type of training: Short term in-service training

Description of training activity: A 2-day workshop focused on plant breeding theory and techniques for all ICTA personnel doing work related to plant breeding in any crop will be invited. In addition, faculty/students from local universities as well as national programs from the Central American region will be invited to participate but they will have to cover their travel expenses.

Location: ICTA/Barcenas

Duration: 2-3 days

When will it occur? - 2017

Participants/Beneficiaries of Training Activity: 12

Anticipated numbers of Beneficiaries (male and female): 7M, 5F

PI/Collaborator responsible for this training activity: Juan Osorno

List other funding sources that will be sought (if any): Some participants from the region will be funded for travel by their institution

Training justification: This training is needed to permit host country scientists to take advantage of the recent advances in crop breeding.

Equipment (costing >\$5,000):

None.

FY 2017 WORKPLAN

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

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

David M. Kramer

Biochemistry and Molecular Biology and MSU-DOE Plant Research Lab

Michigan State University

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

Tim Close, University of California, Riverside

Maren Friesen, Michigan State University

Kelvin Kamfwa, University of Zambia

James Kelly, Michigan State University

Wayne Loescher, Michigan State University

Kennedy Muimui, ZARI, Zambia

Phil Roberts, University of California, Riverside

I. 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 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.

In previous years of the project we have identified environmental conditions that aid in the identification of QTL's in common bean and cowpea. Furthermore, we have successfully deployed

PhotosynQ under field conditions in Zambia. However, a lack of infrastructure is constraining the development of a robust phenotyping center at the University of Zambia.

II. Project Activities for the FY 2017 Workplan Period (October 1, 2016 – September 29, 2017)

The ultimate goal of this project is to increase grain legume productivity in Africa. To achieve this goal, this project aims to 1) accelerate breeding efforts to improve grain legumes thru the development of two innovative phenotyping technologies (DEPI chambers and the PhotosynQ platform) and 2) integrate these phenotyping tools into a region-led effort to improve agricultural grain legume production in Africa. Specifically, we will undertake the following objectives:

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

In 2016, we identified a combination of genotypes and environmental conditions in common bean and cowpea that show strong indications that we can use DEPI and PhotosynQ technologies to map QTL's. In cowpea, the MAGIC line showed large differences in photosynthetic response to high day and nighttime temperature. In common beans, Tepary beans have shown large differences in response to heat and drought tolerance. In both cases, robust phenotypical differences can be observed in seedlings, which can lead to rapid identification of phenotypes.

In 2017, we will explore the feasibility of mapping QTL's for these traits using DEPI under simulated conditions. We will then repeat these experiments under dynamic conditions in the field using PhotosynQ at NDSU and UC Riverside. Furthermore, we will assess the mechanistic basis of heat and cold tolerance in cowpea using biochemical and biophysical analysis.

Collaborators:

Tim Close, University of California, Riverside

Maren Friesen, Michigan State University

James Kelly, Michigan State University

Wayne Loescher, Michigan State University

Phil Roberts, University of California, Riverside

Approaches and Methods:

1.1. Explore the effectiveness of mapping QTL's in common bean and cowpea lines under simulated high and low temperatures and drought conditions in DEPI chambers. The work will be carried out by students (Isaac Osei-Bonsu and Donghee Hoh) under the supervision of Greg Austic, Dan TerAvest, and Jeffrey Cruz (USA, Kramer Lab) (Target Date: Feb. 2017).

- 1.2. Based on the results of these experiments, we will repeat promising experiments in the field at NDSU and UC-Riverside using the PhotosynQ platform (Target Date: Sept. 2017).
- 1.3. Conduct biochemical and biophysical experiments to explore the mechanisms behind temperature and drought effects in cowpea and common bean (Target Date: Sept. 2017).
- 1.4. Train 3 graduate students at Michigan State University.

Objective 2: Develop a data management plan to improve the communication of ideas, results, and analysis to a large network of connected scientists.

As a part of the development process, we have proposed modifying the PhotosynQ platform to meet the needs of project collaborators while concurrently meeting the requirements of USAID's open data policy.

The PhotosynQ platform allows for rapid communication of ideas, results, and analyses. As emphasized by the Data Management Plan, we realize the need to maintain the privacy of researchers and students. Currently the PhotosynQ platform makes all results public at the time of measurements, leading to potential privacy issues. To address these issues, we will further develop and implement a system of privacy and anonymization layers into the PhotosynQ platform. This objective will require some resources in order to travel to consult with USAID and programming resources.

Collaborators:

Greg Austic (MSU)

Venturit (East Lansing)

Approaches and Methods:

- 2.1. Consult with USAID staff to ensure that PhotosynQ's privacy policy conforms to USAID's open data policy (Target Date: March, 2017).
- 2.2. Adjust the privacy policies on the PhotosynQ platform to address privacy concerns (Target Date: Sept. 2017).

Objective 3: 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 2016, we shipped PhotosynQ devices to the University of Zambia and began the process of training research technicians and undergraduate students. However, a lack of infrastructure (e.g. labor and supplies to manage field trials, printers, internet infrastructure, etc.) hampered the ability of our collaborators in Zambia to design, implement, and analyze robust field experiments. To overcome these constraints we will increase the budget allocated to the University of Zambia by \$10,000 and will place an emphasis on developing the training modules and procedure's necessary to strengthen the capacity of plant breeders at the University of Zambia. Additionally, we will develop experimental design tools (e.g. randomization, etc) that are easy to use, do not disturb the PhotosynQ workflow, and enhance the quality of data.

Collaborators:

Kelvin Kamfwa (U. Zambia)

Wayne Loescher (MSU)

Kennedy Muimui, ZARI, Zambia

Jim Kelly (MSU)

Approaches and Methods:

- 3.1. Develop experimental design tools that connect to the PhotosynQ platform to aid in the design of robust experiments (Target Date: Dec. 2016).
- 3.2. Create training modules for PhotosynQ projects that teach users how to design and implement plant breeding projects with high statistical power (Target Date: Dec. 2016).
- 3.3. Provide researchers and students in Uganda with MultispeQ devices and training so that they can successfully use the PhotosynQ platform (Target Date: Feb. 2017).
- 3.4. Train field technicians and undergraduates at UZ and the national bean breeding program in PhotosynQ use (Target Date: Feb. 2017).
- 3.5. Using DEPI results from outcome 1, repeat these experiments in the field at the University of Zambia using the PhotosynQ platform (Target Date: April 2017).
- 3.6. Build the infrastructure needed to establish a field based phenotyping program at the University of Zambia. We will re-allocate \$10,000 in the final year to accomplish this outcome. (Target Date: Sept. 2017).
- 3.7. Train XXX field technicians and undergraduate students on the PhotosynQ platform at the University of Zambia (Target Date: Sept. 2017).
- 3.8. Train 1 Masters student at the University of Zambia on the PhotosynQ platform.

III. Contribution of Project to USAID Feed the Future Performance Indicators:

The “Performance Indicators – Targets” forms for each country have been completed for the project following FTF guidelines.

IV. Outputs:

- 1) Narrow the target potential lines in the Durango and Magic diversity panels of common bean and cowpea to speed up the plant breeding timeline, improve the outcomes.
- 2) Understand the mechanisms behind heat tolerance in cowpea and common bean lines.
- 3) Establishment of a working phenotyping group in Zambia

- 4) Development and implementation of a Data Management Plan for PhotosynQ that includes critical privacy layers
- 5) Training of two graduate students at MSU and 1 at University of Zambia
- 6) Strengthen the capacity of researchers at the University of Zambia to conduct in-field phenotyping to improve their ability to select better adapted grain legume varieties.

V. Engagement of USAID Field Mission(s)

The current stage of work will set up the foundations for direct interactions with regional missions.

VI. Partnering and Networking Activities:

- 1) Establishment of interactions by education and short-term research visits.
- 2) Development of training modules that will allow HC researchers and students to use the PhotosynQ platform.
- 3) Establishment of links through the PhotosynQ platform. A key component of the PhotosynQ platform is the interactive data and project sharing. The training and technology transfer described in the project will enable researchers both in US and HCs to communicate and share results.

VII. Leveraged Resources: The project makes direct use of expertise, technology and on-going research experiments in USAID, McKnight and USDOE-funded projects. This leveraging of resources will allow us to perform the proposed work for very low cost. The leveraged resources include the following:

The MultispeQ sensor is being developed under three projects. The basic technology was developed under a grant from the U.S. Department of Energy. The initial MultiSpeQ sensor for the platform was developed under a grant from the McKnight Foundation “MultispeQ: A Deployable Sensor for the PhotosynQ Network to Enable Critical Plant, Soil and Seed Measurements for African Breeders and Extension Agents,” which we have applied for a renewal. In addition the social networking aspects of the PhotosynQ platform were developed under a grant from USAID through the MSU Global Center for Food Safety Innovations.

VIII. Timeline for Achievement of Milestones of Technical Progress: See attached “Milestones for Technical Progress.”

Appendix 1: Workplan for Training and Capacity Strengthening (FY 2017).

Degree Training:

First and Other Given Names: Susan

Last Name: Chipandwe

Citizenship: Zambian

Gender: Female

Training Institution: University of Zambia

Supervising Legume Innovation Lab PI: Kelvin Kamfwa

Degree Program for training: Masters

Program Areas or Discipline: Plant Breeding and Seed Systems

Host Country Institution to Benefit from Training: University of Zambia

Thesis Title/ Research Area: Genome-wide association analysis of photosynthesis-related traits in common bean

Start Date: 9/01/2016

Projected Completion Date: September 2018

Training Status: Pending

Type of Legume Innovation Lab Support (full, partial or indirect): Full

First and Other Given Names: Isaac

Last Name: Dramadri

Citizenship: Uganda

Gender: M

Training Institution: MSU

Supervising Legume Innovation Lab PI: James D. Kelly and Wayne Loescher

Degree Program for training: Doctorate

Program Areas or Discipline: Plant Breeding, Genetics and Biotechnology

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? Yes

Host Country Institution to Benefit from Training: MSU/U. Zambia

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

Training Status: BHEARD Fellowship from USAID Mission, Kampala.

Type of Legume Innovation Lab Support (full, partial or indirect): Indirect – research support

First and Other Given Names: Donghee

Last Name: Hoh

Citizenship: Korea

Gender: F

Training Institution: MSU

Supervising Legume Innovation Lab PI: David M. Kramer

Degree Program for training: Doctorate

Program Areas or Discipline: BioMolecular Science/Microbiology & Molecular Genetics

If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? No

Host Country Institution to Benefit from Training: MSU

Thesis Title/ Research Area: WTL Analyses of cowpea and common bean photosynthesis

Start Date: July, 2015

Projected Completion Date: September 2018

Training Status: Second year graduate student

Type of Legume Innovation Lab Support (full, partial or indirect): Full

First and Other Given Names: Isaac

Last Name: Osei-Bonsu

Citizenship: Ghanaian

Gender: Male

Training Institution: Michigan State University

Supervising CRSP PI: Dr. David Kramer

Degree Program for training: Doctorate

Program Areas or Discipline: Plant Physiology

Host Country Institution to Benefit from Training: CSIR-Crops Research Institute

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

Type of Legume Innovation Lab Support (full, partial or indirect) for training activity: Indirect – research support

Short-term Training:

Type of training: PhotosynQ

Description of training activity: Training technicians from the Zambian national bean breeding program (Ministry of Agriculture of Zambia) on the use of PhotosynQ technologies in bean breeding experiments.

Location: Misanfu Research Station

Duration: 2 days

When will it occur? December, 2017

Participants/Beneficiaries of Training Activity: Robert Lungu (male), Mary Attoo (female)

PI/Collaborator responsible for this training activity: Kelvin Kamfwa

Approximate budget allocation from USAID funds for training: \$100

Training justification: To ensure that collaborators in Zambia are trained to collect high quality in-field phenotyping data.

Type of training: PhotosynQ

Description of training activity: Train undergraduate students from the University of Zambia

Location: U. of Zambia, Lusaka

Duration: 2 days

When will it occur? January, 2018

PI/Collaborator responsible for this training activity: Kelvin Kamfwa

Participants/Beneficiaries of Training Activity: Male students-2, female students-1

Approximate budget allocation from USAID funds for training: \$0

Training justification: To ensure that collaborators in Zambia are trained to collect high quality in-field phenotyping data.

Equipment to be purchased (costing >\$5,000): **None**

Appendix 2: Budget Narrative

Personnel Cost: Salary and fringe benefits totaling approximately \$74,000 are requested for 2017. In the US, these funds will provide the full salary for one graduate student working on the project and for 3 months of salary for two PhotosynQ staff (D. TerAvest and G. Austic) who will provide technical support and

training to collaborators in the USA and Zambia. In Zambia, the requested funds will provide full-time salary and fringe benefits for one graduate student.

Travel: Funds are requested for local travel in both the USA and Zambia to allow collaborators to travel to field research sites for PhotosynQ data collection (\$3,159) and for international travel for David Kramer to travel to the University of Zambia (\$4,000) for planning and collaborative meetings.

Supplies and Services: In the US, key supplies and services include managing the DEPI chambers (\$2,234) and PhotosynQ devices and related devices (android phones, carrying cases, etc) that will be shipped to the University of Zambia (\$6,704). In Zambia, we have increased our request for supplies due to a lack of infrastructure at the University of Zambia, which has inhibited our collaborators ability to conduct robust PhotosynQ field trials. Therefore, we have requested \$16,162 in supplies and services for the following: field research plot management (seed, fertilizer, weeding), research supplies (stakes, labels, markers, printers, etc) and internet infrastructure (modems, internet service, etc).

Training: We are requesting \$11,984 in tuition/support for one graduate student in the USA and \$5,455 in tuition/support for one graduate student at the University of Zambia.

Indirect Costs: Total indirect costs for the 2017 fiscal year total \$51,067 with the rates based on USAID requirements.

Split of direct costs: Of the total direct costs, 58% are going to support collaborators at the University of Zambia, either thru a direct sub-award to UZ, shipping PhotosynQ and related devices to UZ, or by providing training and technical support directly to UZ collaborators. 45% of direct project costs go to achieving project objectives in the USA.

Cost share: The Kramer lab will contribute an additional \$9,283 in in-kind support to achieving the goals of this LIL project.

Institutional Capacity Building: Approximately 25% of the US funds for the host country (\$11,000) are going to capacity building in Zambia by providing PhotosynQ and related devices and training to UZ staff. Half of the UZ sub-award will go to institutional capacity building by increasing the University's capacity to conduct robust phenotyping experiments using PhotosynQ.

FY 2017 WORKPLAN

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

Lead U.S. Principal Investigator

James D. Kelly, MSU, East Lansing, MI

Collaborating Scientists

Wayne Loescher, Dept. Horticulture, MSU

James Steadman, Carlos Urrea, - University of Nebraska, Lincoln and Scottsbluff

Stanley Nkalubo – NaCRRI, Uganda

Kennedy Muimui – ZARI, Zambia

Karen Cichy, USDA-ARS, East Lansing, MI

I. 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. 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. As a non-traditional agricultural export crop, beans have gained a major dominance in terms of tonnage and monetary value among Uganda's exports. That beans are produced in every district illustrates the dependence on beans as a major food security crop and their importance in farmers' household incomes. The crop is ranked fourth in terms of export volume and eighth in terms of export value. The crop is also the most important source of protein for the Ugandan population providing 45% of the total human dietary protein and

plays a significant role in ensuring food security. Beans provide a cheap source of protein to most vulnerable groups such as children below five years, pregnant mothers and AIDS patients. 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 (ALS, ANT, root rots, BCMV) 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 presence of other stresses such as high temperature, root diseases, shallow infertile soils and climate change all contribute to intensify the problem. Improvements in current understanding of the physiology of drought and evapo-transpiration and the genetics of drought tolerance in common bean and the development of effective molecular and quantitative methods for the selection of drought tolerance are therefore needed. The development of improved varieties and germplasm with high yield potential, healthy root systems, improved BNF 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. Results of this project would contribute to improved yield, farm profitability and human resources in the host countries and indirect benefit to participating U.S. Institutions and bean producers.

II. Planned Project Activities for FY 2016-17

Objective 1: Integrate traditional and marker-assisted selection (MAS) approaches to combine resistances to economically important foliar diseases, drought and improved biological nitrogen fixation (BNF) and assess acceptability of fast cooking, high mineral content in a range of large-seeded, high-yielding Andean bean germplasm for the Eastern Africa highlands (Zambia and Uganda), and the U.S.

Collaborators

Jim Steadman, Carlos Urrea, - Nebraska

Stanley Nkalubo - Uganda

Kennedy Muimui – Zambia

Karen Cichy, USDA-ARS, Michigan

Approaches and Methods

1. Seed increase in each country for all available nurseries. Screen the disease nursery to different pathogens in greenhouse in Zambia. The races to be used will be determined from objective 2.
2. Initiate selection for disease resistance in field and under screen house inoculation condition in Zambia.
3. Screen the disease nursery to different pathogens (, ANT, and ALS field conditions in Uganda. The races to be used will be determined from objective 2.
4. Complete screening for rust and CBB in Uganda
5. Screen the disease nursery to CBB in North Platte, NE.
6. Screen a subset of the Andean panel and NIFA root rot lines to terminal drought in Scottsbluff, NE.
7. Complete screening of the drought nursery in Uganda to intermittent drought stress.
8. Screen the drought nursery in Nebraska to terminal drought stress.
9. Evaluate population s generated from crosses between resistance sources for angular leaf spot (ALS), rust, anthracnose, common bacterial blight, virus resistance and drought tolerance with large seeded lines with contrasting colors in Uganda.
10. Use of markers identified in objective 3 to make selections in each country
11. Screen Andean lines for cooking time using a pin drop (Mattson cooker) method.
12. Canning evaluation of climbing sugar beans from Uganda
13. Evaluate Andean elite lines for micronutrient bioavailability in MI and NE.
14. Evaluate three non-destructive, high throughput methods to measure cooking time and seed chemical composition; including reflectance and transmittance NIR and hyperspectral imaging.
15. Implement NIR cooking time prediction models to develop a bench top prototype to non-destructively measure cooking time in dry beans.
16. Cross lines with superior disease resistance to those with shorter cooking time and high mineral bioavailability. Cross with CBB resistant and anthracnose resistant varieties from ADP and other sources.
17. Advance crosses for anthracnose, brucid (weevil) and virus resistance in Uganda

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.

Collaborators

Jim Steadman, Carlos Urrea - Nebraska

Stanley Nkalubo - Uganda

Kennedy Muimui – Zambia

Approaches and Methods

1. Initiate the collection of isolates of ANT, ALS, CBB, and Rust in different bean production regions of Zambia.
2. Increase seed of the differentials for ANT, ALS and rust in Zambia and Uganda
3. Race characterization of ANT and ALS in Zambia. Rust characterized at UNL.

4. Complete with race characterization for ANT, ALS and Rust in Uganda.
5. Utilize the mobile nursery protocol to determine the effectiveness of rust resistance genes in genotypes in Zambia and Uganda.
6. 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 in Zambia.
7. Increase seed of these selected genotypes for inclusion in the mobile nursery.
8. Choose the most relevant races of ANT, ALS and rust and strains of CBB for screening breeding nurseries in Zambia.
9. Partner with S01.A4 project to characterize isolates of web blight in different host countries to use in search for an improved screening method for resistance. The only current control methods are use of chemicals, so alternative control methods are needed.
10. The project will actively collaborate with MSU and UNL NIFA projects in Zambia and Uganda and with the S01.A4 project to address issues with a variety of pathogens that are not being directly addressed in current workplan.

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.

Collaborators

Jim Steadman, Carlos Urrea, - Nebraska

Stanley Nkalubo - Uganda

Kennedy Muimui – Zambia

Karen Cichy, Michigan

Kelvin Kamfwa, Michigan

Approaches and Methods

1. Conduct greenhouse phenotypic evaluation of two RIL populations for BNF at MSU.
2. Collect DNA from two RIL populations for study of BNF.
3. Genotype two RIL populations using 6K SNP Chip from BeanCAP project.
4. Develop tightly linked SNP markers for major anthracnose resistance genes in collaboration with S01.A4 project that will develop markers for other resistance genes.
5. Sequence information from the bean genome will be used to focus on specific genomic regions where major anthracnose resistance genes have been mapped -MSU.
6. Bean bioinformatic sources such as Bean Genes at UCD will be used as sources to identify new sequence based markers that are located near major resistance genes for mapping in populations segregating for major foliar pathogens.
7. Emphasis will be given to identify agarose based markers that could be implemented in country in addition to using SNP based markers.

8. 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.
9. Conduct sensory evaluation of lines with superior cooking time and mineral bioavailability in Michigan, Uganda, and Zambia.
10. Conduct a field phenotypic evaluation of ADP panel and Portillo x Red Hawk RIL population for drought tolerance in Uganda.

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

Collaborators

Wayne Loescher, Coordinator Obj 4, MSU

Carlos Urrea - Nebraska

David Kramer, Jim Kelly – MSU

Stanley Nkalubo - Uganda

Kennedy Muimui – Zambia

Idupulapati Rao – CIAT

Approaches and Methods:

We will continue to rely extensively on new instrumentation and techniques now available at MSU (at the Center for Advanced Algal and Plant Phenometrics). These allow exposing lines of plants to a set of distinct dynamic environmental conditions that mimic those experienced under realistic field conditions, or allow sophisticated experimental manipulations. These also allow non-destructive and continuing measurements of photosynthetic properties (e.g., gas exchange and chlorophyll fluorescence), growth and plant architecture, and more detailed measurements of photosynthesis. These will contribute to identifying new traits based on relationships between genotype and drought and heat responses.

1. Continue to assemble selected sets of physiologically contrasting genotypes from breeders, both *P. vulgaris* and *P. acutifolius* (e.g., Urrea, Kelly, Porch).
2. Continue conducting phenometric measurements and evaluations of contrasting genotypes. Continue development and testing of new instrumentation for field evaluations of photosynthesis and stress responses (e.g., Loescher, Kramer).
3. Identify physiological differences among genotypes with contrasting responses to high light and high temperature stresses.
4. Extend methodology to include assessments and evaluations of drought stress.

Objective 5: Institutional Capacity Building

MSU Doctoral student, Dennis Katuumura in plant breeding, genetics and biotechnology will conduct field research on culinary aspects of bean lines and genetic population(s) in Michigan and Uganda. MSU Doctoral student, Isaac Dramadri will conduct field research in Uganda on drought screening of the Andean panel and on a mapping population. With the return of Dr. Kelvin Kamfwa to the University of Zambia, expanded collaboration on research related to N-fixation will be continued in Zambia. In addition, short-term trainings for collaborators in host countries will be designed to assist them to undertake the implementation of the project objectives and activities using the latest technologies that are being deployed at MSU and Nebraska. Also training will be provided by in country collaborators to graduate students, technicians on the use of new screening techniques in drought and diseases. Where applicable, extension staff and users (farmers) will be trained on the use of the new technologies developed.

1. Provide short-term training in the areas of bioinformatics, use and management of SNPs for PIs of participating countries (Uganda, Zambia).
2. Provide short term training in the use of various drought and diseases screening methods for PIs of participating countries and institutions personnel (technicians) and where applicable extension staff and users (farmers) in Uganda and Zambia.

III. Contribution of Project to USAID Feed the Future Performance Indicators: The “Performance Indicators – Targets” forms for each country have been completed for the project for FY 2013, 2014, 2015 and 2016 following FTF guidelines. One student is currently in doctoral degree training, and plans exist for short term training for other technicians in the program. The scientific assistance provided to farmers is shared among men and women as both genders are active in bean production in Uganda and Zambia.

Target Outputs

1. The development and release of locally adapted, acceptable, drought and disease resistant bean cultivars for the major production regions in Uganda, Zambia and Michigan.
2. Increased sustainable productivity and profitability of bean production due to increased yield and reduced inputs.
3. Improved grower income and stability of bean production will contribute to better nutrition and health of farm families.

4. Increased awareness and knowledge of genomic and phenomic research methods on drought stress, major foliar diseases, enhanced fixation and nutritional quality will further improve bean productivity, long-term land management, and environmental risk, thus contributing to sustainability of bean production and agricultural communities and improved dietary patterns.

5. Identification of germplasm sources that are of benefit in the improvement of selected bean traits for the U.S. market.

6. Enhanced human resource development, gender equity and improved infrastructure capacity of participating institutions in Uganda and Zambia.

IV. Outputs:

- Training of 6 staff (4 male and 2 female) at ZARI in disease and pest identification
- Seed of different nurseries increased in Zambia
- Angular Leaf Spot Nursery evaluated and source of resistance identified in sites in Zambia
- Common Bacterial Blight Nursery evaluated and source of resistance identified in sites in Zambia
- Anthracnose Nursery evaluated and source of resistance identified in sites in Zambia
- Rust Nursery evaluated and source of resistance identified in sites in Zambia
- Isolates of ANT, ALS, CBB, and Rust collected from different bean production regions of Zambia.
- Initiate crossing of landraces with resistant sources of ALS, ANT, CBB, and Rust in Zambia
- At least five nurseries assembled for drought, ANT, ALS, CBB, and rust
- Drought nursery established, evaluated and contrasting drought tolerant lines identified
- Anthracnose Nursery established, evaluated and source of resistance identified
- Angular Leaf Spot Nursery established, evaluated and source of resistance identified
- Common Bacterial Blight Nursery established, evaluated and source of resistance identified
- Rust Nursery established, evaluated and source of resistance identified
- Seed of different nurseries increased in country
- Isolates of ANT, ALS, CBB, and Rust obtained from different bean production regions of Uganda.
- ANT, ALS and Rust pathotypes/races characterized in Uganda.
- Crosses initiated between Ugandan landraces with tolerant/resistant sources of drought ANT, ALS, CBB, and Rust.
- Progeny screening for different pathogens for resistance (drought, ANT, ALS, CBB and Rust) initiated.
- Training of 8 persons (4 male and female) in breeding data collection and management in Uganda
- Identification of Andean drought tolerant lines from a trial tested in Scottsbluff, NE
- Multi-location evaluation of cooking time and mineral bioavailability in 12 selected Andean lines. Breeding of Andean lines with superior mineral bioavailability, short cooking time and disease resistance.
- Validate high throughput/non-destructive methods for determining cooking time

- Information gathered on farmer/regional preference for fast cooking bean lines as compared to local checks.
- Develop drought screening protocols (using both field and next generation phenometric based techniques) and assemble a drought nursery to be tested across locations in Africa and the US
- Seed multiplication and distribution to participant countries – work through PABRA
- Begin characterization of biophysiological (gas exchange and chlorophyll fluorescence) characteristics associated with drought
- Begin the improvement of both bush and climbing Andean beans introgressing sources of drought and multiple disease resistance
- Enhance country capacity building training 2 PhD students for Africa
- SNP data available to initiate the Association Mapping at least in BNF
- Identified more robust markers for major anthracnose gene(s)

V. Engagement of USAID Field Mission(s). The project PI plans to visit field missions in each country to inform them of the research being undertaken

VI. Partnering and Networking Activities:

- Collaborate with S01.A4 Legume Innovation Lab Project to collaborate on regional nursery and disease screening to improve Mesoamerican beans – Beaver et al.
- Collaborate with BeanCAP project in using SNP Markers developed through that program to map QTL for drought and quality traits.
- NGOs in Uganda include: Community Enterprise Development Organization (CEDO), Integrated Seed Sector Development (ISSD)-Uganda, CARE, ADRA, SHUPO., SASAKAWA Global 2000; Nyakatozi Growers Cooperative Union, Appropriate Technology (Uganda); Seed companies such as (Pearl, Victoria, NASECO, East African Seed, FICA seed).
- African Farm Radio Research Initiative (AFRRI) for radio broadcast delivery of new information being implemented by Farm Radio International, and funded by the Bill & Melinda Gates Foundation, to communicate with farmers in remote areas overcoming geographic, economic and literacy barriers.
- Freshpkt-Food Canning Company in Lukasa works with farmers to increase bean production for the canning industry and would be a logical partner for this project.
- Stewards Globe Seed Company has taken up some of the bean varieties from the Bean Program and is engaged in seed production
- The Bean program is working with Farmer Groups in sustainable agriculture by promoting new and improved bean varieties to diversify local diets and improve their nutrition through community seed systems. It is expected that over 200,000 traditional and new bean growers can be reached through this initiative.
- The Bean program in Zambia has strong partnership with a number of NGOs and CBOs who include Self Help Africa, World Vision, Shangila Seed Growers Association, Concern World Wide, IITA

Miracle Project, Action Aid to mention but a few. These are partners who are working with communities in disseminating improved technologies.

- In Uganda, funding was secured through AGRA – Alliance for a Green Revolution in Africa and PABRA network. Funding prospects from Kirkhouse Trust in NaCRRI with Annet Namayanja and Pamela Paparu.
- Root rot project Funded by BBSRC (UK): Pathogen Distribution, Characterization and Identification of Resistance Markers Associated with Root Rot Resistance in Common Beans in East and Central Africa –PI – Pamela Paparu, NaCRRI, Uganda.
- Bean value chain project funded by Maendeleo Agricultural Enterprise Fund: Enhancing women smallholder farmers’ capacities to produce and market a “sugar bean” in domestic, regional and international markets, “The Sugar bean value chain” - PI Annet Namayanja, NaCRRI, Uganda.

VII. Leveraging of Legume Innovation Lab Resources:

- USDA- NIFA projects: To Develop Common Bean (*Phaseolus vulgaris*) Germplasm with Resistance to the Major Soil Borne Pathogens in Uganda with MSU
- USDA-NIFA: Genetic Approaches to Reducing Fungal and Oomycetes Soilborne Problems of Common Bean in Eastern and Southern Africa with UNL with partners USDA-ARS in Zambia and Mozambique.
- PABRA/SABRN. This project will be in line with the PABRA agenda in Africa and will complement each other and provide opportunity to leverage resources. The choice of Zambia will be an entry point in sharing outputs with other countries as well as link with FTF projects in the region, where Zambia is partnering.
- Agricultural Productivity Program for Southern Africa (APPSA) under the Regional Centre of Leadership-Legumes is set to leverage the project in Zambia with research and capacity building.
- Uganda Ph.D. student in plant breeding, genetics and biotechnology at MSU to work on drought physiology funded through the BHEARD program will work in the project.

VIII. Timeline for Achievement of Milestones of Technical Progress: *The "Milestones for Technical Progress" form for the workplan period for FY13, FY14, FY15 and FY16 have been completed for each objective listed in the workplan.*

Training/Capacity Building Workplan for FY 2016 – 2017

Degree Training:

First and Other Given Names: Dennis

Last Name: Katuramu

Citizenship: Ugandan
Gender: M
Training Institution: MSU

Supervising Legume Innovation Lab PI: James D. Kelly
Degree Program for training: Doctorate
Program Areas or Discipline: Plant Breeding, Genetics and Biotechnology

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? Yes
Host Country Institution to Benefit from Training: Makerere University

Thesis Title/ Research Area: Identification of the genomic loci underlying nutritional quality traits in common bean (*Phaseolus vulgaris* L.) seed and participatory evaluation and selection of nutritious beans by farmers in Uganda

Start Date: August 2016

Projected Completion Date: September 2017
Training Status: Active

Type of Legume Innovation Lab Support (full, partial or indirect): Full

Degree Training:

First and Other Given Names: Isaac

Last Name: Dramadri

Citizenship: Uganda
Gender: M
Training Institution: MSU

Supervising Legume Innovation Lab PI: James D. Kelly and Wayne Loescher

Degree Program for training: Doctorate
Program Areas or Discipline: Plant Breeding, Genetics and Biotechnology

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? Yes
Host Country Institution to Benefit from Training: MSU

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
Training Status: BHEARD Fellowship from USAID Mission, Kampala.

Type of Legume Innovation Lab Support (full, partial or indirect): Indirect – research support

Short-term Training:

1. Type of training: Drought and Disease Screening methods Description of training activity: To orient staff that will be involved in the day to day data collection and monitoring of drought and disease nurseries so as to get reliable and common parameters
Location: Kabwe Research Centre under ZARI, Kasama, Zambia
Duration: One week (5 working days)
When will it occur: November 2015 – March 2016
Participants/Beneficiaries of Training Activity: Research Technicians and Professionals
Anticipated numbers of Beneficiaries (male and female): 12 (5 females and 7 males)

PI/Collaborator responsible for this training activity: James Kelly/Carlos Urrea / Kennedy Muimui could seek CIAT/PABRA for resource person

List other funding sources that will be sought (if any): PABRA/SABRN support will be sought

Training justification: Having good data collection and evaluation methods is a pre-requisite for good research results. It is important that all those involved will have a common understating and methods of evaluation and data collection

2. Type of training: Application and use of hand held gadgets for field data capture

Description of training activity: Take staff through drought use of data capture gadgets like tablets, photosynQ, GPS, etc. to improve data capture accuracy
Location: National Crops Resources Research Institute, Namulonge, Uganda
Duration 5-7 days
When will it occur: Between October 2016- 2017
Participants/Beneficiaries of Training Activity: Research Assistants and technicians
Anticipated numbers of Beneficiaries (male and female) 12 (7 males and 5 females)

PI/Collaborator responsible for this training activity Stanley Nkalubo/Isaac Dramadri/ Paul Asete/Blessing Odogwu

List other funding sources that will be sought (if any) CIAT/PABRA

Training justification: Data capture in the Uganda bean program is normally manual and labor intensive leading to errors and at times data losses due to the nature in which it is captured and relayed. There have been recent advances in data captured through an example being the use of tablets and smart phones. Our staff need to be exposed to these new advances and we hope that this will lead to more efficient day capture and minimize errors and losses.

FY 2017 WORKPLAN

Project Code and Title: S01.A4 - Development and implementation of robust molecular markers and genetic improvement of common and tepary beans to increase grain legume production in Central America and Haiti.

Lead U.S. and Host Country Principal Investigators, Institutions and Countries:

James Beaver and Consuelo Estevez de Jensen - University of Puerto Rico, Mayagüez, PR, USA

Timothy Porch - USDA/ARS/TARS, Mayagüez, PR, USA

Phil Miklas - USDA/ARS, Prosser, WA, USA

Juan Osorno and Phil McClean – North Dakota State University (NDSU), Fargo, ND, USA

Juan Carlos Rosas - Escuela Agrícola Panamericana (Zamorano), Honduras

Julio Cesar Villatoro - Instituto de Ciencia y Tecnología Agrícola (ICTA), Guatemala

Emmanuel Prophete - National Seed Service, Ministry of Agriculture, Haiti

I. Project Problem Statement and Justification:

During the past 30 years, most of the growth in bean production in Central America was due to an increase in the area of production in the lowlands (< 1000 m). Greater heat tolerance combined with resistance to *Bean Golden Yellow Mosaic Virus* (BGYMV), for example, permitted increased bean production in El Salvador. Bean production in both Guatemala and Nicaragua has expanded into more humid lowland regions, whereas a significant portion of the beans in Haiti continues to be produced in the lowlands. Bean production in Africa could be expanded if lines with better lowland adaptation were developed. This Legume Innovation Laboratory project will address several of the biotic and abiotic constraints often encountered by bean producers in the tropical lowlands.

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 (*Acanthoscelides obtectus*). These breeding lines may include the arcelin 2 seed protein from common beans, the null phaseolin trait from *P. coccineus* and the APA locus derived from *P. acutifolius*. 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, red mottled, cranberry, yellow and white beans that have resistance to *Bean Common Mosaic Virus* (BCMNV), *Bean Common Mosaic Necrosis Virus* (BCMNV) and BGYMV. Regional performance trials have been conducted in Central America and the Caribbean to confirm the durability of the resistance when exposed to different genera and ecotypes of bruchids.

The recent arrival of BCMNV in the Caribbean made the selection for resistance to this virus a priority breeding objective in Haiti, the Dominican Republic and Puerto Rico. BCMNV is also a serious disease in lowland bean production regions of southeastern Mexico. Collaborative research supported by the Legume Innovation Lab contributed to the development and release of black bean 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 have been developed at Zamorano and are ready for evaluation in field trials. These BGYMV and BCMNV resistant black and small red bean lines are available in the event that BCMNV emerges as a threat to bean production in Central America.

Increased resistance to common bacterial blight and web blight is needed for beans produced in warm and humid lowland regions such as the Petén and southern Guatemala. This combination of resistances may also permit increased production of beans in Central America during the first growing season when rainfall is more abundant and reliable. Angular leaf spot resistance was identified by participants in the

Bean Research Workshop held at Zamorano in April 2015 as an important disease limiting bean production throughout Central America.

The principal objective of this Legume Innovation Lab project to develop Middle American and Andean bean breeding lines having adaptation to the lowland tropics, different combinations of resistance to the most important diseases (common bacterial blight, rust, angular leaf spot, web blight and root rot) and tolerance to abiotic constraints (low N and P soils and high temperature).

Improved black, red mottled, white, yellow and small red bean germplasm lines and cultivars have been released in Central America and the Caribbean during the first four years of the project. This Legume Innovation Laboratory project will continue, in collaboration with CIAT, to support bean research network activities in Central America and the Caribbean. Collaborative activities such as the regional performance nurseries help to extend the impact of this project through the release of improved cultivars throughout the region.

The project will continue to screen germplasm to identify additional sources of resistance to diseases that limit bean production in Central America, the Caribbean and Eastern Africa. For example, more resistance to ashy stem blight, caused by *Macrophomina phaseolina*, is needed to improve adaptation to hot and dry environments whereas greater resistance to web blight, caused by *Rhizoctonia solani*, is required to increase yield and seed quality of beans produced in more humid environments. Project personnel have the expertise and experience needed to reliably phenotype the Andean and Middle American Diversity Panels for traits of economic importance. This contributes to the identification of new sources of resistance and molecular markers for these traits.

Low soil fertility, in particular low N and P, is a major constraint to bean production in Central America and Haiti. Breeding beans with enhanced biological nitrogen fixation can reduce the effects of low soil N. Previous research has identified a large amount of genetic variation in common beans for biological nitrogen fixation. The BTD project demonstrated that *Rhizobium* inoculants is a technology that is beneficial to bean producers in Central America and Haiti. After two cycles of recurrent selection elite bean lines that combine good nodulation with disease resistance and commercially acceptable seed type have been developed.

There are regions and/or growing seasons in Central America and Haiti 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 high levels of resistance to BCMNV, rust, common bacterial blight, bruchids and other important traits have been identified. Interspecific populations have been developed that may segregate for resistance to BGYMV. Resistance to BCMV, BGYMV, larger seed size and improved agronomic traits, would increase the potential adoption of tepary beans. This effort represents the first systematic attempt to genetically improve tepary beans. The S01.A4 project will collaborate with the USDA/ARS FTF project to select *Bradyrhizobium* efficient strains and to study the inheritance of interspecific tepary bean

x common bean populations for specificity to establish symbiosis with *Rhizobium* and/or *Bradyrhizobium* using *nodC*, *recA* y *atpD* genes.

Bean breeders were early adopters of marker-assisted selection to identify lines with desired combinations of traits. This has 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 SAP-6 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 Legume Innovation Lab project has participated in the effort to develop improved markers for traits such as the *Ur-11* gene for rust resistance.

A better understanding of clusters of disease resistance genes is needed to achieve the goal of developing coupling phase linkage blocks to enhance the capacity to combat multiple pathogens. For example, genes for resistance to rust, anthracnose, ALS, powdery mildew, halo blight and other diseases co-locate on chromosomes Pv01, Pv04, and Pv11. These resistance genes may be in repulsion whereby selection of a specific gene for resistance may cause the displacement of a resistance gene in the recurrent parent that is effective against a different pathogen. Dr. Phil McClean at NDSU and Dr. Phil Miklas, USDA-ARS-Prosser will lead the collaborative effort to develop improved molecular markers.

II. Planned Project Activities for the Work plan Period (October 1, 2016 – September 30, 2017)

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

Collaborators:

James Beaver and Consuelo Estevez de Jensen – University of Puerto Rico, Mayaguez, PR, USA

Timothy Porch – USDA/ARS/TARS, Mayaguez, PR, USA Phil Miklas –
USDA/ARS, Prosser, WA, USA

Juan Osorno and Phil McClean – North Dakota State University (NDSU)

Juan Carlos Rosas – Escuela Agrícola Panamericana (Zamorano), Honduras

Julio Cesar Villatoro - Instituto de Ciencia y Tecnología Agrícola (ICTA), Guatemala Emmanuel Prophete–
National Seed Service, Ministry of Agriculture, Haiti

Approaches and Methods:

Conventional plant breeding techniques and marker-assisted selection will be used by Legume Innovation Lab scientists to develop common bean cultivars and breeding lines with enhanced levels of disease resistance and greater tolerance to abiotic stresses. Plant breeders will focus on the most important biotic and abiotic constraints in lowland (< 1000 m) bean production regions in Central America and Haiti.

Bruchid resistant bean breeding lines developed by Dr. Kusolwa at Sokoine University of

Agriculture have been used to introgress resistance to this pest into commercial seed types (black, small red, red mottled, white, light red kidney and yellow) produced in the target countries. A laboratory screening technique developed at the University of Puerto Rico has been used to evaluate the resistance of bean breeding lines. Molecular markers (arcelin 2 and APA locus) developed by Dr. Kusolwa will be evaluated to determine their effectiveness in identifying lines with high levels of resistance to bruchids. An additional breeding objective is to combine bruchid and virus (BCMV, BCMNV and BGYMV) resistance. A bruchid resistant Andean bean line with BCMV and BCMNV ($I + bc-1^2$) resistance has already been developed and released. Considerable progress has also been made toward the development of black beans that combine bruchid and virus resistance. A small group of lines selected in Puerto Rico for bruchid resistance was tested in Central America and Haiti to confirm the durability of resistance when exposed to different ecotypes of *Acanthoscelides obtectus* and other genera (*Zabrotes subfasciatus*) of bruchids. Seed of bruchid resistant lines has been multiplied at the UPR and Zamorano to conduct on-farm performance trials.

Legume Innovation Lab plant breeders will assist bean research programs in Guatemala and Haiti to develop the capacity to produce populations and test breeding lines that will lead to the release of improved bean cultivars. This should contribute to the long-term sustainability of bean breeding activities in the region. In Haiti, breeding lines will be inoculated with *Rhizobium* and the inoculant production will be carried out with the collaboration of the Zamni Agrikol (NGO) and the assistance of the UPR.

Dr. Juan Carlos Rosas will coordinate the regional testing of small red, white and black bean breeding lines. These trials will be conducted in collaboration with national bean research programs and CIAT. Promising lines will be tested throughout Central America and the Caribbean, including countries that are not participating in this Legume Innovation Lab project. Testing lines in different countries provides more information concerning the potential performance of the lines and expands the potential impact of the research supported by the Legume Innovation Lab. In addition to yield trials, field trials will be conducted to screen bean lines for resistance to different diseases such as angular leaf spot and web blight. Testing sites will be chosen that are expected to produce the most reliable results for screening for specific traits.

The Middle American and Andean Diversity panels will be screened in Central America and the Caribbean for specific traits. For example, the Middle American Diversity Panel will be screened in Honduras and Puerto Rico for reaction to angular leaf spot. Performance of the Middle American Diversity Panel will also be evaluated in low N environments in Central America and the Caribbean.

Although disease resistance is the primary focus of this Legume Innovation Lab project, the performance of bean breeding lines will be evaluated in low fertility soils. Honduras has an ideal site for the evaluation of lines for adaptation to low P soils whereas Puerto Rico has good locations for screening beans for performance in a low N soil and root rot resistance. These sites will be inoculated with efficient *Rhizobium* strains to allow indirect selection for enhanced biological nitrogen fixation. We have screened Andean Diversity Panel for biological nitrogen fixation with *R. tropici* and *R. etli* and selected genotypes efficient for BNF under greenhouse and field conditions. The project plans to screen the Middle American Diversity Panel to identify lines with superior BNF characteristics.

Specific research activities for objective 1 during FY17:

Central America

- Develop and test on research stations and farms black and small red bean breeding lines that combine disease and pest resistance with greater tolerance to abiotic stress, including drought and low soil fertility.
- Coordinate the regional testing of small red, white and black bean breeding lines in the lowlands of Central America and Haiti.
- Multiply and maintain breeder and foundation seed stocks of recently-released small red and black bean cultivars.
- Utilize recurrent selection to develop bean populations for better adaptation to low N soils (recombine lines for third cycle) and greater resistance to web blight (evaluate the third cycle).
- Complete the third cycle of recurrent selection for resistance to terminal drought.
- Characterize the variability of *Phaeoisariosis griseola* isolates from Puerto Rico, Guatemala and Honduras.
- On-farm testing of bruchid resistant lines when exposed to natural infestation of bruchids.
- Support the development of bean breeding populations in Guatemala with the goal of releasing locally-developed cultivars by the end of the current period of funding.
- Phenotype the BGYMV reaction of a population that will be used to identify a molecular marker for the *Bgp* gene that permits normal pod development in the presence of BGYMV.
- Prepare and evaluate a VIPADOGEN nursery in Central America and the Caribbean that can be used to identify promising parents for local bean breeding programs.

Haiti

- Test on research stations and farms, in collaboration with AKOSSA and Zamni Agrikol, elite black and Andean bean breeding lines that combine disease and pest resistance with greater tolerance to abiotic stress.
- Conduct regional field trials and evaluate promising bean breeding lines from Honduras, Puerto Rico and CIAT
- Multiply breeder and basic seed stocks of recently-released bean cultivars.
- Study the potential benefit of thicker pod walls in common bean to prevent seed germination during periods of wet weather during the harvest.
- Support the development of bean breeding populations in Haiti with the goal of releasing a locally-produced cultivar. During the upcoming year crosses will be made to combine multiple virus

resistance with resistance to powdery mildew and germination of seed in the pod under humid conditions.

- Support the production of *Rhizobium* Inoculants to be used for advanced breeding lines
- Strengthen collaboration between the NSS and NGOs in Haiti for on-farm testing of improved bean breeding lines (black, white, pinto, yellow and red mottled)
- if recurrent selection for enhanced biological nitrogen fixation.
- On farm testing of bruchid resistant lines when exposed to natural infestation.

Puerto Rico (UPR and USDA/ARS/TARS)

- Develop and test Andean and Middle American bean breeding lines that combine disease and pest resistance with greater tolerance to abiotic stress.
 - Middle American and Andean bean lines that combine BGYMV, BCMNV and bruchid resistance
 - Black bean lines that combine BGYMV and BCMNV resistance with *Ur4*, *Ur5* and *Ur11* genes for rust resistance
 - Pinto bean lines that combine BGYMV and BCMNV resistance with the *Ur11* gene for rust resistance
 - Yellow bean lines that combine BGYMV and BCMNV resistance
 - Andean and Middle American lines that combine resistance multiple viruses with enhanced BNF and greater tolerance to low N soils
- Screen bean lines from recurrent selection for enhanced biological nitrogen fixation for root rot resistance and adaptation to low N soil.
- Screen bean lines from recurrent selection for web blight resistance.
- Coordinate Andean elite bean line performance trials for the Caribbean.
- Study the inheritance of powdery mildew resistance in Puerto Rico and Haiti.
- Study the effectiveness of molecular markers to select for bruchid resistance

Objective 2: Improve agronomic traits and disease resistance of climate resilient tepary bean.

Collaborators:

Timothy Porch - USDA/ARS/TARS, Mayaguez, PR, USA

James Beaver and Consuelo Estevez de Jensen - University of Puerto Rico, Mayaguez, PR, USA

Phil McClean- North Dakota State University, Fargo, ND USA

Juan Carlos Rosas - Escuela Agrícola Panamericana (Zamorano), Honduras

Julio Cesar Villatoro - Instituto de Ciencia y Tecnología Agrícolas (ICTA), Guatemala

Emmanuel Prophete - National Seed Service, Ministry of Agriculture, Haiti

Kirstin Bett- U. of Saskatchewan, Saskatoon, Canada

Mark Brick- Colorado State University, Ft. Collins, Colorado, USA

Approaches and Methods:

Although tepary bean has high levels of abiotic stress tolerance, it is susceptible to viruses such as BGYMV, BCMV, and BCMNV. In order to expand the potential use of tepary bean in abiotic stress prone regions, a primary focus of this project will be to initiate the introgression of virus resistance from common bean into tepary bean. By project end (FY17) we expect to have tepary breeding lines with improved virus resistance that will be available for pyramiding of virus resistance loci in future efforts.

A tepary breeding program was initiated at USDA-ARS-TARS in 2008. Advanced breeding lines developed from these previous breeding efforts will be increased and shared with the collaborators for testing in Tepary Adaptation Trials (TAT). New tepary F₄ lines will be generated from crosses between promising large and round seeded genotypes from the CIAT collection and breeding lines selected for disease and abiotic stress tolerance. Using leveraged funds, these materials will be initially tested through a shuttle breeding program with M. Brick at Colorado State University. This effort will focus on seed size/shape, drought and heat tolerance, and CBB and bruchid resistance in PR; and on photoperiod insensitivity, broad adaptation, rust resistance, and yield in Colorado. Superior lines will then be tested in the host countries for potential future release.

In order to speed the breeding progress with tepary and to advance genetic analysis, common bean Indel markers will be tested in tepary to evaluate their potential use. Research in BNF will evaluate *Bradyrhizobium* strains USDA 110, USDA 122, USDA 123, USDA 73, USDA 3 (*B. japonicum*), USDA 94, USDA 3254, USDA 76 (*B. elkanii*), and EAP-1001 (*Bradyrhizobium* sp.) with 20 tepary genotypes from the CIAT germplasm bank and will evaluate the genetic diversity of these strains using *nodC*, *recA* y *atpD* genes.

Efficient strains will be selected for BNF in crosses between lines from the CIAT tepary collection and promising breeding lines. In addition, the inheritance of interspecific (teparry bean x common bean) populations to establish symbiosis with *Rhizobium* and/or *Bradyrhizobium* will be studied.

Additional sources of disease resistance will be evaluated using the Tepary Diversity Panel (TDP) of about 320 accessions. These accessions will be evaluated for CBB and BCMV.

Breeding and introgression of BGYMV res., *l* and *bc3* into tepary/common bean hybrids.

- Based on previous Pa x Pv crossing efforts, effective Pv and Pa parents (e.g. Pv 'Beniquez' with all 4 virus genes) were selected for hybridization during FY13-14.
- F₁ Pv x Pa hybrids were completed during FY14 from crosses between selected parents above at ARS-TARS.
- Embryo rescue was initiated from the BC₁F₁ generation material.

Determine potential use of *P. vulgaris* Indels for tepary genetic analysis and mapping.

- A small subset representing tepary genetic diversity will be assembled at USDA-ARS-TARS in FY13 and sent to NDSU.

- NDSU will evaluate a subset of the 3,000 Pv indels on the Pa germplasm to evaluate potential use.

Characterize the CIAT tepary bean germplasm collection for BCMV and CBB resistance.

- A subset of the TDP, the CIAT tepary bean germplasm collection (~250 lines), were evaluated for CBB (FY13), adaptation (FY14) at USDA-ARS-TARS using leveraged ARS-FTF funds.
- The panel was evaluated for response to NL3 at the UPR (FY15) using leveraged ARS-FTF funds. Using GWAS several QTL were identified and markers are being developed for resistance.
- The same subset of the TDP was evaluated for BGYMV and for angular leaf spot (ALS) in Honduras.
- Crosses combining BGYMV tolerance and with resistance to CBB, BCMNV and rust.
- 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.

Objective 3: Develop and implement robust molecular markers for disease resistance genes

Collaborators:

Phil McClean and Juan Osorno, North Dakota State University, Fargo, ND, USA

Phil Miklas, USDA/ARS, Prosser, WA, USA

Julio Cesar Villatoro, ICTA, Guatemala City, Guatemala

Approaches and Methods:

This project will leverage the results from the USDA Common Bean Agricultural Project and the USDA/DOE/JGI common bean sequencing project. The BeanCAP project developed a suite of ~3000 indel markers distributed across all common bean chromosomes. These markers are co-dominant and designed to be functional with a single experimental condition (PCR protocol). 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 that are linked, from 0-5 cM, to important target disease genes. While useful, there has been some difficulty in the portability of these markers from one laboratory to another. They all have unique experimental conditions that preclude multiplexing, and 5% recombination reduces effectiveness due to recombination between marker and target gene.

Dr. Phil McClean and Dr. Miklas will coordinate phenotyping, marker development, and the use of markers to facilitate the breeding of disease resistance beans. Molecular markers for critical gene or gene clusters will be improved and employed in breeding multiple disease resistant bean lines. Major genes for resistance to ALS, anthracnose, BCMV, BGMV, common blight, halo blight, rust and other diseases of economic importance to breeders will be targeted for marker-assisted selection in small and large-seeded market classes, and for specific production regions. Dr. Miklas' research will integrate McClean's genomic work with the needs of Legume Innovation Lab bean breeders. The critical / gene for

BCMV, the *Ur-11* gene for rust, *Phg-1* and *Phg-2* genes for angular leaf spot, the *Co-4²* for anthracnose, and QTL (Pv07 new; SAP6 on Pv10; and XA11.4 on Pv11) for CBB and HBB (Pv04 and Pv05 both new) resistance will be targeted for more reliable and efficient marker-assisted selection.

Identify genetic materials for marker evaluation

Potential targets for improved marker development include:

- Improved markers for bean rust resistance genes (*Ur-3*, *Ur-4*, *Ur6* *Ur-5*, *Ur-11*).
- Improved marker for *I* and *bc-1²* genes developed
- Populations have been developed for subsequent development of improved markers for the BGYMV resistance gene *Bgp*.
- Investigate efficacy of currently available markers for bruchid resistance genes.
- Establish background information for marker development for ashy stem blight resistance by conducting association mapping analysis.
- Evaluate the genetics of web blight resistance through association mapping analysis.
- Resistance genes will be surveyed in the *P. vulgaris* genome.

For each of these targets, we will adopt the same procedure. First, we will search the published literature and communicate personally with breeders, geneticists, and pathologists in both Legume Innovation Lab projects to identify genetic materials with contrasting phenotypes (resistance, susceptibility) for the specific disease. These could be genetic populations or a collection of lines with known phenotype that can then be used for the identification of closely linked indel markers.

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 and the common bean genome sequence. 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 30 indel markers that straddle the physical location of the marker. Those indel markers will be used in PCR amplification to determine which one acts as a definitive marker that is unambiguous in its predictive power. If several markers have equal predictive power, then the one that will best work as a multiplexing marker will be selected. Legume Innovation Lab bean breeding programs in Guatemala, Honduras, Ecuador and Uganda have the facilities and technical expertise needed to immediately adopt the use of indels for marker-assisted selection.

Objective 4: Institutional capacity building

Collaborators:

James Beaver and Consuelo Estevez de Jensen - University of Puerto Rico, Mayaguez, PR, USA

Timothy Porch - USDA/ARS/TARS, Mayaguez, PR, USA Phil Miklas -

USDA/ARS, Prosser, WA, USA

Juan Osorno and Phil McClean – North Dakota State University (NDSU), Fargo, ND, USA

Juan Carlos Rosas – Escuela Agrícola Panamericana (Zamorano), Honduras

Julio Cesar Villatoro - Instituto de Ciencia y Tecnología Agrícolas (ICTA), Guatemala

Emmanuel Prophete– National Seed Service, Ministry of Agriculture, Haiti

Approaches and Methods:

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

Informal training

- In-service training will be provided 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.
- A significant amount of information concerning bean research techniques is already available on the BIC web site <http://bic.css.msu.edu/ResearchTechniques.cfm>. This Legume Innovation Lab project will collaborate with the BIC in developing modules for the BIC web site that will describe research techniques for additional traits such as bruchid resistance.

Formal training

- Undergraduate students at Zamorano will be provided opportunities to participate in bean research activities related to Legume Innovation Lab project objectives.
- Ph.D. degree training at NDSU of two bean researchers from Central America
- M.S. degree training at MSU of two bean researchers from Central America

III. Contribution of Project to USAID Feed the Future Performance Indicators:

- Seed production of improved bean varieties developed with support from the Legume Innovation Lab can provide an indirect estimate of the number of hectares planted in target countries (performance indicator 4.5.2 (2)).
- Ph.D., M.S. and B.S. degree training in the U.S. and Host Countries will contribute to performance indicator 4.5.2(6).
- In-service training and workshops will contribute to performance indicator 4.5.2(7).
- The development of indel markers can be documented as a Phase I performance indicator 4.5.2(39).

- Performance of breeding lines in regional trials and other field trials can be recorded as a Phase II performance indicator 4.5.2(39).
- Release of improved bean cultivars can be recorded as a Phase III performance indicator 4.5.2(39).

IV. Outputs:

- Release and dissemination in the lowlands of Central America and the Caribbean of black and small red bean cultivars with BGYMV & BCMV resistance and greater tolerance to low soil fertility.
- Release and dissemination in the lowlands of Central America and the Caribbean black, white and red mottled bean breeding lines with resistance to bruchids, BGYMV, BCMV and BCMNV.
- Release and dissemination black, pinto and white bean breeding lines with resistance to BGYMV, BCMV, BCMNV, web blight and rust.
- Testing and release in Haiti of yellow and red mottled bean lines with resistance to BGYMV, BCMNV and BCMV.
- New bioinformatic-based approach to enabling marker development.
- Indel markers for traits of economic importance that will facilitate the selection of bean lines with the desired combination of traits.
- Technical personnel in Central America and the Caribbean with greater capacity to conduct field trials and to produce reliable and repeatable results.
- Graduate degree training of students from Central America and the Caribbean.

V. Engagement of USAID Field Mission(s)

Host country scientists will be responsible of informing local USAID Missions about progress of the Legume Innovation Laboratory project toward research and training objectives. Opportunities will be sought to obtain USAID Mission support to expand activities in host countries. Local USAID Missions will be contacted when U.S. scientists visit host countries.

VI. Partnering and Networking Activities:

Dr. Phil Miklas serves as the President of the Bean Improvement Cooperative. Many Grain Legume Innovation Lab scientists publish research achievements in the Annual Report and make presentations or present posters at the biennial meeting.

Several Legume Innovation Laboratory scientists participate in Regional Hatch Project W-3150 which is a multi-disciplinary network of U.S. bean researchers.

Collaboration of US and HC research organizations thru the Central American and Caribbean Bean Research Network coordinated by Zamorano, allows the testing and evaluation of germ plasma and breeding lines and the released of improved cultivars that benefits directly to thousands of small farmers in this target region.

Researchers in Central America and the Caribbean often make scientific presentations at the annual meeting of the PCCMCA. The meeting provides an opportunity for the Central

American/Caribbean research network which includes national programs, CIAT and the Legume Innovation Laboratory scientists to meet to exchange results from research and plan activities for the upcoming year

Dr. Miklas and Dr. Porch receive USDA-ARS FTF funds which complement Legume Innovation Laboratory research and training activities. Dr. Miklas, Dr. Porch, Dr. Rosas, Dr. Beebe and Dr. Beaver participate in the Penn State University FTF project led by Dr. Jonathan Lynch dealing with abiotic stress. Legume Innovation Lab project personnel will strive to coordinate activities so that regional field trials, training and travel plans complement the goals of both projects.

VII. Leveraging of Legume Innovation Laboratory Resources:

Project scientists continue close collaboration with other Legume Innovation Laboratory and FTF projects focused on genetic improvement of beans. Promising breeding lines are frequently exchanged among U.S. and Host Country scientists. The exchange of breeding lines developed by the Legume Innovation Lab can also benefit U.S. bean breeding programs. Interspecific lines originally developed for web blight resistance were found to have the high levels of resistance to white mold (McCoy et al. 2012. BIC 55:153-154).

Dr. Porch is coordinating collaboration between the USDA/ARS and Legume Innovation Lab in the evaluation of the Andean Bean Diversity Panel for powdery mildew and root rot resistance, low fertility response, and biological nitrogen fixation efficiency.

The McKnight Foundation supports work in Tanzania on the development of bruchid resistance in farmer-preferred varieties and the integration of botanical and physical methods to control bruchids. Bean lines developed from this project will be useful to the Legume Innovation Lab project for bean improvement in collaborating countries. During the past year, the UPR, Oregon State University, the USDA-ARS and Sokoine University had a joint release of a bean germplasm line that combines bruchid, BCMV and BCMNV resistance. Marker-assisted selection will be used to develop bean lines with bruchid resistant genes.

Dr. Rosas continues to collaborate with Dr. Lynch in the selection of bean lines having root traits that improve performance in low P soils. Several scientists in this Legume Innovation Lab project will participate in a USAID-funded project led by Dr. Jonathan Lynch that seeks to use marker-assisted selection to develop bean lines with greater tolerance to drought and heat.

Legume Innovation Lab breeders and pathologists (Kelly, Steadman, Urrea, Osorno, Beaver, Estevez and Porch) have an opportunity to meet at least once a year in Puerto Rico. This facilitates communication between the Legume Innovation Lab bean breeding projects.

The USDA Participating Agency Service Agreement program requested a proposal to increase the availability of seed of improved bean cultivars in Haiti. We proposed a scheme that would involve the production of basic seed stocks in the Western U.S. during the summer months when bean production in Haiti is threatened by high temperature and tropical storms. This high-quality basic seed would be sold to NGOs and farmer associations who produce seed under irrigation during the winter months. The seed produced by the NGO's and farmer associations would be sold to small-scale farmers who plant on the hillsides beginning in April. Funds generated from the sale of basic seed stocks would be deposited in a rotating account to enable the basic seed production to become a self-sustaining activity. Thirty pounds of seed of XRAV-40-4 planted in Prosser, WA by Dr. Phil Miklas produced > 1,000 lbs. of seed. Dr. Ron Riley of Basin Seed Company in Nampa, Idaho plans to conduct a seed increase of XRAV-40-4 during the summer of 2016. Emmanuel Prophete plans to identify a buyer of the seed in Haiti to test the concept.

VIII. Timeline for Achievement of Milestones of Technical Progress:

Please refer to the document describing milestones

Training/Capacity Building Work plan for FY 2017

Long-term training:

First and Other Given Names: Giovanni Lorenzo Last
Name: Vazquez

Citizenship: U.S.

Gender: M

Training Institution: University of Puerto Rico
Supervising CRSP PI: James Beaver

Degree Program for training: M.S.

Program Areas or Discipline: Plant breeding

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: TBD

Start Date: Aug. 2014

Projected Completion Date: Dec. 2016

Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP
Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Héctor

Last Name: Martínez

Citizenship: Guatemala

Gender: M

Training Institution: University of Puerto Rico Supervising CRSP

PI: James Beaver and Tim Porch

Degree Program for training: M.S.

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: To be defined

Start Date: Aug. 2015

Projected Completion Date: Aug. 2017

Training status (Active, completed, pending, discontinued or delayed): Pending

Type of CRSP Support (full, partial or indirect) for training activity: Full

First and Other Given Names: Iveth

Last Name: Rodriguez

Citizenship: Honduras

Gender: F

Training Institution: University of Puerto Rico

Supervising CRSP PI: James Beaver and Tim Porch Degree

Program for training: M.S.

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: To be defined

Start Date: Aug. 2015

Projected Completion Date: Aug. 2017

Training status (Active, completed, pending, discontinued or delayed): Pending Type of CRSP Support (full, partial or indirect) for training activity: Full

First and Other Given Names: Lucy

Last Name: Lund

Citizenship: U.S.

Gender: F

Training Institution: North Dakota State University

Supervising CRSP PI: Phil McClean

Degree Program for training: M.S.

Program Areas or Discipline: Plant breeding and genetics

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? - No Host Country Institution to Benefit from Training: TBD

Thesis Title/Research Area: Development of a Molecular Marker to Track APA Introgression in Common Bean for Bruchid Resistance.

Start Date: August 2015

Projected Completion Date: August 2017

Training status (Active, completed, pending, discontinued or delayed): Active

Type of CRSP Support (full, partial or indirect) for training activity: Full

First and Other Given Names: Carlos

Last Name: Maldonado

Citizenship: U.S.

Gender: M

Training Institution: North Dakota State University

Supervising CRSP PI: Juan Osorno

Degree Program for training: M.S.

Program Areas or Discipline: Plant breeding and genetics

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? - No Host Country Institution to Benefit from Training: TBD

Thesis Title/Research Area: Identification of new sources of anthracnose resistance in climbing bean germplasm from Guatemala.

Start Date: August 2015

Projected Completion Date: August 2017

Training status (Active, completed, pending, discontinued or delayed): Active

Type of CRSP Support (full, partial or indirect) for training activity: Full

First and Other Given Names: 15 senior students (Please refer to details in Table 1)

Last Name: (Please refer to details in Table 1)

Citizenship: (Please refer to details in Table 1)

Gender: 3 women and 14 men

Training Institution: Zamorano

Supervising CRSP PI: Juan Carlos Rosas

Degree Program for training: B.S.

Program Areas or Discipline: Agronomy

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: (Please refer to details in Table 1)

Projected Completion Date: Dec. 2016

Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: (Please refer to details in Table 2)

Last Name: (Please refer to details in Table 1)

Citizenship: (Please refer to details in Table 1)

Gender: 7 women and 6 men

Training Institution: Zamorano

Supervising CRSP PI: Juan Carlos Rosas

Degree Program for training: B.S.

Program Areas or Discipline: Agronomy

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: See details on Table 2

Projected Completion Date: Dec. 2017

Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

Table 1. List of senior students at Zamorano, countries of origin and research topics for the period from January to December 2016.		
Name	Country	Research topic
Oscar Humberto León Marco Antonio Granadino	Guatemala Honduras	Tolerance to low fertility
Edwin Palomino Velasquez Michael Palomino Chaves	Peru Peru	Characterization of races of <i>Uromyces appendiculatus</i> and resistant lines
Edison Elvis Rodriguez Luis Gamarra	Peru Peru	Evaluation of bean lines under high temperature
Maritza Anabelle Ortega Macedonio Casavilca	Ecuador Peru	Characterization of <i>Rhizobium</i> strains using a bean differential nursery
David Antonio Moreira	Nicaragua	Common bacterial blight resistant beans using artificial inoculation and SCAR markers
Marlon Josue Rodriguez Juan Carlos Quezada	Nicaragua Nicaragua	Evaluation of the Tepary Adaptation Trial under drought
Ivan Alexander Alarcon Kevin Xavier Burgos	Ecuador Ecuador	Evaluation of 120 BASE Trial under drought
Fatima Cecilia Avaroma Fatima Arteaga	Bolivia El Salvador	Evaluation of resistance of tepary lines to bruchids (<i>Zabrotes subfasciatus</i>)

Table 2. List of senior students at Zamorano, countries of origin and research topics for the period from January to December 2017.		
Name	Country	Research topic
Maria Belen Besilia Sara Elizabeth Salgado	Ecuador Ecuador	Characterization of races of <i>Peronospora griseola</i> and resistance on bean lines

Ana Priscila Campos Jorge Stiven Chanaluisa	Ecuador Ecuador	Characterization of Rhizobium strains using a bean differential nursery
Klever Alejandro Arroba Segundo Melchor Gavilanes	Ecuador Ecuador	BGYMV resistant lines using field evaluation and SCAR markers
Belky Jhoder Cabana Carlos Enrique Zeballos	Peru Peru	TBD on May 2016
Elisa Michelle Solis	Guatemala	TBD on May 2016
Katya Michelle Rivera	Honduras	TBD on May 2016
Sara Astudillo	Honduras	TBD on May 2016
Luis Daniel Daza Andrés Sebastian Rosas	Ecuador Ecuador	TBD on May 2016

Short-term Training:

Type of training: In-service training

Description of training activity: In-service training will be provided at NDSU for Legume Innovation Lab scientists to review recent advances in sequencing the bean genome and the utilization of a SNP arrays to develop indel markers for traits of economic importance.

Location: NDSU

Duration: Two weeks

When will it occur? - 2017

Participants/Beneficiaries of Training Activity: 2

Anticipated numbers of Beneficiaries (male and female): 1M, 1F

PI/Collaborator responsible for this training activity: Phil McClean

List other funding sources that will be sought (if any): None

Training justification: This training is needed to permit host country scientists to take advantage of the recent advances in the development and use of molecular markers for bean breeding programs.

Equipment (costing >\$5,000): None during FY-17

FY 2017 WORKPLAN

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

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

Philip A. Roberts, University of California, Riverside, CA 92521

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

Timothy J. Close, Dept. Botany & Plant Sciences, University of California, Riverside, CA

Issa Drabo & Benoit Joseph Batiéno, Institut de l'Environnement et des Recherches Agricoles (INERA), Koudougou and Kamboinse, Burkina Faso

Francis Kusi & Ibrahim Atokple, CSIR Savanna Agricultural Research Institute (SARI), Tamale, Ghana

Ndiaga Cisse, Centre National Recherches Agronomie, Bambey, Institut Senegalais de Recherches Agricoles (ISRA) & CERAAS, Thies, Senegal

I. Project Problem Statement and Justification:

The primary 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 with desirable grain characteristics; and 4) provide training and capacity building in modern cowpea breeding. In addressing these primary constraints, the objectives are well-aligned with Feed The Future research strategic priorities of 1) crop resistance to heat, drought, salinity and flood; 2) West African Sudano-Sahelian systems with emphasis on insect-resistant cowpea; and 3) grain legume productivity. Our plan includes the FTF focus countries Ghana and Senegal, and also Burkina Faso, which offers regional importance from an agro-ecological perspective for cowpea yield gain in the Sudano-Sahel region. Strategically, these countries represent the primary agro-ecologies underpinning cowpea production in this region.

We will employ genomics and modern breeding methods to improve cowpea for yield limiting constraints. By leveraging genomic resources developed under complementary cowpea genomics and modern breeding work funded by the CGIAR Generation Challenge Program and USAID Innovation Lab for Climate Resilient Cowpea, we will apply comprehensive modern breeding tools and methods for genetic improvement of cowpea emphasizing insect tolerance and resistance. Insect pests are seen as a major constraint to cowpea productivity in West Africa. The project team has determined that significant gain can be made by targeting the major insect threats that occur at early (aphids), mid-flowering and pod-set (flower thrips), and later pod-filling (pod-sucking bugs) stages of the cowpea season. Although discovery work through phenotyping,

genetic mapping and QTL identification needs to be done in most cases for these insect pests, some progress on resistance and tolerance donors and initial QTL discovery provide good starting points in the project. High-throughput SNP genotyping platforms, high density consensus cowpea genetic maps, plus numerous discovered QTL for important biotic stress resistance and abiotic drought tolerance traits are now available through our work. We are completely familiar with these technological advancements and have experience in their application to modern cowpea breeding. We are also working closely with the CGIAR-GCP Integrated Breeding Platform – Breeding Management System development using our cowpea data as a test user case, and bring these technologies into the project work. The project breeding programs have a range of early generation populations carrying various target traits, providing valuable resources for breeding advancement.

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. Cowpea varieties with increased productivity (yield per unit area) without the need for purchased inputs especially benefit poor farmers, many being women who lack access to the most productive lands. By targeting insect tolerance and combining with drought tolerance, we have the opportunity to increase cowpea productivity. Productivity is key to increasing rural incomes and new resources can then be invested in other activities that help boost total family income. Productivity increases also help reduce prices to urban consumers. Sustainable increases in cowpea productivity in Africa and the US can be achieved through development of varieties with resistance to insects, nematodes and pathogens, Striga, drought tolerance, and the ability to thrive under of low soil fertility.

To increase marketing options, new cowpea varieties must have features desired by consumers; grain appearance, cooking and processing characteristics are especially important. Large white grains with rough seed-coat are good for direct dry-milling, and can be marketed over a wide area, buffering supply and prices in the region. Regionally adapted cowpea varieties with large white grain and resistance to pests would increase the marketing opportunities of cowpea farmers and traders in both West Africa and the US. Considerable demand exists for large rough brown grain types, especially in the large urban centers and command a premium price. However standard varieties like 'Ife Brown' are susceptible to pests and diseases and require improvement.

II. Project Activities for the Workplan Period (October 1, 2016 – September 29, 2017)

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

Collaborators: Dr. Bao Lam Huynh, UC Riverside, USA

Dr. Clementine Dabire, INERA, Burkina Faso

Dr. Isgouhi Kaloshian, UC Riverside, USA

Dr. Barry Pittendrigh, U Illinois, USA

Dr. Manu Tamo, IITA, Benin

Dr. Christian Fatokun, IITA, Nigeria

Dr. Ousmane Boukar, IITA, Nigeria

Dr. Ibrahima Sarr, ISRA, Senegal

Approaches and Methods:

Overall approach to sub-objectives: We have developed the necessary tools to exploit molecular breeding for cowpea. We have also worked with the CGIAR-GCP to develop a publicly available integrated breeding platform, essentially a pipeline for conducting marker-based selection from initial crossing to new variety release. Requisite tools developed include genic SNP markers, high density SNP-based genetic maps including consensus maps using African cowpea germplasm for sub-Saharan Africa relevant breeding use, a high-throughput SNP genotyping platform for cowpea, with conversion to a format provided through an outsource genotyping service, QTL for many major biotic and abiotic stress resistance and tolerance traits (drought, heat, fungal, bacterial and viral diseases, some insects, nematodes, Striga), and accompanying software programs. These tools, documented in the Technical Application, enable selection of multiple traits simultaneously across the genome (rather than single marker-trait selection). We will apply these technologies to existing and new breeding populations, for both QTL discovery and breeding.

Breeding targets for Africa will be to develop and release varieties that have preferred large white grain type for both domestic and export markets, and rough brown types primarily for domestic markets. The primary traits for grain yield enhancement include QTL for tolerance or resistance to three target insect pests. We have already identified a series of QTL controlling biotic and abiotic stresses. We have selected parent combinations and initiated breeding populations from their crosses which will enable selection for progeny carrying combinations of the insect tolerance with the other traits (specifically drought tolerance, nematode, Striga and *Macrophomina* resistance and also some virus resistance). In California, QTL for resistance to Fusarium wilt (*Fot3-1*, *Fot4-1*, *Fot4-2*), aphids (*QAc-vu1.1*, *QAc-vu7.1*) and root-knot nematodes (*Rk*, *Rk2*, *Rkn*) will be bred in backgrounds with Lygus bug tolerance, targeting the primary biotic stress constraints to yield.

Three sub-objectives focus on aphid resistance (Obj. 1.1), flower thrips resistance (Obj. 1.2), and pod-sucking bug resistance (Obj. 1.3). Each of these foci has the same goal, to discover and validate QTL underlying the target insect tolerance/resistance traits, then to apply the QTL knowledge to breeding population development and advancement, leading to enhanced yield performance cowpea varieties.

Genotyping approach: We will apply a combination of the KASP SNP platform that we developed with the GCP IBP and LGC KBioscience and the new 49,000 Illumina iSelect SNP platform for genotyping both in the QTL discovery phase and for breeding. The Illumina iSelect SNP platform with its high density marker resource has been applied in FY15 and FY16 and will

be applied during FY17 to parents and derived mapping populations focusing on QTL discovery. This platform is fixed for cost per sample run using all SNPs and requires local DNA extraction, although discussion is underway to convert the mapped SNPs to a KASP platform format. The KASP platform has 1022 mapped SNPs providing excellent coverage across the cowpea genome. For cost efficiency, on a cost per data-point basis we can choose the number of SNPs to be tested on the number of genotypes needed for each QTL discovery population or breeding decision. Using genotype profiles of the parents with all SNPs, the subset of polymorphic SNPs for a desired pair of parents are selected and used to genotype the progenies (individuals or bulked families), thereby building in cost-efficiency. Our ability to choose the cM distance of markers across the genome (for background selection) and specifically QTL flanking markers for the population-specific SNP marker subsets (using our in-house 'SNP selector' program available at Breedit.org) from the polymorphic subsets, efficient genetic gain by pyramiding the target traits can be made. This approach can be used for backcross populations to select the appropriate individuals (BC1F1 or BC2F1, etc.) carrying positive alleles for making the next backcross. We will employ this genotyping approach in the workplan period. The NARS breeders will grow plants in the host country, then either take leaf punches at the young plant stage, place in 96-well plates, dehydrate with silica gel and then express ship to LGC KBioscience in the UK or USA, or for the Illumina iSelect, send dried whole leaf samples to UCR in silica gel-packed bags where DNA will be extracted and sent to USC for genotyping. The genotyping data will be analyzed and jointly interpreted for a breeding decision (which plants to use for crossing or to advance) or for QTL discovery. Iterative rounds of genotyping and periodic phenotyping to validate will be used to foreground select the desired complement of positive QTL.

Phenotyping and data handling approach: Phenotyping will be conducted under field, greenhouse and lab conditions (insect screens) at NARS locations using standard test protocols. Phenotypic data analyses will be by standard ANOVA. When drought tolerance is being selected, performance testing under water-limited conditions will be done at NARS field sites. Sites and protocols will be determined by the target insect pest (see below). We will use the CGIAR IBP Breeding Management System tools for data recording, processing and archiving. The variables will include geographical coordinates and dates of each trial, soil and weather data, persons conducting experiments, trait dictionary language and other parameters set up in the IBP FieldBook (tool for software tablets). This data capture format allows for export into the ICI mapping, Optimas and Backcross programs for QTL analyses and molecular score selection indices. These tools are now familiar to the project team members in Burkina Faso, Ghana, Senegal and UC-Riverside from their use in the TL1 project and through hands-on experience during the last three years (short-term training workshops and adoption).

1.1 Aphid resistance: We will finalize testing the genetic relatedness of five sources of cowpea aphid (*Aphis craccivora*) resistance. Field observations in Africa and California indicate differential effects of resistance sources on aphid populations from different cowpea production areas. Cowpea lines IT97K-556-6, KvX295-2-124-99, an IITA wild donor line (TVNu1158), UCR01-11-52/SARC1-57-2, and 58-77 representing a set of resistance donor genotypes plus known susceptible control lines were seed-multiplied in 2014 and 2015 and also in spring 2016. A uniform test design and coordination planning for the aphid resistance assessment was developed by the project team in FY13 – FY14. Additional germplasm lines are included in the screening sites to search for more sources of resistance. Uniform screens in field locations across all project NARS (Burkina, Ghana, Senegal) and California were conducted in 2014-2015 in field plots or in screenhouses, with 4-fold replication, using standard resistance assessment scales across all test sites, although some sites had insufficient aphid infestation. This multi-site phenotype screening for resistance response is being repeated in FY16 starting in July. Following additional seed increases, the tests will be conducted again in main (rainy) season FY17 to ensure a validated data set relevant to the target areas. For example, INERA will conduct the screens through a student study at both Saria and Kamboinse. Also, in the same trials, F2, BC1F1 and F3

populations generated from resistance donor KvX295-2-124-99 (see below) will be screened to identify the mode of heritability of the genes involved in the resistance. The resistance donors and susceptible controls were SNP genotyped in FY14, coordinated by UCR. 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 to delineate aphid biotypes on the cowpea resistance sources. Samples of aphids will be collected and stored for DNA and RNA extraction (using RNAlater kits), to develop sequence and expression-based profiles to distinguish the isolates. We will also be advised by Dr. Kaloshian at UCR who has been working on the complete aphid genome sequence.

New segregating populations and some existing ones between aphid resistant and susceptible parents will be used to phenotype screen for QTL discovery. Depending on the source, we are at different stages of QTL mapping. We have completed a QTL discovery effort for aphid resistance in IT97K-556-6, identifying one major and one minor QTL, to which other resistance sources are being compared. Preliminary evidence from joint efforts of UC-R and SARI indicate resistance in SARC1-57-2 maps to a different chromosome than the QTL in IT97K-556-6. In Ghana, new populations are also being developed from the SARC1-57-2 source of aphid resistance, including SARC1-57-2 crossed with other sources of resistance effective against aphids in Ghana to assess uniqueness of resistance genes. Phenotyping and genotyping will continue in FY17. Phenotyping of an aphid/striga resistant population with SARC1-57-2 as donor to match the genotyping data at UCR for QTL mapping will also be completed in FY17. In Burkina, an F3 population between a susceptible elite line and resistance donor KvX295-2-124-99 for QTL mapping, is being phenotyped and genotyped in FY16 and the phenotyping will be repeated in FY17. From the wild donor IITA line TVNu1158 a RIL population has been developed for mapping QTL and seed increase was made in FY15. We phenotyped and genotyped this population in FY16 and the phenotyping will be completed in FY17. This work is being conducted in collaboration with Dr. Fatokun at IITA, Nigeria. The QTL will be included in foreground selection in the breeding populations, with a plan to target effective resistance sources within a given NARS region (i.e., match effective resistance with preferred and adapted cowpea types for the relevant production area).

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 Txv3236. In Senegal and Ghana both RIL populations will be field-phenotyped for tolerance to flower Thrips using the Jackai and Singh (1988) tolerance scale, at sites in Bambey, Nioro, Tamale and Manga during the FY16 and FY17 workplan periods. This will provide multiple years and locations of phenotyping data to deal with the inherent variability of low to high insect populations. Additional germplasm lines will be included in the screening sites to search for more sources of resistance in both FY16 and FY17. Screens will be designed as a 4-replication RCBD and include the parents, and run by entomologists Ibrahima Sarr (Senegal) and Francis Kusi (Ghana).

In Senegal the different tolerance sources in Sanzi, 58-77 and Txv3236 were intercrossed in all combinations by Dr. Cisse in FY14; these populations were advanced to F3 in FY15 and to F6 in FY16 and are being and will be phenotyped in FY16 and FY17. These sources of resistance have poor seed quality, so the F1s of their intercrosses were also crossed with the new large-seeded varieties in FY15. These are being advanced to F4 in FY16 and F6 in FY17. M5 populations of Melakh, Yacine and Mouride obtained through mutation breeding for resistance to Bruchids, thrips and Macrophomina will be tested during FY17 in Senegal.

In Ghana, three Sanzi-derived F7 populations segregating for seed color (including white) and flower thrips resistance are available for QTL discovery and breeding. One parent is IT97K-499-35, now the popular Ghana variety 'Songotra', a high yielding black-eye resistant to Striga but thrips sensitive which can be improved for thrips tolerance via the F7 population. The SARI team has been phenotyping the three F7 populations for thrips tolerance and Striga resistance in FY15 – FY16 using the previously described experimental protocols. The phenotyping will be completed in FY17. The families are being SNP genotyped using bulked leaf disks from 20 plants per family. Leaf samples of 272 single seed families have been sampled for SNP genotyping and the plants grown out to produce enough seeds for phenotyping. The FY17 workplan will therefore be concentrated on the results of both the SNP genotyping and field phenotyping. The selected individuals from the IT97K-499-35 (Songotra) derived population that combine Striga and Thrips will be a major focus. The seeds of the selected families will be increased to provide enough seeds for further evaluation.

1.3 Pod-sucking bug resistance: The Heteropteran Coreid pod-sucking bugs (*Clavigralla tomentosicollis* complex) are a major yield suppressor in Burkina Faso, Ghana and neighboring countries. We have not yet identified genes or QTL for resistance to pod-sucking bugs but resistant cowpea accessions are available. We started to use biparental resistant x susceptible segregating populations in FY14 to map QTL and initiate their selection as a new breeding target. This work is a focus of effort in Burkina Faso. A primary tolerance source is IT86D-716 (used in Burkina Faso); pods (maternal, F2) on F2, BC1F2 plants are being genotyped and phenotyped in FY16 to identify the underlying QTL, using standard screens of young pods in petri dishes to score bug viability and fecundity. The phenotyping will be repeated in FY17 to provide validated QTL mapping data. Additional potential tolerance donor lines are included in the initial phenotyping screens in FY16, including those in the pedigree of resistance donor IT86D-716, to broaden the knowledge base and potentially identify additional sources of tolerance. Five existing F2 populations generated from resistance donor IT86D-716 with parents KVx775-33-2G (Tiligré), KVx442-3-25SH (Komcallé), Gourgou, KVx771-10G (NAFI), and IT98K-205-8 (Niizwè) enable combining Striga resistance with pod-sucking bug tolerance. The parents have been genotyped through LGC Genomics and the F2, BC1F2, and F3 populations will be phenotyped in FY16 and FY17 for pod bug resistance in Burkina Faso, in collaboration with Dr. Dabire. The F2 were advanced to F3 in FY16 to provide screening resources for FY16 and FY17. Using leaf samples collected from phenotyped plants in Burkina Faso, single F2 plants and F3 family bulks consisting of a minimum of 12 individual plants are being genotyped in FY16. In FY17, the phenotype and genotype data from the F2 and F3 generations will be used for QTL discovery with the ICI Mapping program, which will be conducted at UCR.

For the three insect groups (aphids, thrips, pod bugs), we will continue to collaborate with Dr. Pittendrigh and Dr. Tamo (Project SO1.B1) to utilize our project trial sites to collect insect samples for use in molecular characterization of the insect populations. Collections will be made at all test locations, thereby allowing a robust comparative profiling of insect populations. We have tested a protocol for insect DNA and RNA collection, in which insects are placed in plastic bags with silica gel packs or in RNAlater (Qiagen) kits; the former dries the insect samples and preserves the DNA, the latter preserves RNA integrity. Tests on aphid DNA with primers for the COX1 gene demonstrated excellent DNA integrity in comparisons of African and California aphid populations.

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

Collaborators: Dr. Bao Lam Huynh, UC Riverside, USA

Dr. G. McClaren, CGIAR GCP IBP
Dr. Ousmane Boukar, IITA, Nigeria
Dr. TJ Higgins, CSIRO, Canberra, Australia
Dr. Prince Addae, AATF, Nigeria
Dr. Samba Thiaw, ISRA, Senegal
Dr. Mywish Maredia, Michigan State U., USA

Approaches and Methods:

2.1. We will continue to use our genotyping capability to advance the BT gene introgression for Maruca 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 Komcalle, Gourgou 3, 7 and 11, Nafi, and IT98K-205-8). We are genotyping Burkina Faso BC5F3 and Ghana BC2 progenies in FY16 and our plan for FY17 is to continue with additional rounds of SNP genotyping on the next generation of breeding lines. In FY15 the new 49,000-SNP Illumina iSelect genotyping panel developed under the USAID Innovation Lab for Climate Resilient Cowpea was applied to the most advanced BC lines for selection. 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 and Dr. Prince Addae, Project Manager of AATF, Abuja, Nigeria, received extensive hands-on training at UCR in March 2014 and 2015, and are being further trained in using their own datasets under this objective. The genotyping will mostly follow the same protocol as outlined under the Objective 1 work. We will use leaf samples from young greenhouse grown plants in the phenotyping and crossing blocks for DNA extraction in Burkina Faso and Ghana. Following shipping, the DNA samples will be SNP-assayed by LGC Genomics for KASP or at USC for iSelect and the genotype data sent to UCR for quality checking. The genotype data will be analyzed for molecular scores using Backcross Selector software. In Ghana, DNA extraction has been completed to conduct genotyping in FY16–FY17.

2.2. We plan to capitalize 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. Specifically, in Senegal five large white grain type cowpeas (new variety names Lisard, Thieye, Leona, Kelle and Sam, with at least 25 g /100 grains) developed by Dr. Cisse were processed for release approval by the national variety release committee during 2015. These were performance tested in 20 on-farm demonstration trials in main season FY13, and the data combined with performance data from 2011 and 2012 to support the formal release. The demonstration trials were conducted in the northern cowpea zone (Louga, Mekhe, Thilmakha). Dr. Cisse will continue with Foundation Seed production in the FY16 and FY17 seasons using sites at Bambey. The Foundation Seed will be used by Certified Seed

producers in the main seasons 2016 and 2017, with training inputs from Dr. Cisse. BC4F3 lines of Melakh with Striga resistance are available for evaluation during the FY16 main season. The best selected lines from FY16 will be pooled and tested in FY17 to obtain a new version of Striga resistant Melakh for Senegal.

In Burkina Faso, 20 pre-release CRSP advanced lines developed by Dr. Drabo were on-farm performance tested in 2013, and a sub-set of the best nine lines were re-evaluated in 2014. Multi-location tests are being used at Saria, Pobe, and Kamboinse in Burkina Faso. The best performing of the nine lines from FY15 are being re-evaluated in main season 2016, emphasizing yield and grain quality, plus any disease susceptibility in trials using 4-row plots, 5 m long and 4 reps arranged in a RCBD. The release petitions to the national variety release committee will be made in late 2016 depending on the committee meeting schedule. The committee was installed in 2014 but is still not operating to ease new varieties release. Breeder Seed of the best lines chosen for release submission based on main season 2014 and 2016 and off-season 2015 performance data will be produced at Saria in FY17 during the off-season (October-December, 2016). The Breeder Seed will be used to initiate Foundation Seed production in the FY17 off-season (February to April) and start Certified Seed production in the FY17 main season.

In California, we will field test advanced breeding lines for release potential, based on performance data collected in 2015 - 2016. These represent CRSP developed lines and they require at least one year more of field performance testing. The lines carry a combination of lygus bug tolerance, and root-knot nematode and Fusarium wilt resistance. For the best advanced blackeyes from 2015, we are conducting on-farm yield strip trials in 2016 in four farmer's fields in the southern San Joaquin Valley main blackeye production area, to assess commercial yield performance. The three experimental lines are compared with industry standard variety CB46, on 6-row strips (0.5 acres) under commercial production and processing procedures. The lines also will be tested at the Kearney field station (Fresno Co.). The test design will be four-row 4-fold replicated RCBD trials with the center two rows machine harvested. Yield weights, 100-seed weights and lygus damage to seed will be assayed. All yield and performance data will be analyzed by standard ANOVA. In FY 2017 main season we will repeat these trials with the best lines and conduct Breeder Seed increases in on-station isolation blocks for preparation of release documents.

In Ghana, the project has supported the development and selection of early maturing lines with large white seed and black-eye plus rough seed-coat texture during an MPhil study of Emmanuel Owusu. In FY17 these lines will be evaluated in multi-location on-farm trials as part of the efforts to release them.

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. 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.

Collaborators: Dr. Bao Lam Huynh, UC Riverside
Dr. G. McClaren, CGIAR GCP IBP
Dr. Ousmane Boukar, IITA, Nigeria

Approaches and Methods:

Short-term Training: Molecular breeding for young trainee breeders and NARS scientists will be conducted. Continuous short-term training will occur through iterative data analysis and interpretation cycles using the phenotyping and genotyping data generated by each of the three Host Country partner teams (about 12 participants). To provide periodic intensive training, we convened a training workshop in March 2014 and again in March 2015 at UCR, using training modules developed by the UC-R team and by the CGIAR GCP Integrated Breeding Platform program (IBP) Breeding Management System (BMS). The IBP-BMS is using our tropical legumes project cowpea breeding population data for training modules development. We continued training during a workshop in FY16, held in Livingstone, Zambia in February 2016 preceding the World Cowpea Conference. We plan to do additional training via workshop mode linked to the LIL Global Meeting in Burkina Faso and through site visit (Senegal) during FY17. For Ghana, we are currently hosting the SARI cowpea program molecular lab manager, Richard Agyare, for 6-months training at UCR with LIL Capacity funds. We will work with him during FY17 to continue and complete specific molecular breeding objectives for aphid and flower thrips resistance. The molecular breeding approach is complex and requires a combination of hands-on experience with self-generated data sets, augmented with periodic intensive training 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 will also be used by the NARS breeders to train the technical staff in the NARS programs after NARS breeders have been trained further on the standardized electronic fieldbook, leaf assay, and field phenotyping protocols.

Degree Training: We plan to conduct degree training for two graduate students in the workplan period:

1. Arsenio Ndeve, Mozambique, male student in PhD Plant Pathology program at UC Riverside, working in pathology, genetics and breeding of SE African cowpea germplasm.
2. Sassoum Lo, Senegal, female student in PhD Plant Genetics program at UC Riverside, working in genomics and breeding of cowpea seed traits.

III. Contribution of Project to USAID Feed the Future Performance Indicators:

Please see the attached completed “Performance Indicators – Targets” form for FY 2013, 2014, 2015, 2016 and 2017.

IV. Outputs:

Under Objective 1.1 -- Aphid resistance

A differential cowpea panel of aphid resistance sources and control lines seed-multiplied for multi-location field screening (Project team).

Molecular characterization of aphid populations collected from multiple locations.
Discovery of the extent of aphid biotype differences across four partner locations.

Under Objective 1.2 -- Thrips resistance

Two RIL populations will be phenotyped for QTL refinement in Senegal and Ghana.
Advanced lines will be generated from thrips resistance intercrosses (Senegal).
Data from phenotyping 3 F7 populations with Sanzi donor parent (Ghana).
Genotyping data from F7 populations with Sanzi donor (UCR).

Under Objective 1.3 – Pod bug resistance

Data generated from genotyping parents, F2 and F3 populations derived from resistance donor IT86D-716 (UCR).
Five F3 populations developed from existing F2 for pod bug resistance (BF).
Data from phenotyping 2 F3 populations with IT86D-716 donor parent (BF).
Initial QTL from IT86D-716 discovered by ICI Mapping (UCR and BF).

Under Objective 2.1 – SNP markers for Bt introgression

Genotype data produced from Burkina Faso and Ghana Bt-transgene segregating populations (UCR).
Selection of advanced BC lines with Bt-transgene (BF and Ghana).

Under Objective 2.2 – Variety releases

Foundation and Certified Seed of 5 large white-seeded CRSP varieties in Senegal.
Breeder Seed and Foundation Seed produced of the best candidates of 9 pre-release CRSP lines evaluated in on-farm trials in FY14 to FY16 (BF).
Farmer-field strip trial performance data on California blackeye pre-release lines.

Under Objective 3 – capacity Building

Degree training of two African graduate students (UCR and Senegal).
Short-term intensive training of HC breeders in molecular breeding.

V. Engagement of USAID Field Mission(s): During the main cowpea season July-September in 2017, the UC-R PI and Co-PI will make a field visit to HC Burkina Faso to review and coordinate field based phenotyping activities. During this HC trip, we will arrange to visit the Burkina Faso USAID mission staff. The mission visit will be made together with the respective Host Country PI and Co-PI plus senior NARS administrators where feasible, and will be used to inform the mission staff of our LIL cowpea modern breeding project goals and activities in the country and in the region. In Burkina Faso, Ghana, and Senegal field visits were made in 2014 to Burkina, 2015 to Ghana, and 2016 to Senegal (planned), and we plan to visit Burkina Faso in August 2017. The UC-R team will assist the NARS PIs in developing project activity briefs for them to share directly with the US Mission staff to keep them informed and to solicit possible Mission buy-ins.

VI. Partnering and Networking Activities: We will work closely with other national and international cowpea breeders, including Drs. Ousmane Boukar and Christian Fatokun, Senior Scientists and Cowpea Breeders at IITA, Dr. Mohammed Ishiyaku of the IAR in Nigeria, Dr. Prince Addae, AATF, Nigeria, and Dr. Rogerio Chiulele, Eduardo Mondlane University, Maputo, in Mozambique. We will continue to work with national extension services, World Vision International, World Bank and other NGOs to extend new cowpea technologies. Specifically in the Host Countries for this project, we will network with NGOs and farmers' cooperatives in Burkina Faso, Senegal, and Ghana. Although we do not have a formal seed systems objective in the project, the new cowpea varieties developed by the project will be fed into the NARS coordinated seed systems structure in each country. New varieties will be assured of entry and promotion in the seed systems. Exciting events are occurring to aid in this realization for seed multiplication and distribution to farmers. In Senegal, HC PI N. Cisse is working with World Bank on its recent \$60M commitment to agricultural productivity of the cowpea seed system, while CORAF and AGRA with Foundation support are working to advance the seed systems in Burkina Faso, Ghana and neighboring countries. HC PIs I. Drabo and Benoit J. Batiemo (INERA) and I. Atokple and F. Kusi (SARI) are involved in these efforts and can promote the introduction of the new CRSP and LIL cowpea varieties. This will be especially important for Objective 2 activities through which CRSP variety releases are in progress in Senegal and Burkina Faso. In Ghana the project is collaborating with the newly launched USAID cowpea dissemination project (Taking cowpeas to scale in West Africa). The LIL project team are actively involved in the planning, protocol preparation and implementation of the project. The five large white grain type cowpeas (at least 25 g /100 grains) developed by Dr. Cisse and other lines to be released by Burkina Faso will be helpful to the cowpea out-scaling project assuming access to the seeds in Ghana. The LIL project in Ghana is also collaborating with: 1) Promise project of CARE International which seeks to introduce improved quality cowpea varieties as well as IPM strategies for cowpea production to farmers; 2) with CGIAR-managed BMGF funded TL3 project in cowpea seed systems; and, 3) with University of Cape Coast in multi-location evaluation of Striga resistant lines developed from a local donor GH3684.

VII. Leveraged Resources: Other resources leveraged from current and future funded complementary cowpea research projects include the following:

California Dry Bean Advisory Board and its Blackeye Varietal Council (funds currently and typically set at \$20,000 per year) funded for cowpea breeding in California. This is a continuing, long term research arrangement in support of the UC Riverside cowpea breeding program.

The CGIAR Generation Challenge Program (GCP) Tropical Legumes I Project Phase 2 funded from May 2010-April 2014 was extended to November 2015. The cowpea component of this project led by UC Riverside (Roberts and Close) included collaborative funded cowpea breeding and research with the cowpea breeding programs in Burkina Faso (with PI I. Drabo), Mozambique (PI R. Chiulele), Senegal (PI N. Cisse), and IITA-Nigeria (PI, O. Boukar). This project funded at \$2.729M plus a \$221,739 extension applied cowpea genomic resources based on SNP genotyping for cowpea marker-assisted breeding. Use of the high throughput marker platform for major traits including insect pest, nematode and disease resistance, and drought and heat tolerance is being applied in African breeding populations. A new project, Tropical Legumes III (Improving livelihoods for smallholder farmers: Enhanced grain productivity and production in sub-Saharan Africa and South Asia), funded by the Gates Foundation and administered by CGIAR-ICRISAT, with IITA leading the cowpea component, was approved for funding for four years commencing in summer 2015. In the cowpea objective, UCR (\$260,000) is contributing SNP genotyping work and guiding its application in cowpea breeding, while INERA–Burkina Faso (\$519,396) and SARI-Ghana (\$319,271) contribute trait discovery and breeding line development plus cowpea seed system development. These projects provide excellent leveraging for LIL activities described here to be used for cowpea modern breeding. The projects also link us to the GCP-Integrated Breeding Platform project and its breeder’s workflow system, which we are applying to the LIL project activities for data collection, analysis, interpretation and curation.

The project team plus Dr. O Boukar, IITA, Nigeria, led by Close and Roberts at UCR, were awarded \$4,972,542 for five years starting September 2014 for the USAID Innovation Lab for Climate Resilient Cowpea. This project enables development of new cowpea genomic resources, particularly a 49,000-SNP Infinium iSelect genotyping platform developed during the last year. We are leveraging this advancement by applying it to our LIL project genotyping needs, thereby enhancing the quality and efficiency of the genotyping component.

UCR (Close and Roberts) was awarded a \$1,587,345 three-year NSF/BREAD grant in early 2016 for analysis and enhancement of the cowpea 8-parent MAGIC population and cowpea whole genome sequence.

The LIL funds proposed herein will also be leveraged with opportunity funds within the Host Countries via NGOs and national sources through presentation of the LIL effort and the associated opportunities for participatory funding.

AGRA is supporting multiple traits resistance breeding project at Kamboinse in Burkina Faso under Dr. Batiemo.

Kirkhouse Trust supported Dr. Cisse at ISRA on molecular breeding for Striga resistance (July 2012 – June 2015; \$90,000).Completed.

Kirkhouse Trust provided funding for SARI to improve the field resistance of five cowpea lines using MABC. These lines are currently being evaluated in multi-location on-farm trials and inspected by the National Variety Release and Registration Committee to gather the necessary data for their release. The five lines will serve as the recipients of the traits currently being screened under LIL. These traits include resistance/tolerance to Thrips, Striga, drought, heat, diseases as well as pyramiding the different sources of aphid resistance genes.

The Bt cowpea project being conducted by the Burkina Faso and Ghana HC teams is being funded by USAID via AATF.

VIII. Timeline for Achievement of Milestones of Technical Progress:

Please see completed "Milestones for Technical Progress" form for the workplan period.

Appendix 1: Workplan for Training and Capacity Strengthening (FY 2017)

Degree Training:

First and Other Given Names: Sassoum

Last Name: Lo

Citizenship: Senegal

Gender: Female
Training Institution: UC Riverside

Supervising CRSP PI: Close and Roberts, UC-R

Degree Program for training: PhD
Program Areas or Discipline: Cowpea genomics and 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: Senegal
Thesis Title/Research Area: Cowpea molecular breeding

Start Date: 03/2014

Projected Completion Date: 12/2018

Training status: Active, started degree program 03/2014
Type of CRSP Support: partial

Degree Training:

First and Other Given Names: Arsenio
Last Name: Ndeve
Citizenship: Mozambique
Gender: Male
Training Institution: UC Riverside

Supervising CRSP PI Roberts and Close, UC-R

Degree Program for training: PhD
Program Areas or Discipline: Plant Pathology, genetics and 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: Mozambique
Thesis Title/Research Area: Genomewide selection for disease and drought tolerance in SE African cowpeas

Start Date: 01/2012

Projected Completion Date: 09/2017

Training status: Active
Type of CRSP Support: partial

Short-term Training:

Type of training: Molecular breeding for young trainee breeders and NARS scientists
Description of training activity: As described under capacity building Objective 3, continuous short-term training will occur through iterative data analysis and interpretation

cycles using the phenotyping and genotyping data generated by each Host Country partner team. To provide periodic intensive training, we will convene a training workshop in each project year, using a combination of training modules developed by the UC-R team and by the CGIAR GCP Integrated Breeding Platform program (IBP) which is using our tropical legumes project cowpea breeding population data for the training modules. The first three of these workshops were held in March 2014 and March 2015 at UCR, and preceding the Pan-African Grain Legume and World Cowpea Conference in Zambia.

Location: Ougadougou, Birkina Faso

Duration 2 days

When will it occur? August 2017

Participants/Beneficiaries of Training Activity

Anticipated numbers of Beneficiaries (male and female): 12 (9 male, 3 female)

PI/Collaborator responsible for this training activity: Dr. Bao Lam Huynh, UC-R

List other funding sources that will be sought (if any): Training funds through USAID Climate Resilient Cowpea project will be leveraged to share costs.

Training justification: 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.

Equipment to be Purchased (costing >\$5,000): None requested during this period.

Appendix 2: Budget Narrative

Host Country Institutional Budget Split

The direct costs split between US and HC institutions is 40% (\$162,056.00) for US (University of California, Riverside) and 60% (\$239,683.00) for African Host Countries (Burkina Faso, Ghana, Senegal, and degree training country). This includes the degree training of African graduate students and the molecular genotyping costs for African breeding populations, both paid by UC-Riverside on behalf of the Host Countries

Personnel Costs

Salaries: Salary is requested for 1 month of summer salary for Project PI Professor Roberts at UCR, who will direct the project. Salary support will allow him to co-ordinate the breeding activities of the cowpea project, contribute cowpea genetics, germplasm manipulation and agronomic expertise to preparing various cowpea genotypes to be used in this project, to oversee aspects of

the phenotyping and breeding selection, and to work closely and co-ordinate with the Host Country cowpea breeders and trainees in West and Central Africa.

PhD level research scientist (Asst. Professional Researcher) Dr. Bao Lam Huynh will be supported at 70% (\$71900 base). Salary support will allow him to co-ordinate day-to-day breeding activities of the cowpea project, contribute cowpea genetics, germplasm manipulation and agronomic expertise to preparing various cowpea genotypes, to oversee genotyping and aspects of the phenotyping and breeding selection, and to work closely and co-ordinate with the Host Country cowpea breeders and trainees in West Africa.

Lab Assistant I, (TBD) will be supported at 70% (\$31,696 base). Salary support will allow LA1 to conduct field and greenhouse growth, harvest and post-harvest preparation of seed and shipment of cowpea germplasm and populations from breeding selections for both UC-R and Host Country breeding programs.

Salary base indicated to increase by 3% per annum according to standard UC-R projections.

Fringe Benefits: Benefit rates are consistent with University of California policies and include health insurance. Rates are 12.7% for Professor, 58.42% for Asst. Professional Researcher, and approximately 40% for the Lab Assistant I.

Travel

Funds are requested to cover local (within California) costs of multiple trips between UCR and field research stations in the Coachella Valley and San Joaquin Valley to conduct field screening and breeding selection experiments plus grower field strip trials. Each field location will require 8-10 trips each year, from plot preparation to cowpea harvest and trait phenotyping. Two trips each year are planned for project researchers (PI, Co-PI, or Prof Researcher) to go to Africa to visit with the NARS cowpea programs and help in the assessment of the phenotyping and breeding performance trials and for training. Travel costs will be leveraged with funds from other funded projects involving the same project team members. Host Country travel is for multiple within-country trips for conducting multi-location field trials for phenotyping and yield performance testing.

Equipment

None requested

Supplies

Funds are requested to cover supplies for field, greenhouse and laboratory experiment costs. Supplies are requested for conducting field and greenhouse phenotyping experiments in multiple

locations in California and West Africa. These screenings are for the primary targeted biotic and abiotic stress resistances. The UCR experiments will be complemented by the field location tests to be conducted by the cowpea breeding programs of the NARS in Burkina Faso, Ghana and Senegal. Supplies required for cowpea breeding population development and for generation of crosses for new breeding populations are also included.

Consumable lab supplies and equipment access recharge costs for growth of cowpea seedlings, leaf collection supplies, dessicants, irons and sealers, DNA purification, concentration determinations, and storage. Consumable lab supplies (reagents, restriction endonucleases, plastic ware, Nalgene bottles for seed storage) to support molecular breeding will be required. Supplies for field, greenhouse and lab growth for preparation of pathogen inoculum, insect colonies and their use in cowpea resistance screening are also included.

Training

Funds are budgeted for PhD degree training (\$52584) of one African Host Country student at UCR. Project research on genetic improvement emphasizing molecular-marker assisted selection will be used for the scientific framework of the degree experience, under our leadership. Support for an additional African graduate student at UCR will involve a combination of Legume Innovation Lab funds together with leveraged training opportunity funds from Foundation and other USAID project IL for Climate Resilient Cowpea) sources.

Non-degree training efforts are budgeted at \$5000 for training module preparation, data sharing and videoconferencing costs and workshop costs associated with other travel-paid team meetings based on the research work in the project.

Other

SNP genotyping costs will be paid by UC-R on behalf of African Host Countries for the molecular breeding analysis. This arrangement is necessary to ensure a rapid turn-around time on the data generation based on reliable billing and payment processing. Genotyping costs are estimated at nearly \$40,000 based on our current experience with outsourced SNP genotyping from LGC Genomics (KBioscience) in the UK and for the Illumina iSelect platform at University of Southern California, Los Angeles. Based on current cost per data-point ranging from 21c for <500 to 4.5c for >10,000 with LGC of \$80 per sample for 49,000 SNPs with the Illumina iSelect at USC, this estimate will allow genotyping of all parental lines, F2-7 or RIL populations, and BC populations.

Indirect Costs

Indirect costs are calculated as 52% of the modified direct costs for the UCR component. No additional UC-R IDC will be taken on the HC subagreements. Indirect Costs of 26% for the SNP genotyping (Column G, Other) were agreed to by UC-R because the work will be off-campus on behalf of the HCs. A waiver by UCR of IC charges on the degree training support of an African

graduate student at UC-R has been granted. The current negotiated IC rates for the participating Host Countries are Burkina Faso, 15%; Ghana 23.6%; and Senegal, 30%.

Cost share contributions

(in-kind & cash) by the U.S. and Host Country institutions

University of California - Riverside cost share contribution is calculated to be 15% (\$24,308) of UCR total direct costs (\$162,056). Contribution is in-kind based on Principal Investigator salary and benefits. Host Country cost share projection is 10% in-kind based on HC PI salary and benefits in each Host Country.

Budgetary attribution to institutional capacity building

Attribution to institutional capacity building is projected at 96% (\$154,919) of the total budget, based on training programs (degree, postdoctoral, and senior scientist training), and development of improved cowpea germplasm and molecular marker systems for use in Host Country programs.

FY 2017 WORKPLAN FORMAT

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

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

Dr. Barry Pittendrigh, Lead-Principle Investigator, Michigan State University (MSU)
Dr. Kenneth Paige, SO1.B1 project Principle Investigator (PI) with signatory authority over all UIUC sub-subcontracts with host country institutions (UIUC)

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

Dr. Manuele Tamò, IITA-Benin (HC-PI)
Dr. Clémentine Dabiré-Binso (requested replacement of Fousséni Traoré in FY17), INERA-Burkina Faso (HC-PI)
Mr. Laouali Amadou, INRAN-Niger (HC-PI)
Dr. Ibrahim Baoua, University of Maradi (collaborator with INRAN; no direct funding)
Dr. Stephen Asante, SARI, Ghana (HC-PI)
Dr. Haruna Braimah (requested replacement of Dr. Moses Mochiah in FY17), CRI- Ghana (HC-PI)
Dr. Julia Bello-Bravo, UIUC/MSU (US Co-PI)
Mr. Eustache Biaou, INRAB-Benin

I. Project Problem Statement and Justification: *(Please describe constraint to be addressed, its importance, and status of research progress to date) Maximum 4000 characters*

Insect pests of cowpeas dramatically reduce yields for cowpea farmers in West Africa, many of who live on less than \$2 per day. Arguably, the greatest biotic constraints on cowpea (*Vigna unguiculata* [L.] Walp.) production are insect pests. The major pests of cowpea in the field in northern Nigeria, Niger, and Burkina Faso include: (i) the legume pod borer, *Maruca vitrata* Fabricius; (ii-iii) the coreid pod-bugs, *Clavigralla tomentosicollis* Stal and *Anoplocnemis curvipes* (F.); (iv) the groundnut aphid, *Aphis craccivora* Koch; and, (v-vi) thrips, *Megalurothrips sjostedti* Trybom. Foundational work has been initiated to understand these insect pests in the areas where we propose to work to develop and deploy solutions. This foundational work, has positioned us well to have a better understanding of pest biology and population structure (due to molecular tools) – which will help direct current and future pest control strategies. Up until our last phase of this project, there were few alternatives to pesticide sprays for many of these pest species. Our program, over the past several years, has developed multiple promising integrated pest management (IPM) solutions for the pests of cowpeas. Additionally, for *M. vitrata*, there exists a potential biotechnology-based pest control solution. Transgenic cowpea expressing the *Bt*-protein Cry1Ab, effective against *M. vitrata* already exists, but has not been released, and may be a component of IPM in the next phase of this project. However, before transgenic Bt-cowpea can be released there will be a need for an insect resistance management (IRM) plan and our

program has already set the stage for just such a plan (Onstad et al., 2012). *Bt*-cowpea, even if/when it becomes available to farmers, will only control one of many pests that attack cowpea. For more immediately tangible control strategies, we have other pest control solutions at hand for *M. vitrata*. Host plant resistant traits are being brought forward by Dr. Phillip Roberts at California at Riverside (UC-R), some of which is being done in collaboration with our collaborators at INERA and IITA. We will continue our work with the aforementioned investigators, to bring forward such host plant resistance traits. However, over the past phase of this project we have developed multiple IPM pest control options for cowpea systems, many of which will require the next phase of research to bring them forward to larger-scale release and testing of impact.

Although biocontrol agents, transgenic plants, and traditional plant breeding for insect resistant varieties are all potentially effective methods for controlling pests of cowpeas, a continued refinement of our understanding of pest populations is needed in order to integrate these, and other, pest control options into an overall integrative pest management (IPM) plan to maximize cowpea production in the field. IPM refers to a pest control strategy where a variety of complementary approaches are used to minimize the negative effects of pests on a given crop or cropping system. As we develop, refine and deploy IPM strategies, we must understand the important life-history parameters of these pest insects in relationship to their environment. In the past phase of CRSP we developed a more in depth understanding of *M. vitrata* populations and have recently determined that *M. vitrata* living on cowpea have a great diversity of alternative host plants and common populations – this insight (due to the use of genomics tools) is extremely important as it means all alternative host plants, for *M. vitrata*, can likely act as a refuge for *Bt*-cowpea and when releasing biocontrol agents onto alternative host plants, programs can choose the host plants that are most useful and cost effective. We term the use of genomics tools to help direct IPM strategies as IPM-omics. The IITA group has demonstrated that the release of biocontrol agents, for *M. vitrata* control, on different alternative host plants can be done with varying levels of cost-effectiveness and IITA along with other partner groups the biocontrol agents are being released in targeted countries/areas. Additionally, we are moving into the final phases (in FY17) of completing studies on the population dynamics of all the major pests of cowpeas. We have developed molecular tools to accomplish such a task (Agunbiade et al., 2013). We have and will continue to investigate the presence of these insects on cowpea and the population structure of these species, as well, if they prove to be pests causing significant economic losses.

Over the upcoming year we will research, develop, implement and determine the impacts of an IPM-omics program for cowpea in West Africa. We have actualized larger-scale impact through donor community buy-in through a Bill and Melinda Gates Foundation grant.

II. Planned Project Activities for the Workplan Period (October 1, 2016-September 30, 2017)

Our objectives all emerge from the following vision, with three critical major objectives, supported and intertwined with the fourth objective of capacity building.

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

$$\text{IPM-omics} = \textit{define the pest problems} + \textit{appropriate solutions} + \textit{scaling of solutions}$$

In order to define “IPM-omics” we will (1) define IPM, ”omics,” and how these dovetail together, and (2) the operational approaches we will take over the next 1-year towards our goals. **IPM** was first defined in 1967, by Smith and Van Dan Bosch, as a concurrent application of multiple control measures to reduce damage caused by insects to crop plants. In practical terms, this involves understanding pest systems in detail to define when and where they are a problem, defining ecologically and economically viable solutions, suppression of pest populations below an economic threshold level for increased yields and sustainable solutions. **Omic**s is a term used in molecular biology to describe biological processes in large scale or high throughput. We use it to describe large-scale approaches now available to us in IPM. Thus, we define **IPM-omics** as the use of scalable technologies to understand, develop and deliver pest control solutions. IPM-omics is both a paradigm shift in how we need to think about best control in the present and in the future based on the use of cutting edge technologies available to us right now.

In our IPM-omics “equation” we must first *define the pest problems*. First, we must ask what are the paradigms and technologies that are in our “toolbox” and how can we use them? At the current moment we have the following “tools” to work with: (1) scouting, field experiments, light traps; (2) genomic markers to define pest and biocontrol agent populations – movement patterns and sources of the outbreaks; (3) computational modeling; and, (4) GIS systems – understanding pests in the background of their ecology and life history. These aforementioned combined tools will be focused on a regional understanding of pest problems on cowpea across West Africa.

In our IPM-omics “equation” the second step is *appropriate solutions*. We have developed a Biocontrol/Biopesticide pipeline, in order to develop a series of environmentally and economically appropriate pest control solutions. This is not a pipeline of “magic bullets”, but instead a diversity of technologies to provide farmers with a variety of solutions to suppress pest populations.

The final step in the IPM-omics “equation” will be the *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: (1) direct release into the environment and natural establishment; (2) educational solutions; and (3) private sector and NGO involvement. **Direct release into the environment and natural establishment** has and will involve the release of bio-control agents that ultimately become endemic in the environment and suppress the insect populations. The most effective places to deploy these bio-control agents is directly influenced by the knowledge we gain from our studies of “Defining the pest problems” and such agents come directly from our bio-control pipeline. **Educational solutions** are and will be pest control strategies that will require primarily educational interventions. Our past program has taken two educational approaches: (1) farmer field fora (FFF) (labor intensive, but scalable through partner organizations) and (2) cell phone animations (potentially highly scalable) voice overlaid in many West African languages and can be distributed by a variety of electronic

mechanisms (through the Scientific Animations Without Borders, SAWBO, program). We will study models of deployment and scaling of solutions through these approaches. Two major questions arise around these. First, for the cell phone approaches we will continue to determine (experimentally) what people learn, what they retain, and what are their changes in behavior and what are the benefits for the farmers and their communities. In the past phase of the Legumes Innovations Lab (Dry Grain Pulses CRSP) our team collaborated with the INRAN team and Dr. Mywish Maredia's team to ask the question regarding if these animations would increase adoption of pest control technologies as much as a visit by an extension agent. A recent analysis of the results demonstrated that this approach has the potential to be a highly effective tool for teaching.

We will continue to explore the most efficient pathways for deployment of such educational content. How do we make it accessible and who will use it with the greatest impact? Second, for FFF how can we make this approach scalable through educational programs and technology packages for NGOs and other extensions groups, and can we demonstrate that these groups have had positive impacts in their target communities (e.g., increased production or reduced labor/input costs). Finally, solutions requiring **private sector involvement** (e.g., where a "product" needs to be produced and distributed) will continue to be explored and implemented through co-operatives and other business models that empower women and unemployed youth. Finally, we will test deployment strategies of an App that allow for the use of our "solutions" well beyond our own team – thereby allowing for greater impact. An App has already been created and tested over the past year with a set of users – 1.0 version has been completed and released with all legal disclaimers/approvals by UIUC. The App is already available for free use on select Android operating systems (explanation at <https://www.youtube.com/watch?v=pPk16UiZ7bY>) from offline file sharing systems and downloadable from a variety of websites (e.g., <https://play.google.com/store/search?q=sawbo%20deployer&c=apps&hl=en>). Briefly, a user can choose the country they are in, the language they want, and the topic – where we have the content available they can then download it onto their phone (e.g., at a WiFi location). Then, when they travel to a location to do a presentation the animation can be shown on the cell phone/tablet and then transferred to local cell phones using Bluetooth®. The user can also transfer the App to other users that have Android devices, such that they can have access to the SAWBO library. Based on feedback and experiences from the 1.0 version, the SAWBO team will release in FY17 a 1.1 version, which will resolve outstanding issues discovered in the 1.0 version (mainly cosmetic) and the 1.1 version will be released and supported by the Pittendrigh laboratory from Michigan State University.

It is important to note that through another grant that the UIUC team has received from the ADM Institute for the Prevention of Postharvest Loss, to work in Ethiopia, we have had success with engaging local partners to invest in the development of deployment strategies for the animated content. In this separate project we worked with an Assistant Professor of Business at Adama Science and Technology University (Adama, Ethiopia) and the Ethiopian Agricultural Transformation Agency (ATA) to create animated content on the reduction of Postharvest Loss in teff. ATA purchased 640 tablet computers, loaded our animations onto these tablets, and distributed these devices to extension agents across the country. These extension agents are responsible for educating a total 168,000 teff growers (http://news.illinois.edu/news/14/0519sawbo_BarryPittendrigh.html). This group has recently received funding from the Ministry of Agriculture in Ethiopia to deploy SAWBO animations on a DigiSoft Android projection systems. Additionally, we have engaged NGOs in host countries in Africa, including one in Ghana that has included our animations both in their extension programs and as part of their ICT training sessions.

The World Health Organization (WHO) has also partnered with SAWBO on the creation and release of a Zika animation and a Yellow Fever animation. To date, the WHO has released these materials out to tens of thousands of end users. In addition to this, Drs. Pittendrigh and Bello-Bravo, through SAWBO, have a P20 NIH grant to work with health related issues within the midwest for minority populations (starting in the fall of 2016). Finally, the SAWBO website receives about 50,000-100,000 visitors every month, with about 7500 of those visiting the video library per month.

SAWBO has both trained their group directly in ICT approaches and participated in online ICT training sessions where their group has organized the participants in-country. We will continue to make efforts to engage partner groups who can use our content for their educational programs. For example, Dr. Samuele Amoa Mensa of the Center for Learning and Community Development (in Ghana) has been actively using SAWBO materials in his trainer of trainer programs and a TV station in Kano uses SAWBO animations as part of their programming in Hausa (with estimated viewers in the million to multiple millions). We have also engaged Dr. Robert Mazur's team, also of the Legume Innovations Lab to develop and test, directly with farmers, learning gains with the animations in Mozambique with excellent immediate and one-year later results. We have and will engage other programs within the Legumes Innovations Lab and other Innovations Labs (e.g., the Innovation Lab for the Reduction of Post-harvest Loss) for creation and use of our educational content in their programs. In FY17 we will increase our focus on pathways for "pass off" of our educational content to other groups that can integrate these materials into their educational and extension programs. Most importantly we have already reached and exceeded our target numbers for our Impact Pathway for SAWBO educational content (Step 4.5 of Aim #4).

It is important to note that we have received funding from the Bill and Melinda Gates Foundation on a planning grant involving an interactive IPM-omics system for identifying pest insect populations, making of management decisions and pushing back of solutions to farmers. This separate online system complements our work in this project, however, it is separate and beyond the scope of what we proposed to do in this project. It will focus on the development of a new App focused on assessing pest problems in the field and delivery of recommendations. We will start with *M. vitrata* in Southern Benin and our efforts will build on the insights gained in the last phase of the CRSP/Innovations Lab. We would hope that this planning grant would lead to a subsequent grant bringing in all our Legume Innovation Lab host country partners to scale this approach out across multiple countries in Africa.

However, it is important to note that multiple aspects of the IPM-omics equation are researchable questions that we expect will allow us to develop efficient pathways from IPM innovations to scaling of these solutions. As part of the development of our scaling pathways, we will work with multiple local and transnational programs such as AATF, FARA, and CORAF to play active roles in bringing pest management solutions to cowpea farmers. We will continue our ongoing work in Burkina Faso, Niger, Benin, and Ghana on all the above activities.

Objective 1: Define the pest problems. First, we must ask what are the paradigms and technologies that are in our “toolbox” and how can we use them? At the current moment we have the following “tools” to work with: (1) scouting, field experiments, light traps; (2) genomic markers to define pest and biocontrol agent populations – movement patterns and sources of the outbreaks; (3) computational modeling; and, (4) understanding pests in the background of their ecology and life history. We expect to work on Steps 1 and 2 in our impact pathway for “1 – defining pest problems”. In terms of “Program Logic” we will continue to work on Step 4.4 to 4.5 - Collection of pest populations using scouting throughout the year on cowpea crops and wild alternative host plants in Ghana, Burkina Faso, Niger, and Benin. Insects will be genotyped at MSU to determine pest movement patterns within regions (on cowpeas and alternative host plants). We will also complete an interface to summarize our findings in a visual format.

Collaborators:

Dr. Brad Coates, USDA, Iowa State University

Dr. Phil Roberts, UCR

Dr. Baoua Ibrahim, University of Maradi

Approaches and Methods:

The following activities will occur in FY17 (Step 4.4 in our Program logic/Impact Pathway Worksheet document). IITA, INERA, INRAN, CRI, and SARI will scout for insects in their respective countries, both on cowpea plants and on wild alternative hosts. Technicians and students will be trained at each institution to properly identify each species as well as the host plants where they are known to occur. We also will work with SO1.A5 on the analysis of collected insects from their field tests. The scouting will occur when and where appropriate in each host country during the time intervals when cowpeas are not being grown. Once cowpeas are planted, the scouting intensity will occur in cowpea fields and on wild alternative host plants. Once by trimester (outing lasted ten days) insects will be collected, labeled and stored in box for molecular characterization studies in BF and US. Again, for example, the INERA team in the cowpea growing off-season, in cowpea seed production plots, will investigate damage on cowpea due to new emerging pests. Understanding such pest problems and developing solutions has the potential to allow farmers in some areas to ultimately develop a second season crop of cowpea – thus, these studies are extremely important for potentially increasing overall cowpea production. Samplings of insects on cowpea will be performed at the INERA/DI research station on the Sourou River, Bagré plain and the Kou valley near Bobo-Dioulasso, where foundation seeds are yearly produced.

Thus, all host country teams, except INRAB, will continue to perform field collections on cowpea pests on alternative host plants for genetic analysis. Field collected insects will be sent back to MSU for analysis. We have performed such an analysis with *M. vitrata* and we published this work in PLoS One in 2014 (Agunbiade et al., 2014). We will take the same strategy with the other pest insects of cowpea: collect insects on cowpea and wild alternative hosts. The UIUC team will continue to analyze the aphid samples

from the Dr. Phil Roberts URC team – a collaboration we started in FY14 - with this collaboration we have made comparisons of pest populations.

The intent of these experiments will be to determine the location and host plants that provide a reservoir for the pest populations that ultimately move to the cowpea crops during the cropping system. In terms of the IITA budget \$5,000 of salaries will be used for this effort and \$500 in benefits, along with \$6,000 in travel and \$2,000 in supplies and costs. In terms of the INERA budget \$5,000 of salaries will be used for this effort and \$500 in benefits, along with \$1,000 in travel and \$1,000 in supplies and costs. In terms of the INRAN budget \$5,000 of salaries will be used for this effort and \$500 in benefits, along with \$1000 in travel and \$1,000 in supplies and costs. Both at SARI and CRI the following budget will be used for these activities: (1) \$1,000 in salaries, (2) \$100 in benefits, (3) \$500 in travel; and \$350 in supplies. Our primary focus will be on the pests beyond *M. vitrata*. The samples will be sent to UIUC for SNP and microsatellite analyses (the \$71,260.74.00 in salaries and in \$24,941.26 benefits along with \$12,825 supplies will benefit this section). The UIUC and IITA team (in conjunction with the MO) has received funding for a planning grant from the Bill and Melinda Gates Foundation (BMGF) to develop a complex IPM-omics interface to collect data on pest populations (using cell phones) and deliver solutions (using cell phones) back into the field for people to make pest management decisions and push out to them educational solutions. However, we are currently (as part of this project) in the process of creating a much simpler website to make our work and insights highly transparent to other researchers and outside groups that can help deploy our IPM approaches. We have found from our experience with the SAWBO program that making such materials available online in an easy to follow manner is important for bringing in other outside groups that can help us scale. Such will could then be fed into a more complex interface system; however, the BMGF system will be about a highly interactive approach to capturing pest problems in real time and then guiding farmer pest management decisions in real time (using cell phones). Thus, there is no funding overlap in terms of interfaces and our interface (for this program) will be focused on helping IITA and NARS programs make better IPM decisions within the context of this project.

Objective 2: In our IPM-omics “equation” the second step is appropriate solutions. We have developed a biocontrol/biopesticide pipeline, in order to develop a series of environmentally and economically appropriate pest control solutions. As step 4.5 of the our Impact Pathways we will (a) do mass rearing of *Maruca* parasitoids and inoculative releases in all countries; (b) assessment of regional impact of thrips parasitoids; (c) deployment devices for pod bugs egg parasitoids tested in farmer participatory trials in at least two participating countries (e.g., Benin, Burkina Faso and where time and resources permit Niger); (d) seed-based application of endophytic strains of *Beauveria bassiana* field tested in partnership with private sector (Benin); and (e) *Maruca* virus bio-pesticide mixtures available in select locations on the local market in Benin and potentially in Niger and Burkina Faso.

During this phase we will continue (1) to test novel natural enemies of the pod borer, including novel parasitoids from South East Asia (IITA); (2) to continue scaling up for the rearing and releases of thrips parasitoids in all countries (IITA and NARS programs – funds for this work in Ghana will come from the IITA budget – however, they will interact with the NARS programs as part of these releases); (3) to develop and test novel release devices for egg parasitoids of pod sucking

bugs (IITA) (including potential work with sex pheromones); (4) to develop and test endophytic strains of biopesticides (IITA); (5) and to address technical aspects of cost effective, income-generating production of bio-pesticide products by youth and women groups (IITA) and (INRAB); and (6) interact with the UCR group to develop in field tests for potential host plant resistant/tolerant varieties that we will test in our FY16, and onwards, program (INERA). We expect to work on Steps 1-4 in our impact pathway for “2 - Discover, document, and set the stage for scaling of appropriate solutions”. In terms of “Program Logic” we will work on Step 4.5 for this section (as given above).

Collaborators:

Dr. Ramasamy Srinivasan, AVRDC, Taiwan

Dr. Rousseau Djouaka, IITA, Benin

Dr. Ousmane Boukar, IITA, Nigeria

Dr. Phil Roberts, UCR, USA

Approaches and Methods:

During FY17 we plan to conduct the following activities:

In terms of scaling up activities, our in country teams will perform the following activities. (1) Continue to carry out experimental releases of *M. vitrata* parasitoids *Therophilus javanus* (IITA, INERA, INRAN, CRI) and *Phanerotoma syleptae* (IITA, INERA) (2) Scaling out rearing of *T. javanus* and *P. syleptae* (IITA, INERA, INRAN). (3) We will continue to scale up the rearing and releases of the flower thrips parasitoid *Ceranisus femoratus* in all participating countries. For this purpose, nursery plots of *Tephrosia candida* will be used for the planned releases, targeting the Sudano-Sahelian zones of Burkina Faso (INERA) and Niger (INRAN/University of Maradi) as well as in Ghana (SARI/CRI). (4) We will continue investigating recently discovered male aggregation pheromones in pod sucking bugs (*Clavigralla tomentosicollis*) for developing release strategies for the egg parasitoid *Gryon fulviventre*. A PhD candidate jointly supervised with *icipe* will continue to elucidate the nature of these aggregation pheromones. (5) We will continue to develop and test microbiological and molecular techniques for detecting endophytic strains of the entomopathogenic fungus *Beauveria bassiana* applied to cowpea, both as seed application and as a foliar spray. Also, we will start testing mixed formulations of emulsifiable neem oils with *B. bassiana* in on-station trials (6) We will continue to follow up on the production of the MaviMNPV virus by the women’s groups at multiple localities in Benin, with the aim of optimizing the workflow and assuring quality control. We will also continue to establish farmer-participatory trials with combinations of bio-pesticides including MaviMNPV. (7) Our INERA team will continue to work with UCR to determine potential host plant resistance and tolerance traits (e.g. thrips, pod sucking bugs, etc.) for in field studies in FY17. (8) It is important to note that in the last phase of the CRSP we found that neem sprays and neem+MaviMNPV sprays were very effective in minimization of cowpea pest populations. At INRAN and University of Maradi our team will continue to test and explore “pass off” of this approach to farmer groups. (9) At INERA studies on two promising parasitoids will be continued. *Gryon fulviventre* will be tested in a greenhouse for the control of

Pods sucking bug; and parasitoids of thrips will be tested on *Tephrosia candida* at Farakoba research station and Bama. After testing of these parasitoids, a sampling will be done to know the success level of this technology. (10) Our Ghana team (CRI and SARI) will continue to explore the potential for the development of a locally created low-cost neem press; reducing the costs of such a press and making it more portable has the potential to increase the numbers of women's groups that could enter in the neem oil production market. They have worked with (and will continue to do so) an individual(s) with mechanical skills to help determine if the development of such a device (using local materials) is feasible. They will also work jointly on this project and the same amount of funds for each of the two groups will be dedicated to this activity; both at SARI and CRI the following budget will be used for these activities: (1) \$1,000 in salaries, (2) \$100 in benefits, (3) \$500 in travel; and \$350 in supplies.

The following aspect of the IITA budget will be used for both these above steps and for the testing of these approaches in the field: (1) Salaries of \$10,000, (2) benefits of \$1,000, (3) \$3,000 in travel costs, and (4) \$17,145.00 in S&E costs. For the steps above that INERA will be involved in, the following funds will be used: (1) \$5,000 in salaries, (2) \$500 in benefits, (3) \$1,000 in travel, and (4) \$1,000 in supplies.

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: (1) direct release into the environment and natural establishment; (2) educational solutions; and (3) private sector and NGO involvement. In terms of Program Logic, step 4.5 will occur: 1) Releases of biocontrol agents scaled out; 2) Educational solutions - ICT training materials, online and in-country ICT training sessions available for testing with current partners and potential new partners, FFF program available for testing of impact leading to educational packages for scaling, potential pathways for deployment of educational videos explored, and begin testing of pathways to deploy videos; and, 3) Private sector/NGO involvement. IITA will use \$5,000 in salaries, \$500 in benefits, \$4,000 in travel and \$3,000 in supplies to work with INRAB, UIUC, and MSU to investigate potential pathways for impact. For INERA the following funds will be used for scaling of solutions activities: (1) \$10,000 in salaries, (2) \$1,000 in benefits, (3) \$1,000 in travel, and (4) \$3,000 in supplies. For INRAN the following funds will be used for scaling of solutions activities: (1) \$5,500 in salaries, (2) \$550 in benefits, (3) \$2,000 in travel, and (4) \$1,500 in supplies.

Collaborators:

Mrs. Kemi Fakambi, Director of Enterprises Solidaires Benin (CBO)

Dr. Mywish Maredia, MSU

Dr. Byron Reyes, MSU

Approaches and Methods:

(1) Direct release into the environment and natural establishment - In FY17, we will continue to conduct inoculative releases of biocontrol agents against thrips (*Ceranisus femoratus*) and pod borers (*Therophilus*

javanus and *Phanerotoma syleptae*) at selected locations in Burkina Faso (INERA) and Niger (INRAN) according to the priority ecological zones established in the previous phase of the project. Natural enemies will be either brought from the IITA cultures, or reared locally prior to the releases, depending on the available capacities and infrastructures. In Burkina Faso, these releases will occur in the area where we performed (in collaboration with Dr. Maredia) a pre-biocontrol agent assessment with cowpea farmers. In FY17, we will investigate the post release of an establishment impact on cowpea crops and their expected positive impacts on cowpea farming systems and cowpea farmers themselves.

(2) Educational solutions – As part of 4.5 in our impact pathway, ICT training packages and content will be made available through online and in country training, available packages undergoing another year of tests of FFF for impact through collaborative organizations. We previously developed educational packages (both online and ones that are printed booklets and CDs/DVDs) that have and will be used to train both groups on our teams and with groups outside our program for long-term scaling (funded by our Chancellor’s Office - UIUC). In FY15 we completed an Android App (SAWBO Deployer App) that allows users of select Android devices with the capacity to download and share all educational content. These have included and we will: (1) continue to create educational content that people can use to educate farmers about IPM techniques and about pest problems (including animations, written materials for the educators, and these materials in a diversity of formats for people to use – all will be made available online to be shared on the Scientific Animations Without Borders deployment sites); summarization of lessons learned from previous FFF and what the educators need to know to make these more successful along with beginning to develop training packages for educators (e.g., NGOs and extension agents) to successfully perform FFF on IPM for cowpeas and (2) refinement creation and deployment (online training sessions and in country training sessions) of ICT packages to educators outside of our groups on how to download our current content, translation of our current content into new languages (we continue to do the actual co-creation of new language variants). The ICT training package was completed in FY14 and has been used in training sessions in multiple countries. Our Chancellor’s office at UIUC already funded in FY13 an in Ghana SAWBO training session for 28 representatives from two NGOs and one university. We have continued to host trainings sessions in Ghana, Burkina Faso, Benin, and countries funded by other programs/projects such as Mozambique, Ethiopia, Sierra Leone Bangladesh and Uganda. One of these NGOs has already started their own ICT training sessions, of which the SAWBO team has participated in through Skype. We continue to work with other people and groups from West Africa, through an online collaborative network, to create new West African language variants of existing animations. A study by Drs. Maredia, Reyes, Dabire, Ba, Bello-Bravo and Pittendrigh has demonstrated that the animations are basically as effective as extension agents for learning gains and in one technology encouraging the adoption of pest control technologies – suggesting real potential for the animated approach in dissemination of the technologies we have and will continue to develop. Additionally, we have an “App” for easy access and download for our educational materials. The Android App is available on “Google Play”. The Android App allows deployers of the animations to easily access them on their cell phones, download them and then transfer them, VIA Bluetooth®, onto other simpler, but video capable phones that can be found in the hands of a significant number of farmers in West Africa.

For the upcoming Legumes Innovations Lab, we have educational animations on a series of IPM solutions: neem sprays, solar treating of cowpea seeds, the concepts explaining biocontrol, etc. In the past phase of the CRSP we observed that the animations spread rapidly, people learned from these videos the main concepts, they found these entertaining, and with groups outside of our CRSP program we worked with testing of

animations as an educational tool, with the results strongly suggesting that people could easily understand the content and repeat the techniques (funded separately and done separately from the previous CRSP). Through a past study with Dr. Michelle Shumate at Northwestern University we have developed experience working with deployment pathways for technology-based educational materials in Burkina Faso. We previously completed studies on (1) which groups in the country are the most logical to deploy the educational materials. We need to continue to place many of these videos in more local languages – we have refined a system where we can work with groups virtually in a given country (they just need Internet access and a computer with a built in microphone) to develop new voiceovers in local languages and deliver videos back to them to use in the field. SAWBO, created as a direct output of CRSP funding, has also resulted in the creation of animations (funded by University of Illinois at Chicago Hospital systems) that help educate US citizens on topics such as cancer screening, use of inhalers with spacer and sickle cell treatment (all in US-base populations). SAWBO animations have been used in Illinois for issues associated with TB screening and prevention.

For the FFF that will be held in Niger and Burkina Faso we will work with partner groups where we will train them on proper experimental design such that from their results we will be able to obtain statistical data demonstrating potential increases in yields of specific IPM techniques. We will continue to incorporate animated videos into some of these FFF's to determine their usefulness in increasing learning in the FFF and potential impacts on positive outcomes of adoption of specific technologies.

(3) Private sector and NGO involvement - We will continue to collaborate with the self-help enterprise producing bio-pesticides in Benin, focusing on refining formulation and application methodology for bio-pesticides and their mixtures. Also, we will follow up the virus production by women groups who have undergone training in FY15 and FY16, making sure the production can be sustained and deliver a good quality product which can enter the already existing biopesticide 'value chain' within the self-help enterprise. The SAWBO program has had a significant amount of success with "passing off" educational animations to NGOs and we will seek to determine the numbers and the type of impact some of these organizations have had with such videos.

(4) Assessing Market Potential - We also need to assess the market potential for biopesticides, potential groups that can develop these materials and logical "pass-off" groups in our host countries for our various technologies. In Benin, INRAB has the mandate to assess the market potential for such biopesticides (e.g., what farmers are willing to pay, what will be the costs to enter the market place for small industries, what are skill-sets that need to be developed for womens' groups to potentially make and profit from selling such materials) and what will determine the networks of NGOs and other organizations where we can "pass-off" educational approaches (be it FFF or animations or both) for scaling. The full INRAB budget (of \$7,000) direct spendable will be used for these activities, including \$1,500 (non-degree training) of which will be used in INRAB personnel time to train IITA staff of these assessment approaches. Another \$2,000 will be used toward student-funded support for this project in order for the INRAB team to complete their projects where they are collaborating with the IITA team.

Objective 4: Capacity building - To increase the capacity, effectiveness and sustainability of agriculture research institutions which serve the bean and cowpea sectors in the target FTF countries

Collaborators:

Dr. Brad Coates, USDA, Iowa State University

Dr. Baoua Ibrahim, University of Maradi

Approaches and Methods:

Objective – Capacity Building - *To increase the capacity, effectiveness and sustainability of agriculture research institutions which serve the bean and cowpea sectors in the target FTF countries.*” In terms of Program Logic, step 4.5 will occur, as well as (1) Ongoing undergraduate and graduate education across all four HCs will occur, (2) we will promote an App that will allow for easy access to our educational content and continue to make available the individual animations, (3) technician training on biocontrol agent production and release. Both at SARI and CRI \$1,100 of their budgets will be used for this technician training.

Approach -

Degree training – We will have one West African graduate student (PhD), at UIUC, that has completed here UIUC PhD and is now a Postdoctoral fellow at Yale University, previously supported by a Howard Hughes Fellowship, and all of her papers have been accepted as of the end of FY16. We expect her final paper to be published in FY17. A second U.S. citizen (female PhD student) and a Korean student will also continue to be trained (no funds from the Legumes Innovations Lab will be directly used for their training). At IITA and all NARS programs the student training will continue and we will make every effort to make sure these students submit manuscripts towards publishing their work. We will continue to train students at the B.S./B.Sc., M.S./M.Sc. and Ph.D. levels – each country will train students at different degree-levels depending on needs and opportunities – with a focus on completing as many of these students as possible in FY17.

We will continue with the students: (1) one BS student will be partially supported at SARI in Ghana (entomology - \$1,500), (2) one BS student will be partially supported at CRI in Ghana (entomology - \$1,500), (2) one PhD graduate student will work with both INRAB and IITA (but will be funded through IITA) (in order to strengthen their partnership – this student will assist on the assessment studies - \$5,000 for this partial support), (3) one PhD student will be partially supported at INERA (entomology - \$5,000), (4) one honors or MS student will be partially or fully supported at INRAN in Niger (entomology \$2,950), and (5) three more PhD or MS students will be partially/fully supported at IITA in Benin (entomology – partial support for each student at \$5,000 per student). This brings a total of eight students.

Short-term training – We continue to explore approaches for scaling of short-term training as part of a solution for cost-effective scaling of our outputs. We will develop tangible educational content for training of farmers both in terms of FFF and through ICT approaches. What emerged from our previous efforts is that “piggy backing” on other educational programs or existing extension/education networks is likely to provide us with the most “cost effective” pass off educational content to other groups that can use them in their educational programs.

For the ICT approaches we will (1) continue to place our existing animations in the diversity of major languages needed, make available educational content in a diversity of formats (online, on cell phones, USB-card SAWBO video libraries that people can carry in their wallets and distribute videos when needed, and we will hope to release an “App” for educators to easily gain access to content based on country, language and topics – such that they can download what they need – take it to the field and distribute it on to people’s phones VIA Bluetooth), (2) we will promote and perform ICT training sessions for our collaborators and outside groups like NGOs, other government and international organizations. These sessions will be important as learning exercises for us to refine materials, but are absolutely critical for us to develop the necessary networks of outside collaborators who can help scale our efforts. It is important to note that with these ICT approaches we can measure online use and downloads of materials. Partner groups can also give us feedback on their use and potential for scaling in their programs. A total of \$53,058.00 will be used at MSU to support activities to develop and implement training materials and sessions. An additional \$2,030.00 will be set aside to provide HC scientists with offline tools (e.g., SAWBO USB cards and all-inclusive solar-powered portable project systems) to disseminate this educational content.

For the FFF program we will host a minimum of three (upwards of six) FFF in Niger and Burkina Faso. These will be hosted by outside groups that we will train and throughout the year we will work with them to develop the most effective training packages and ICT materials that can be incorporated into these programs. For INERA and INRAN each team will use \$5,000 for FFF and ICT activities.

Additionally, we will hold technician-training programs for the biocontrol agents that will be released. This will involve sending technicians across to different programs (training primarily at IITA, however the NARS programs will also exchange between Burkina Faso, Niger, and Ghana where necessary). This will occur where necessary and where time and resources permit. We expect at least one exchange to occur in FY17. IITA will use \$11,300 of their budget for these activities.

Capacity building awards. The details of these awards and activities were outlined in their proposals and approved by the TMAC. All activities are in progress or completed.

III. Contribution of Project to USAID Feed the Future Performance Indicators:

Please see our “Performance Indicators – Targets” form for the project for FY16.

IV. Outputs:

Defining the pest problems - We expect to collect a final year of data on the major pests of cowpeas (beyond *Maruca*) in terms of timing, location, and wild alternative host plants. We expect to continue to perform molecular work on these populations.

Appropriate solutions – We will bring forward, in the biocontrol pipeline, new promising agents. We expect to bring forward biopesticides and develop tools and an understanding to take them to the next step towards commercial production (not only the technology, but a better understanding of who to work with to “pass off” the technologies to the marketplace. We also expect to have an understanding of the potential for a low-cost neem press.

Scaling of Solutions – We expect to continue to perform inoculative releases of natural enemies in Niger, Burkina Faso, and Benin; we expect these to ultimately suppress insect populations. We expect to have developed and expanded on partnerships that can help us scale our solutions – we expect the most immediate tangible results will be NGOs using our educational materials. We expect this to be the beginning of developing larger-scale in country deployment networks for our materials. Also, as SAWBO materials have been translated into languages beyond these countries, we also expect to work with and interact with NGOs and other organizations that will use these materials in their educational programs. We also expect some of our assessments on the potential for scaling will give us important insights for continued scaling.

V. Engagement of USAID Field Mission(s)

Dr. Pittendrigh has met with the Ghana mission during our program planning meeting and Dr. Pittendrigh presented on IPM-omics at the Innovation Lab Workshop that was held in Accra, Ghana, on July 8 and 9, 2013, a meeting involving USAID Mission staff (FY13). Additionally, one of the Ghana mission’s representatives contacted Drs. Tamo (at IITA) and Dabire (INERA) about the possibility of exploring intercropping of cowpea with crop(s) important for FTF value chains. They were interested in the IPM technologies we are working on and seek opportunities for connections with their focus. Our Ghanaian PI’s were involved in the July 8 and 9 (2013) meeting involving USAID Mission staff. Dr. Pittendrigh also met with the USAID Mission staff in FY15 and hopes to have FY16/FY17 meetings respectively in the summers of 2016 and 2017. Thus, we will continue this important process of engaging missions in West Africa in regards to our program.

VI. Partnering and Networking Activities:

Our partnering activities have several aspects to them. First, IITAs development of novel pest control solutions (both technologies and biocontrol agents), through the biocontrol/biopesticide pipeline worked upon by the NARS programs for testing, use and are deployed in their host countries. The FFF will be conducted in

conjunction with local NGOs and other non-Legumes Innovations Lab programs (i.e., groups that we are not funding, but can use our materials in their programs). We will have FFF in Niger and Burkina Faso, with these outside programs, and after training these groups on how to properly set up experiments in the FFF we will assess the impacts on yields in the experimental plots. We will also use our ICT training sessions (both online and one in-country – in year FY17 our focus will be Burkina Faso and Niger for pass off to) to meet with and partner with NGOs that can use our materials in scaling with their own educational programs. The travel funds for MSU will be used for MSU faculty, staff and/or students to visit with IITA and/or NARS scientists in the course of the FY17. We will continue to expand our networks with other NGO and international organizations – with the goal of “pass off” practical solutions to other groups that can integrate them in their programs for potential scaling.

VII. Leveraging of Legumes Innovations Lab Resources:

The MSU team will leverage funds from the startup and endowment funds. Additionally, the MO, IITA and UIUC/MSU have received a planning grant from the Bill and Melinda Gates Foundation (BMGF) of IPM-omics technologies. However, it is important to note that activities for the BMGF will be kept separate from our Legumes Innovation Lab objectives (no overlap in objectives). There exist multiple complementary technologies and scaling issues that required funding levels in keeping with a BMFG planning grant. IITA will continue to receive funding through the CGIAR Research Program on Grain Legumes, including competitive grants. We also view the use of the SAWBO animations by NGOs in their educational programs as a leveraging of the Legumes Innovations Lab resources.

VIII. Timeline for Achievement of Milestones of Technical Progress:

Please see out "Milestones for Technical Progress" form for the workplan period.

Training/Capacity Building Workplan for FY 2016 – 2017 (use format below)

Degree Training:

First and Other Given Names: Laura

Last Name: Steele

Citizenship: USA

Gender: Female

Training Institution: UIUC

Supervising CRSP PI: Pittendrigh

Degree Program for training: PhD in Entomology

Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? No

Host Country Institution to Benefit from Training: Benin, Niger, Burkina Faso, and Ghana – indirectly (this student has and will continue to play a major role in the development of ICT tools for these countries as well as work on the molecular aspects of our program)

Thesis Title/Research Area: To be determined

Start Date: Continuation (Started Fall 2011)

Projected Completion Date (Fall 2016)

Training status (Active, completed, pending, discontinued or delayed): Active

Type of Innovations Lab Support (full, partial or indirect) for training activity: Indirect

First and Other Given Names: Keon

Last Name: Seong

Citizenship: Korean

Gender: Male

Training Institution: UIUC

Supervising CRSP PI: Pittendrigh

Degree Program for training: PhD in Entomology

Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? No

Host Country Institution to Benefit from Training: Benin, Niger, Burkina Faso, and Ghana – indirectly (this student has and will continue to play a major role in the development of ICT tools for these countries as well as work on the molecular aspects of our program)

Thesis Title/Research Area: To be determined

Start Date: Continuation (Started Fall 2013)

Projected Completion Date (Fall 2017)

Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) g for training activity: Indirect

First and Other Given Names: Djibril Aboubakar

Last Name: Souna

Citizenship: Benin

Gender: Male

Training Institution: IITA

Supervising CRSP PI: Tamò

Degree Program for training: PhD in Entomology

Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? Host
Country Institution to Benefit from Training: Benin

Thesis Title/Research Area: Bio-ecology of *Therophilus javanus*, a promising biocontrol candidate
against *Maruca vitrata*

Start Date: 2014

Projected Completion Date: 2018

Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Judith

Last Name: Honfoga

Citizenship: Benin

Gender: Female

Training Institution: IITA

Supervising CRSP PI: Tamò

Degree Program for training: MSc in Entomology

Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID?

Host Country Institution to Benefit from Training: Benin

Thesis Title/Research Area: Detection and quantification of *Therophilus javaus* parasitism in
Maruca vitrata larvae using species-specific qPCR primers.

Start Date: 2014

Projected Completion Date: 2016

Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Hilaire

Last Name: Kpongbe

Citizenship: Benin

Gender: Male

Training Institution: IITA

Supervising CRSP PI: Tamò

Degree Program for training: PhD in Chemical Ecology

Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?

Host Country Institution to Benefit from Training: Benin

Thesis Title/Research Area: Elucidating the nature of male aggregation pheromones of *Clavigralla tomentosicollis*

Start Date: 2015

Projected Completion Date: 2018

Training status (Active, completed, pending, discontinued or delayed): Active

Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Nicolette

Last Name: Montcho

Citizenship: Benin

Gender: Female

Training Institution: IITA

Supervising CRSP PI: Tamò

Degree Program for training: MSc in Entomology

Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?

Host Country Institution to Benefit from Training: Benin

Thesis Title/Research Area: Host finding behavior of *Therophilus javanus*, a novel parasitoid of the pod borer *Maruca vitrata*

Start Date: 2015

Projected Completion Date: 2016

Training status (Active, completed, pending, discontinued or delayed): Completed

Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Anne Marie

Last Name: Ahandessi

Citizenship: Benin

Gender: Female

Training Institution: IITA

Supervising CRSP PI: Tamò

Degree Program for training: MSc
Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID?

Host Country Institution to Benefit from Training: Benin
Thesis Title/Research Area: Bacteria colonizing gut and frass of the pod borer *Maruca vitrata* feeding on different host plants

Start Date: 2015

Projected Completion Date: 2016

Training status (Active, completed, pending, discontinued or delayed): Completed
Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Nazyath

Last Name: Imorou
Citizenship: Benin
Gender: Female

Training Institution: IITA

Supervising CRSP PI: Tamò

Degree Program for training: MSc
Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID?

Host Country Institution to Benefit from Training: Benin
Thesis Title/Research Area: Olfactometric responses of *Therophilis javanus* to different host plants

Start Date: 2016

Projected Completion Date: 2017

Training status (Active, completed, pending, discontinued or delayed): Completed
Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Fiacre

Last Name: Agbaka
Citizenship: Benin
Gender: Male

Training Institution: IITA

Supervising CRSP PI: Tamò

Degree Program for training: MSc
Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID?

Host Country Institution to Benefit from Training: Benin
Thesis Title/Research Area: Interactions between *Therophilis javanus* and *Phanerotoma syleptae*

Start Date: 2016

Projected Completion Date: 2017

Training status (Active, completed, pending, discontinued or delayed): Completed
Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Rahina

Last Name: Souley Mayaki

Citizenship: Niger

Gender: Female

Training Institution: INRAN

Supervising CRSP PI: Ibrahim Baoua/Amadou

Degree Program for training: Bsc in Entomology

Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID?

Host Country Institution to Benefit from Training: Niger

Thesis Title/Research Area: The effects of Neem grain-based biopesticide on the development of *Clavigralla tomentosicollis* at rural level in the region of Maradi

Start Date: 2012

Projected Completion Date: 2016

Training status (Active, completed, pending, discontinued or delayed): Active
Type of Innovations Lab Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Soumaila

Last Name: Abdou Issa

Citizenship: Niger

Gender: male

Training Institution: INRAN

Supervising CRSP PI: Ibrahim Baoua/Amadou

Degree Program for training: Bsc in Entomology

Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID?

Host Country Institution to Benefit from Training: Niger

Thesis Title/Research Area: The effects of Neem grain-based biopesticide on the development of *Clavigralla tomentosicollis* at rural level in the region of Maradi

Start Date: 2012

Projected Completion Date: 2016

Training status (Active, completed, pending, discontinued or delayed): Active
Type of Innovations Lab Support (full, partial or indirect) for training activity: partial

First and Other Given Names: Nafissatou

Last Name: Illa Boube

Citizenship: Niger

Gender: Female

Training Institution: INRAN

Supervising CRSP PI: Ibrahim Baoua/Amadou

Degree Program for training: in Entomology

Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID?

Host Country Institution to Benefit from Training: Niger

Thesis Title/Research Area: Study of the population dynamics of *Maruca vitrata* on station.

Start Date: 2011

Projected Completion Date: 2016

Training status (Active, completed, pending, discontinued or delayed): Active
Type of Innovations Lab Support (full, partial or indirect) for training activity: partial

First and Other Given Names: Rakia

Last Name: Gonda

Citizenship: Niger

Gender: Female

Training Institution: INRAN

Supervising CRSP PI: Ibrahim Baoua/Amadou L.

Degree Program for training: Bsc. in Entomology

Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID?

Host Country Institution to Benefit from Training: Niger

Thesis Title/Research Area: Study of the biology of *Clavigralla tomentosicollis* in laboratory

Start Date: 2012

Projected Completion Date: 2016

Training status (Active, completed, pending, discontinued or delayed): Active
Type of Innovations Lab Support (full, partial or indirect) for training activity: partial

First and Other Given Names: Kader

Last Name: Djibo Amadou

Citizenship: Niger

Gender: Male

Training Institution: INRAN

Supervising CRSP PI: Ibrahim Baoua/Amadou

Degree Program for training: Bsc in Entomology

Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?

Host Country Institution to Benefit from Training: Niger

Thesis Title/Research Area: Study of the development cycle of *Clavigralla tomentosicollis* in laboratory conditions

Start Date: 2012

Projected Completion Date: 2016

Training status (Active, completed, pending, discontinued or delayed): Active

Type of Innovations Lab Support (full, partial or indirect) for training activity: partial

First Name: Haouaou

Last Name: Issaka

Citizenship: Niger

Gender: Female

Training Institution: INRAN

Supervising CRSP PI: Ibrahim Baoua/Amadou

Degree Program for training: Msc in Entomology

Program Areas or Discipline: Entomology

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?

Host Country Institution to Benefit from Training: Niger

Thesis Title/Research Area: Effect of biopesticide neem seeds extract for the control cowpea pods pest (*Maruca vitrata* and *Clavigralla tomentosicollis*) on station

Start Date: 2015

Projected Completion Date: 2016

Training status (Active, completed, pending, discontinued or delayed): Active

Type of Innovations Lab Support (full, partial or indirect) for training activity: partial

First name: TBD

Last name: TBD

Citizenship: Ghanaian

Gender: TBD

Discipline: Entomology
Host Country Institution to benefit from Training: Ghana
Supervising Legume Innovation Lab PI: Asante and Braimah through the University for Development Studies, Tamale, Ghana
Start Date of Degree Program: TBD
Program completion Date: TBD
Training Status During Fiscal – Year 2014: Undergraduate research project
Type of Legume Innovation Lab Support: Partial

First name: Akosua Addai Asare
Last name: Asare
Citizenship: Ghanaian
Gender: Female
Discipline: Entomology
Host Country Institution to benefit from Training: Ghana
Supervising Legume Innovation Lab PI: Asante and Braimah through the University for Development Studies, Tamale, Ghana
Start Date of Degree Program: Fall 2015
Program completion Date: 2016/2017
Training Status During Fiscal – Year 2015: Undergraduate
Type of Legume Innovation Lab Support: Partial

First name: Mariam
Last name: Derra
Citizenship: Burkinabè
Gender: Female
Discipline: Entomology
Host Country Institution to benefit from Training: INERA
Supervising Legume Innovation Lab PI: Traoré
Start Date of Degree Program: September 2014
Program completion Date: TBD
Training Status During Fiscal – Year 2016: Graduate student (PhD)
Training status (Active, completed, pending, discontinued or delayed): Delayed
Type of Legume Innovation Lab Support: Partial

First name: Appoline
Last name: SANOU
Citizenship: Burkinabè
Gender: Female
Discipline: Entomology
Host Country Institution to benefit from Training: INERA
Supervising Legume Innovation Lab PI: Dabiré and Traoré
Start Date of Degree Program: September 2013

Program completion Date: 2017

Training Status During Fiscal – Year 2016: Graduate student (PhD)

Training status (Active, completed, pending, discontinued or delayed): Active

Type of Legume Innovation Lab Support: Partial

First name: Edouard

Last name: Drabo

Citizenship: Burkinabè

Gender: Male

Discipline: Entomology

Host Country Institution to benefit from Training: INERA

Supervising Legume Innovation Lab PI: Traoré

Start Date of Degree Program: September 2015

Program completion Date: 2016

Training Status During Fiscal – Year 2016: Graduate student (Master II)

Type of Legume Innovation Lab Support: Partial

First name: Théodore

Last name: Ouédraogo

Citizenship: Burkina Faso

Gender: Male

Discipline: Entomology

Host Country Institution to benefit from Training: INERA

Supervising Legume Innovation Lab PI: Traoré

Start Date of Degree Program: May 2015

Program completion Date: 2016

Training Status During Fiscal – Year 2016: Graduate student (Master II)

Training status (Active, completed, pending, discontinued or delayed): Active

Type of Legume Innovation Lab Support: Partial

Short-term Training:

Type of training: FFF

Description of training activity: These will be training of NGOs and outside groups and then these materials will be used in FFF, where INERA and INRAN will work with them closely throughout the FFF sessions.

Location: Niger and Burkina Faso

Duration: Several months

When will it occur? Fall of 2016

Participants/Beneficiaries of Training Activity: We expect direct impact on NGOs and other groups that can use these in their educational programs. We expect benefits to cowpea farmers to also result.

Anticipated numbers of Beneficiaries (male and female): We expect >250 (equally split between males and females) to benefit

PI/Collaborator responsible for this training activity: Traoré and Baoua/Amadou

List other funding sources that will be sought (if any): N/A

Training justification: We have already observed that training outside groups in our educational content has significant potential for scaling of our technologies and approaches that have been developed. This will both be a training system and a testing of scaling.

Type of training: ICT training sessions (online and minimally one in country)

Description of training activity: Minimally once in a year in Burkina Faso or Niger and several online when and where opportunity permits with collaborating organizations.

Location: One in Niger or Ghana or both and others virtually or during other training opportunities/trips.

Duration: Several hours to one-day sessions – followed by week long collaborative efforts for new content.

When will it occur? To be determined, but this will occur during other trips for other activities.

Participants/Beneficiaries of Training Activity: We expect direct impact on NGOs and other groups that can use these in their educational programs. We expect benefits to cowpea farmers to also result. We will also involve senior scientists and technicians in these training sessions.

Anticipated numbers of Beneficiaries (male and female). In FY17 we will have trained >200 individuals from NGOs/government agencies/private sector firms and we expect these groups (and out online systems) to impact >100,000,000 people to our materials. In fact, AREWA24, which broadcasts SAWBO animations has a viewership which is likely in the excess of multiple millions of viewers. We also expect “spill-over” of SAWBO animations into other countries and projects/regions. For example, SAWBO animations have been used by IIAM in Mozambique for hour-long training sessions (Pittendrigh and Bello in attendance with 100+ farmers) and in Ethiopia. Additionally, SAWBO animations are shown frequent on a Hausa TV station in Nigeria (Arewa24 - <http://us9.campaign-archive1.com/?u=a2b1b23a8f7e117aa0402399c&id=a7349aa0fa>), which broadcasts in Nigeria and Niger. Conservative estimates place the viewership in the million to millions level.

PI/Collaborator responsible for this training activity: Pittendrigh, Tamo, Traoré, Ibrahim/Amadou, Bello-Bravo

List other funding sources that will be sought (if any): Endowment funds and startup funds provided to Pittendrigh from MSU, P20 NIH grant to Pittendrigh and Bello-Bravo and (a) smaller NGO grant(s) provided to SAWBO.

Training justification: We have already observed that training outside groups in our educational content has significant potential for scaling of our technologies and approaches that have been developed.

Type of training: Technician cross-training

Description of training activity: Technicians will be cross-trained across IITA and the NARS programs

Location: Niger, Burkina Faso, Ghana, and Benin

Duration: 1-day to multiple weeks

When will it occur? Throughout FY17

Participants/Beneficiaries of Training Activity: Minimally 6 technicians and/or students

Anticipated numbers of Beneficiaries (male and female): We expect the NARS programs to benefit and increase their ability to have impact with biocontrol agents and biopesticides

PI/Collaborator responsible for this training activity: Tamo, Baoua/ Amadou, Traoré, Braimah, and Asante

List other funding sources that will be sought (if any): N/A

Training justification: We have found this a highly cost-effective way to exchange the technologies between institutions.

Equipment (costing >\$5,000): N/A

Specific Type of Equipment to be purchased

Justification for equipment to achieve workplan objectives

Institution to benefit from equipment

Institution to purchase equipment

Amount budgeted for equipment item

Appendix 2: Budget Narrative

We have outlined above how many of the expenditures relate to each of the activities for each of the groups involved in the overall program. The below explanations provide other details not given above.

U.S./H.C. Direct cost split – The direct cost split will be 48.79% to UIUC and MSU combined to 51.21% for the host countries. We are requesting that funds to support Dr. Pittendrigh’s efforts will be moved to MSU. The MSU costs will focus on the molecular analysis of the cowpea pests (paying for primarily staff scientist time and technician time; combined salaries of \$71,260.74 and 35% benefit rates totally \$24,941.26), travel costs for Drs. Pittendrigh and Bello-Bravo (for one trip to Niger or Burkina Faso), as well as supply costs. Dr. Pittendrigh will cover for Dr. Bello-Bravo’s travel costs from his MSU budget or from his endowment

funds or both. For part of FY17 Dr. Bello-Bravo will work at UIUC and the later part she will move to MSU. The \$53,058 will be used for staff support time and supplies and expendables to further scale and pass off the SAWBO educational content in the HCs. An overhead rate of 55% will be applied to these funds for a total of \$263,012.00, which will go directly to the Pittendrigh laboratory at MSU as Dr. Pittendrigh will move to MSU prior to FY17 and he will remain as the Lead-Principle Investigator. The remaining \$221,988.00 will go to UIUC, with a continued pass through to the HC collaborators of \$212,416.00 and \$9,300 remaining at UIUC for Dr. K. Paige for travel costs and O/H (\$6,000 in travel costs and \$3300 in overhead). Dr. K. Paige will be project Principle Investigator (PI) with signatory authority over all UIUC sub-subcontracts with host country institutions (UIUC). At MSU, an in-kind contribution of Dr. Pittendrigh's time (totally \$26,641.00) will occur and at UIUC an in-kind contribution of Dr. Paige's time of \$2,000 will occur.

For the H/C programs staff salaries (and benefits) are given as follows: (1) IITA - \$20,000 (\$2,000), (2) INERA - \$20,000 (\$2,000), (3) INRAN - \$10,500 (\$1,050), (4) INRAB - \$3,000 (\$300), (5) SARI - \$2,000 (\$200), and (6) CRI - \$3,000 (\$300). Travel expenses are highest for IITA (at \$15,000) as Dr. Tamo will both travel to meet with HC collaborators in the year and will travel to meet with Dr. Pittendrigh outside of West Africa. The travel budgets for the remaining HC groups are primarily within country trips or neighboring countries or both. At IITA the \$20,000 degree training budget represents partial or full support for multiple graduate students. At INERA and INRAN this is also the case. However, at INRAB all training will be non-degree and at CRI and SARI it will be used to support undergraduates who will work on projects towards their undergraduate degrees.

At all institutions 50% of the budget will be used in some way to perform institutional capacity building, in terms of training and development of staff, travel to build inter-institutional capacity, and finally generation datasets and tools that will be used by these institutions in their IPM recommendations. Additionally, for IITA, INRAN, INERA, CRI and SARI, they will ultimately have the capacity to rear or release or both biocontrol agents – a long-term capacity building effort that will be critical for IPM of cowpea pests in the region.

FY 2017 WORKPLAN

Project Code and Title: SO2.1 - Farmer Decision Making Strategies for Improved Soil Fertility Management in Maize-Bean Production Systems

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

Robert E. Mazur - Iowa State University

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

Andrew Lenssen - Iowa State University

Eric Abbott - Iowa State University

Ebby Luvaga - Iowa State University

Russell Yost - University of Hawaii at Manoa

Barry Pittendrigh - Michigan State University

Julia Bello-Bravo - University of Illinois

Moses Tenywa - Makerere University, Uganda

Richard Miiro - Makerere University, Uganda

Onesimus Semalulu - Soils & Agro-meteorology, National Agricultural Research Laboratories, Uganda

Ricardo Maria - Institute of Agriculture Research of Mozambique

Sostino Mocumbe - Institute of Agriculture Research of Mozambique

I. Project Problem Statement and Justification

This research project is based on two premises: (1) sustainable intensification of agricultural production requires improved soil fertility management in which legumes are an integral part of cropping systems; and (2) effectively addressing soil-related constraints is based on enhancing smallholder farmers' capabilities to diagnose and find solutions to important yield constraints.

Project research activities focus on key common bean production regions – in Masaka and Rakai districts in south-central Uganda and in Gurùè district in northern Mozambique, important Feed the Future focus countries. To understand potentially limiting soil nutrients, the team analyzed physical and chemical properties of the three predominant soil types used to grow beans in these regions in each country. The nutrient omission study laboratory experiment for Masaka and Rakai showed that low P availability limits bean growth across all three soil types - black, stony and red. Effects of N, K, Mg and Ca on number of leaves and biomass varied with soil type, particularly affecting stony and red soils. Some negative interactions between macro and micronutrients were observed for the complete treatment. Nutrient addition study field experiments in Gurùè during the 2016 rainy season have recently been harvested, with data analysis and determination of implications pending. Lime requirement studies addressed low pH, Ca and Mg availability, and Al toxicity. In Uganda, this showed that black soil is not significantly affected by pH related limitations, excessive Al or low P availability. However, red soils (pH 5.02, CEC 12.3) require more lime [Ca(OH)₂] (11.3T/ha) than stony soils (8.0T/ha) to raise pH to 6.5. In Mozambique, liming material had an additive effect with inorganic fertilizer and increased bean yield.

Researcher-managed field experiments in Masaka and Rakai produced specific recommendations of N, P and chicken manure for black, stony, and red soils. Researcher managed field experiments in Gurùè during the 2015 dry season in lowland fields indicated that N, P and K are the most limiting nutrients for

beans in paddy rice fields. In Gurùè, field experiments from the 2016 rainy season have recently been harvested, with data analysis and determination of implications pending. These results will guide treatment design of field experiments in Gurùè during the 2017 rainy season and 2017 dry season.

Two multistakeholder innovation platforms (IPs) have been established in Masaka and Rakai districts with project assistance. Members across the value chain share interests, concerns and strategies to address bean productivity and marketing constraints. In season 2016A, IP members in Masaka hosted 18 field trials to demonstrate improved management practices and technologies (MPTs) for bean production. These trials are currently being harvested, with data analysis and determination of implications pending. Additional field trials will be conducted in Masaka and Rakai during 2016B. In Gurùè, field experiments in early 2017 will serve as the basis for farmer field days to stimulate widespread interest through direct observation and comparison of site-specific MPT. These activities will engage producers and other stakeholders in social learning, stimulate interest among community members in the demonstrations and trials, and stimulate widespread use of MPT that are proven successful in local conditions.

This project team is developing aids (methods and procedures) that will enable smallholder producers with varying levels of education to better diagnose soil and other production constraints, and make improved site-specific crop system management decisions that contribute to higher bean productivity and improvements in soil fertility. These improved crop management systems cover soil characteristics and associated nutrient deficiencies, field preparation and measurement, seed selection, plant spacing, application of organic and inorganic fertilizers, weeding, post-harvest handling, and farm business economic analysis. We have field tested video animations, in both Uganda and Mozambique, delivered via smartphones as one innovative communication approach. We are developing a dissemination strategy that integrates the use of radio, animations 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.

II. Project Activities for the Workplan Period (October 1, 2016 – September 29, 2017)

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

Approaches and Methods

In Masaka and Rakai districts in Uganda, beans are planted in both rainy seasons. In Mozambique's Gurùè district, beans are planted in the single rainy season and, in communities with paddy rice fields, in the subsequent dry season. Our interviews and interactions with smallholder farmers in Uganda and Mozambique have revealed a variety of management practices and technologies (MPTs) used to maintain or increase bean productivity. There is significant variation by location regarding type and extent of use - reflecting awareness, availability, access and affordability. Our baseline farming system and socioeconomic surveys have provided detailed profiles of farmers' acreage and number of fields, practices of field selection and preparation, crop and variety selection, procurement of seeds, planting methods and spacing, use of various types of inputs (manure, inorganic fertilizers, foliar sprays, pesticides, herbicides), intercropping and rotation patterns, weeding, burning or incorporating crop

residues in soil, mounding ridges, mulching, and fallow. Understanding methods and criteria of problem identification and management practices currently utilized by farmers is important to our study. These findings have guided the research team in its observations and learning how farmers use existing knowledge to help determine crop system needs and to improve farming conditions.

Our project's field experiments and community-based field trials being conducted in Masaka and Rakai and Gurùè have demonstrated the key management practices and amendments specific to soil type that can improve soil fertility and help farmers significantly increase their bean crop yield. Assessment of access to required inputs and labor, combined with detailed analysis of costs and profits, will provide farmers with the basis for determining which improved management practices and technologies are appropriate for their farming system and goals. While individual and household resource endowments significantly shape farmers' decisions, the context in which alternative farming practices are learned and evaluated is fundamentally social in nature. Learning and decision making are influenced by discussion with group members, peers and other key stakeholders. Social learning will be especially important in horizontal (farmer-to-farmer) dissemination of information about new management practices and technologies (MPTs), both within a community that is participating in project activities and potentially have spillover effects to neighboring communities. Our approach involves engaging farmers' in design, implementation and assessment of on-farm trials in Uganda and in farmer field days in both Mozambique and Uganda (described under Objective 2 below). We will monitor involvement and obtain feedback from participants regarding their learning experience to guide our overall dissemination strategy.

Obj. 1a. Engage farmers in design, implementation and assessment of on-farm trials and through farmer field days (lead researchers: M. Tenywa, O. Semalulu, R. Miiro, R. Maria)

1a.1. Assist, monitor and assess on-farm trials with farmers' groups and field experiments (also: A. Lenssen, R. Yost)

1a.2. Document methods of learning and sharing information among farmers participating in on-farm trials and with other farmers, and participants in farmer field days (also: R. Mazur, E. Abbott)

Milestones

Oct. 2016 – Mar. 2017 and Apr. 2017 – Sept. 2017

1.1 - Reports on community learning through on-farm trials in Masaka & Rakai

1.2 - Reports on community learning through farmer field days in Gurùè

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

Making Collaborators:

Josephine Nampijja, GIS specialist, Makerere University, Uganda

Venâncio Salegua - Institute of Agriculture Research of Mozambique

Approaches and Methods

Information obtained during participatory rural appraisals, household interviews, student research projects, and interactions with farmers during on-farm trials and farmer field days has provided insights about key social, cultural, and economic factors which shape farmers' decision making about bean crop and soil fertility management. These include: information sources and credibility; assets, flows and constraints of key resources (land, labor, finance, etc.); gender roles; food security; market sales; and risk management strategies. Contextual factors of relevance include availability, accessibility and affordability of key resources; value chain development (input and output markets); group and network

size and strength; and collective action experience. Together, these help explain current knowledge, attitudes, practices; provide insight into which households are more able and likely to make fundamental changes and why; and inform our approaches to information dissemination, training, and support to stimulate and sustain widespread change.

Farmer groups and social networks play key roles in experimentation and adoption of new MPTs, involving changes in beliefs, knowledge, and behavior. Farmers observe, ask questions and seek answers, and make sense of each other's experiences and knowledge alongside scientific knowledge. This process of *sensemaking* enables people to collectively: devolve new 'mental maps;' set their own goals and outcomes; experiment, evaluate, collectively frame and legitimize the 'way forward;' develop a sense of identity, efficacy and pride; and encourage each other and persuade others to take similar actions.

Key dimensions of the institutional context play significant roles in farmers' interest in and ability to make investments for improved crop production and soil fertility. Uganda and Mozambique have weak and uneven extension systems and rural social and economic institutions, which limit widespread access to improved crop management information, quality inputs, and credit; Mozambique is particularly problematic in this regard. The existence and strength of farmers' groups and associations, typically the principal mechanisms to access training and other support, vary significantly. However, in the research focal regions in both countries, the situation is dynamic and indicators of improvement have been identified and are being followed up by the project team.

In Uganda, the development of two multistakeholder Innovation Platforms (IPs) in Masaka and Rakai districts indicates strong interest in coordination across the value chain from inputs to markets. The project research institutions are collaborating with private sector businesses (trade, microfinance, input supply, etc.) and an agricultural NGO which supports development of certified seeds (Community Enterprises Development Organization - CEDO). The IPs have established 18 farmer hosted field trials which exhibit 'best bet' management practices and technologies (MPTs) identified through project research as IPs transition toward collective market linkage development. Availability of markets for beans is creating demand for the recommended MPTs in order to meet market quality and quantity targets. Good platform leadership and commitment by all actors underpins the significant progress achieved to date. The IPs currently have more than 400 active members.

Farmer groups in the IPs in Masaka and Rakai participate in on-farm trials that test and demonstrate the impact of variations in recommended improved management practices and technologies (MPTs) for bean production. These on-farm trials enable us to confirm nutrient limitations on farmers' fields and improved systems that address the most critical limiting soil nutrients and management practices. These activities engage farmers in social learning, stimulate interest among other community members in the trials and demonstrations, and are already contributing to adoption of proven MPTs.

In Mozambique, an array of cash crops have been introduced or efforts intensified in the past decade by private sector foreign investors, NGOs and international research organizations which provide training, seed and other inputs, and marketing (including exports) – for soybean, pigeon pea, sunflower, pineapple, cotton, and tobacco. This 'support system' has significant implications for farmers' decisions to prioritize cultivation of specific crops for income. In contrast, common bean production and sales have been primarily driven by domestic market actors. Initiatives by Maputo-based 'market women' during the past five years have helped increase market prices for common beans. Efforts to promote development along the value chain for several key crops valued for food security and income, including common beans, have been recently initiated in Mozambique through several development projects and programs.

- IITA (with CIAT, ICRISAT and IIAM) operates the SEMEAR program (Improved Seeds for Better Agriculture, 2015-2019) that 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.
- CLUSA (NCBA CLUSA) operates a project on 'Conservation Agriculture and Climate Change Resilience Farming Techniques and Technology for Food Security' in and around Gurúè.
- FAO's Millennium Development Goals program is working in Gurúè district, including our research areas of Tetete and Mepuagúua, on seed production, farmer field schools, demonstration plots, home gardening and nutrition, poultry vaccination against Newcastle, and improved granaries.
- TechnoServe is providing assistance to the COPAZA (Production and Commercialization of Soy) project in Gurúè to improve the quantity and quality of soybean seed.

Project team members have recently held initial discussions with IITA, CLUSA and FAO in Mozambique to explore possible bases for collaboration through sharing results of research, dissemination of information about recommended management practices and technologies, etc.

Obj. 2a. Characterize resources and actions required for increasing bean crop productivity and marketing, and improving soil fertility (lead researchers: R. Miiro, V. Salegua, S. Mocumbe, R. Mazur, E. Abbott, E. Luvaga)

- 2a.1. Identify and quantify resources and actions required for increasing productivity and marketing, and improving soil fertility
- 2a.2. Document farmers actions to invest in and adopt (or intentions to do so) new management practices and technologies

Milestones

Oct. 2016 - Mar. 2017 and Apr. 2017 – Sept. 2017

- 2.1 – Reports on activities of members of multistakeholder innovation platforms and successes in promoting improved bean crop management practices, investments and marketing
- 2.2 – Reports on farmers' investments in and adoption of management practices and technologies to increase bean crop productivity and marketing, and improve soil fertility

Obj. 2b. Refine models of farmer decision making and identify recommendations for training and support to increase bean crop productivity and marketing, and to improve soil fertility (lead researchers: R. Mazur, R. Miiro, V. Salegua, E. Luvaga, E. Abbott)

- 2b.1. Analyze data from farmer interviews to model farmers' decision making
- 2b.2. Identify specific information and knowledge gaps to be addressed through training

Milestones

Apr. 2017 – Sept. 2017

- 2.3 – Updated models of farmer decision making vis. mgmt. practices, investments and marketing
- 2.4 – Recommendations for training and support for bean production and soil fertility management

Objective 3: Develop and Validate Diagnostic and Decision Support Aids

Collaborators:

Charles Kizza Luswata, soils lab senior technician, Makerere University, Uganda
Josephine Nampijja, GIS specialist, Makerere University, Uganda
Stanley Nkalubo, bean breeder, NaCRRI, Uganda

Approaches and Methods

To improve bean crop and soil management decision making, diagnostic and decision support aids (DDSAs) are being developed with and for farmers who have varying levels of education. These aids are based upon field-observable soil classification characteristics in diverse agroecologies in Masaka and Rakai districts in Uganda and Gurúè district in Mozambique. We are utilizing farmer experience, local and indigenous knowledge and soil classification systems, and input from soil scientists and crop systems agronomists, drawing from results obtained from field experiments and trials in our project. We also access the global knowledge base of appropriate practices and technologies, soil and cropping system management strategies and options appropriate for various smallholder farm systems. DDSAs enable farmers to compare stages and outcomes, using readily observable characteristics, based on conventional and improved management practices and technologies. The method of their introduction and context of their use will provide farmers with the basis for assessing benefits and costs, and weighing 'trade-offs' among alternatives. The development of DDSAs is being done using photographs from the nutrient omission and addition studies, scientist-managed field experiments, and productive innovative farmer fields that document differences in bean plant growth and development, bean leaf health, and subsequent bean yields.

In Uganda, shortened or more typically non-existent fallow periods, lack of fertilizer inputs, reduced soil organic matter concentration, and erosion from water have resulted in stagnant or decreased bean yields. The soil survey conducted in Masaka and Rakai districts in January 2014 and replicated field research conducted in Masaka in 2014-2016 documented that Liddugavu (black) soils generally had adequate levels of nutrients, and rooting depth generally was not constrained by excessively low pH or Al^{+3} concentrations. Results from our soil survey documented that the Limyufumyufu (red) soils were strongly acidic in the 15-30 cm depth, while available P, K, Ca, Mg, S, and Zn likely were limiting bean growth, and this was confirmed with scientist-managed field research in Masaka over three rainy seasons. Additionally, Al^{+3} levels were often significant in red soil, further constraining potential root growth for water and nutrient extraction; improved systems that included the addition of limestone proved highly effective, doubling bean yields. Research studies documented that addition of fertilizer P, K, Ca, Mg, S, and Zn improved bean yield on black soil similarly to addition of chicken manure with synthetic N and P fertilizers.

Farmer-assisted on-farm field trials were hosted at 18 sites in Masaka in the 2016A rainy season. The four treatments included N and P fertilizer, chicken manure, N and P fertilizer with chicken manure, and an untreated control. The sites used included four black, four red, and four stony (Luyinjayinja) soils. Soils and chicken manure were sampled for nutrient availabilities prior to treatment initiation. All beans were planted in rows 50cm apart with two seeds at 10cm within-row spacing. Bean varieties were chosen by farmers and included NABE 14 and NABE 17. Visual assessments by farmers and scientists indicated that the combination of N and P fertilizer with chicken manure provided superior bean growth and vigor compared to the other three treatments on 11 of 12 farms for which complete data are being collected. On one farm only, beans in the manure only treatment were not different from the N and P plus chicken manure treatment. At harvest, pod harvest index, pod density, seed per pod, individual seed weight, and total seed yield will be determined. Economic analyses will be conducted on the trial plots using costs obtained from farmers for seed, fertilizers and chicken manure, pest management, and

labor. Farmers consistently mentioned that planting in rows initially required more time per unit area compared to the time required to scatter plant. Some acknowledged that with experience the time differential is reduced or eliminated, especially since row planting reduces weeding time. All farmers reported that row planting allows for superior weed, pest and disease management with far less time and effort required.

In the coming seasons, on-farm trials and demonstrations will continue in Masaka. Six farms will include comparisons of banded vs. broadcast N-P-chicken manure. An additional six farmer groups in Masaka and 12 farmer groups in Rakai will compare the four treatments used in 2016, N and P fertilizer, chicken manure, and N and P fertilizer with chicken manure, and an untreated control. Data collection will include yield components (pods/m², seed/pod, seed weight, pod harvest index); analysis of variance, regression techniques, and economic analyses will be used to compare soil management techniques.

Yet to be determined is exactly how much lime is required to moderate the effects of low pH on red soil and the profitability of lime addition. The application of P, K and 295 kg/ha limestone more than doubled bean yield in the scientist-managed field research compared to the management system used by farmers in Masaka. Addition of N and P with chicken manure also improved bean yield on red soil. However, in the long term, chicken manure will likely increase soil acidification. At current prices, a large addition of limestone to red soil in Uganda is not profitable. In the U.S., federal farm programs subsidized limestone additions to soil for several decades. Perhaps this will be necessary in Uganda and elsewhere in sub-Saharan Africa for long term sustainability of crop production on red soils.

In Gurúè, visual observations of the nutrient omission experiment and the measured results indicate that rainy season bean growth on upland soils is responding to both N and P. These are the most costly of the nutrients when added as purchased fertilizer. Therefore, means to provide both N and P to local farmers for the extensive upland soils using low cost systems they can manage are being explored. The inclusion and expansion of the local practice of a pigeon pea rotation in bean production systems may be one way to add biological nitrogen fixation inputs of N into otherwise N limited bean production. This study was initiated in 2016 with pigeon pea preceding bean to provide increased N input.

In the Tetete and Mepuagúua administrative posts in Gurúè, replicated studies were conducted with two bean varieties comparing N, P, K, Ca, Mg, S, and Zn. Harvests are being completed in June 2016. Analysis of soil samples obtained from farmers in Gurúè will yield similarly useful results and provide insights regarding nutrient limitations in bean productivity and yield enhancement by fertilizer additions, resulting in management practices and technologies (MPTs) for improved bean production. Red soils in Gurúè are highly acidic. Farmers currently do not plant beans on them because beans do not grow well using conventional farmer production practices. The incubation study established that 2.3T/ha of locally available limestone is needed to ameliorate soil pH from initial level of 4.6 to an adequate level for bean production. In the 2017 rainy season, experiments will be conducted with beans on these soils comparing the effects of limestone, rock P, and fertilizer additions. In another study, the rate of limestone, with and without fertilizer blend addition, will be tested on a red soil site. In Tetete, bean production with blended fertilizer addition rates will be tested.

In Uganda, our field experiments and on-farm trials have been demonstrating improved management practices and technologies (MPTs) that have tangible benefits in terms of increased bean production. They are also feasible in terms of adoption by farmers. These MPTs that together more than double bean yield are: use of certified seed; planting in rows appropriately spaced apart and spacing within rows to achieve optimal stand density; addition of fertilizer (organic and inorganic) to provide key limiting nutrients; banded vs. broadcast nutrient application; and timely weeding. Recommended fertilizer amounts differ according to soil type. We have also determined that farmers will benefit from developing relatively accurate estimates of field size (area) where beans will be planted in order to

correctly calculate the amount of quality seed needed and to apply fertilizers at the optimal rate; relatively simple methods of estimating area are being devised. These MPTs serve as the bases for initial DDSAs. Farmers will be interviewed after each cropping cycle to determine the impact of using the DDSAs.

Obj. 3a. Determine Solutions to Soil Fertility and Other Bean Production Constraints

(lead researchers: M. Tenywa, O. Semalulu, R. Maria, R. Yost, A. Lenssen)

3a.1. Conduct on-farm trials of bean crop management systems

3a.2. Analyze results and recommended solutions

Milestones

Oct. 2016 – Mar. 2017 and Apr. 2017 – Sept. 2017

3.1 – Updated reports for on-farm trials of bean crop management systems

3.2 – Updated analyses and recommendations for bean crop management systems

Obj. 3b. Develop Diagnostic Methods and Aids

(lead researchers: M. Tenywa, O. Semalulu, R. Maria, R. Yost, A. Lenssen)

3b.1. Engage farmers in a participatory assessment of all diagnostic and decision support aids

3b.2. Finalize all diagnostic and decision support aids

Milestones

Oct. 2016 - Mar. 2017 and Apr. 2017 – Sept. 2017

3.3 - Participatory assessment of all diagnostic and decision support aids

Apr. 2017 – Sept. 2017

3.4 – Refined and finalized diagnostic and decision support aids

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

Collaborators:

Freddie Kabango, Masaka District Agricultural Officer, Uganda

Charles Katabalwa – Community Enterprises Development Organization (CEDO), Rakai, Uganda

José Eufertes - Gurúè District Agricultural Extension Officer, Mozambique

Venâncio Salegua - Institute of Agriculture Research of Mozambique

Approaches and Methods

To realize our goals, the team is working with existing institutions and organizations to identify and develop messages to provide farmers with appropriate and reliable information to make critical decisions about beans and soil fertility, and pathways that can provide relevant information in an effective, efficient, and sustainable manner. In Uganda, groups and Innovation Platforms (IPs) are especially important sources of valued information, along with fellow farmers and extension. Local and national radio programs also are used by some farmers. In Mozambique, fellow farmers are a major source of information, and there is much less access through groups, contact with extension agents, or radio. Development projects led by organizations such as IITA, TechnoServe and CLUSA offer information and advice through farmer groups, demonstration plots and on-farm trials. In addition, our project team is working through the recently established Center for Interdisciplinary Studies and Development (CEID) in Gurúè to coordinate and facilitate information gathering and dissemination activities.

The project is engaging producers and other stakeholders, women and men, in testing innovative communication approaches and technologies for learning and sharing information about new management practices and technologies for increasing bean yields and improving soil fertility. Given limited extension system resources in Uganda and Mozambique, methods that enhance the ability of extension services (public, NGOs, and private sector) to deliver messages as well as local peer-to-peer dissemination and learning (field days, exchange visits, local community based organizations, farmer associations) will be important. To ensure that those with low literacy skills can benefit, especially women, our communication approaches and technologies utilize visual aids (print materials and animated videos developed through collaboration with Scientific Animations Without Borders - SAWBO), and radio messages in local languages.

In 2015, to test the potential of video animations delivered through smartphones, we developed and field-tested an animation addressing a widespread problem (weevil damage) by utilizing training materials developed during the previous Pulses CRSP project in Uganda's Kamuli District regarding anaerobic bean grain and seed storage using jerry cans and the triple bag system. Sostino Mocumbe's field research with 314 farmers in Mozambique confirmed that farmers learn just as effectively from animated videos displayed on smartphones as they did from extension-led on demonstrations. Follow-up interviews at six months and one year later indicated that farmers still clearly remember the steps involved in the process. Additional video animations focusing on the project's primary research-based recommendations concerning bean production will be produced and field tested during 2016-2017. To test and disseminate the video animations and other materials, the project will partner with existing organizations that already are using tablets, smartphones, or other devices to reach farmers. CEDO in Uganda, for example, has provided smartphones to 62 of its village enterprise agents (VEAs). Our new animation video will be provided to each VEA so that, in turn, each will show the video to their member groups (up to 215 farmers each). Similar use of partner and group-based dissemination systems may be tested in projects in Mozambique led by organizations such as IITA, TechnoServe and CLUSA, with which preliminary discussions were initiated during June 2016.

Communication messages work best as part of a system that reinforces the messages and provides needed logistical support. For example, to grow beans effectively using the project's recommendations, farmers need access to certified seed and fertilizer. They also need to be assured that markets exist for their beans. By partnering with existing Innovation Platforms in Uganda and organizations leading development projects in Mozambique, farmers will have access to seed, fertilizer, credit and marketing services needed to take advantage of the communication messages. In addition to learning about recommendations through the animated videos, the Innovation Platforms and partner organizations also sponsor on-farm trials or demonstration plots where farmers can see and compare results of following the recommendations directly. Interviews suggest that the combination of awareness-raising by video animations, hand-on demonstrations in the field, and access to supporting services will be effective in persuading a number of farmers to adopt the recommendations. Video animations are most effective when the communication problem involves a process – showing specific steps to take. Printed materials to compare costs and benefits of using the recommendations, and to provide support for other crop system management diagnostic and decision support aids are being developed by project researchers working in a participatory manner with farmers and other stakeholders. In each case, prototype materials will be developed, pre-tested with farmers, revised as appropriate, and prepared for initial dissemination. Optimum levels of training and follow-up support will be determined to identify efficient use of resources (extension personnel, material, financial); this will enable development projects to utilize our research results for scaling up and achieving widespread impact. Emphasis in each country will be placed on utilizing communication approaches/technologies that maximize available resources in a sustainable manner.

Obj. 4a. Devise Evidence-Based Information Dissemination System

(lead researchers: E. Abbott, J. Bello-Bravo, B. Pittendrigh, R. Miiro, S. Mocumbe)

4a.1. Analyze results of field tests of new video animations for Uganda and Mozambique

4a.2. Develop new messages based on soil tests and research results and align with appropriate media

Milestones

Oct. 2016 - Mar. 2017 and Apr. 2017 – Sept. 2017

4.1 – Analysis of dissemination system and effectiveness of new video animations

4.2 – Message and media for dissemination of additional diagnostic and decision support aids

Obj. 4b. Refine Content and Information Dissemination System

(lead researchers: E. Abbott, J. Bello-Bravo, B. Pittendrigh, R. Miiro, S. Mocumbe)

4b.1. Engage farmers and other key stakeholders in a participatory process of assessing the messages and media for all diagnostic and decision support aids

4b.2. Develop strategy for effective dissemination of all diagnostic and decision support aids utilizing existing groups, organizations and communication systems

Milestones

Apr. 2017 – Sept. 2017

4.3 – Participatory assessment of messages and media for all diagnostic and decision support aids

4.4 – Strategy for dissemination of all diagnostic and decision support aids

Objective 5: Enhance Institutional Research Capacity Relative to Grain Legumes

Approaches and Methods

A key element in building institutional research capacity to increase effectiveness and sustainability of agricultural research institutions that serve the bean sector in Uganda and Mozambique is to provide graduate student training. Our project has supported training and research of graduate students in academic programs in U.S. institutions (three completed, two continuing) and in host countries (three nearing completion). Specific research foci and affiliations of current students follow:

- one Ph.D. student from Uganda is studying Sustainable Agriculture and Sociology at Iowa State University, will conduct research on farmers' perceptions, knowledge and socioeconomic factors influencing decision making for improved soil fertility management
- one M.S. student from Mozambique is studying soils/crops at the University of Hawaii and conducting research on alternative management practices for improving bean production

Three graduate students who have received training at Makerere University and are near completion in M.S. programs that contribute directly to project objectives:

- one student studied soils/crops and conducted research on limiting nutrients and lime requirements for bean production
- one student studied soils/crops at Makerere University and conducted research on evaluation of bean production under different soil fertility management options in Masaka, Uganda
- one student studied agricultural extension and innovation at Makerere University and is conducting research on gender dimensions of bean farmers' decision making for bean production and soil fertility management in Masaka and Rakai Districts, Uganda

Short term training is planned for 2016-2017, in which Makerere University staff, Ph.D. and M.S. students, and undergraduate students will learn how Innovation Platforms work. They will also participate in responding to farmers' technical questions using an ICT based response mobile phone operated system. In addition, a Ph.D. student supervised by Richard Miiro has joined the field research team, under private funding; he is studying 'The Effect of Smallholder Farmers' Engagement in Agricultural Innovation Platforms on Their Innovation Capacity.'

Three types of short-term training sessions are planned to enhance the understanding and skills of important bean production value chain stakeholders in Uganda: (1) equip agro-input dealers with skills for appropriate fertilizer application in quantity, quality and method of application; (2) empower frontline field extension workers with skills for appropriate soil fertility problem diagnosis; and (3) empower Innovation Platform leaders and farmer group leaders to use sound governance and leadership skills to keep a strong farmer base with capacity to absorb the technologies developed in the project. Details are provided in Appendix 1 below.

In Mozambique, IIAM is planning a workshop to share research findings with farming communities, agricultural development organizations and policy makers. This will cover information and analyses gained through the participatory rural appraisal, baseline household survey, and biophysical and agronomic studies. Details are provided in Appendix 1 below.

Milestones

Oct. 2016 - Mar. 2017 and Apr. 2017 – Sept. 2017

5.1 - Students continue/complete graduate study programs

5.2 - Short-term training of partners and communities

III. Contribution of Project to USAID Feed the Future Performance Indicators

(Performance Indicators / Targets Spreadsheet for FY 2015, FY 2016, FY 2017 = attached)

IV. Outputs

Project activities are producing the following outputs:

- Characterization of smallholder bean farmers' agricultural motivations, current knowledge and practices, problem diagnoses, and livelihood and risk management strategies
- Models of farmer decision making strategies that reflect influences of social, cultural, economic, institutional and contextual factors are developed and refined
- Innovative diagnostic aids using observable characteristics that enable farmers to make site-specific management decisions are developed and validated
- Process for identifying alternative strategies and management practices for improving cropping system productivity and soil fertility is developed
- Materials to compare costs and benefits of using the recommendations, and to provide support for other crop system management diagnostic and decision support aids, are being developed
- Effective and efficient methods and media for information dissemination to intermediate and end users are developed and assessed
- Capacity strengthening through applied research-based training is conducted
- Research results published in peer-reviewed literature and at the Legume Innovation Lab website hosted by the Management Office at Michigan State University

The project's *Impact Pathway Worksheet* provides details of outputs, uses, and steps to achieving our vision of success.

V. Engagement of USAID Field Missions

We will continue to maintain and enhance communication with USAID Mission staff in Uganda and Mozambique. In 2016 in Mozambique, project PIs Russ Yost (University of Hawaii) and Ricardo Maria (IIAM) met with USAID staff members Paula Pimentel (Senior Agricultural Research & Technology Transfer Advisor), Karelyn Cruz (Agricultural Project Officer), and Surrendra Bhatta (Feed the Future Coordinator, Agriculture, Trade, and Business Office) in Maputo on February. PIs Rob Mazur, Andy Lenssen and Ricardo Maria – accompanied by Cynthia Donovan (Legume Innovation Lab Associate Director) met with Isabel Alves, Paula Pimentel and Ken Hasson (Agricultural Development Officer) on March 8. These meetings provided great opportunities to discuss project objectives and activities in the context of recent and current USAID programs in Mozambique, and identify appropriate organizations and individuals to contact to explore possible bases for collaboration.

In Uganda, on June 2, 2016, project researchers Rob Mazur, Eric Abbott, Andy Lenssen, Ebby Luvaga (all ISU), Moses Tenywa, Richard Miiro (both Makerere University), Onesmus Semalulu (NARL), and Sostino Mocumbe (IIAM) met with USAID's Andrew McCown (Agricultural Officer), Apell Oceng (Program Management Specialist for Policy) and Simon Byabagambi (Agronomist and Program Management Specialist) in Kampala. Ugandan Co-PIs maintain contact with Robert Anyang (Deputy Chief of Party of the USAID Uganda Feed the Future 'Commodity Production and Marketing' project) and William Luyinda (Program Manager) and Mary Arach of AKORION (ICT for Agriculture). Following our discussion in 2015 with Mark Tamale, General Manager of Buddu Broadcasting Services in Masaka, we met with Robert Kayabula (marketing) and Godfrey Dixon (presenter) on May 25, 2016. These meetings established the basis for radio broadcasts in Masaka and Rakai concerning project research results and crop system recommendations.

We will be pleased to respond when the Missions express interest in an Associate Award that would enable us to provide technical assistance and access to grain legume technologies.

VI. Partnering and Networking Activities

In Masaka and Rakai, multistakeholder Innovation Platforms (IPs) are consortia of partners - private sector, researchers, extension workers, district local government staff, and NGOs. The Bean Program of the National Crops Resources Research Institute (NaCRRI), through its Pre-cooked Beans Project with CIAT, has joined the bean Innovation Platform. The African Forum for Agricultural Advisory Services (AFAAS), and the Ugandan equivalent (UFAAS) have also joined the platform. They will contribute resources for promoting relevant technologies as our project team addresses soil improvement issues and market opportunities. They will also be part of the collective learning process, informing how to scale up the use of IPs as farmer learning centers alongside value chain actors. Project activities in Uganda, particularly through the IPs, have stimulated efforts to involve pathologists to address potential bean seed and soil borne diseases. Discussions are underway with the leadership of the National Agricultural Research Organization in Uganda to become more involved in the platforms and offer more technical and resource support. The AFAAS and UFAAS network will facilitate sub-regional connections and information sharing.

The IPs and the forms of technology dissemination such as using animated videos - are attracting other partners, such as the m-Omulimisa meaning 'mobile extensionist.' The m-Omulimisa proprietor

has demonstrated the use of mobile phones to access agricultural information. Discussions are underway with the International Institute of Tropical Agriculture (IITA) to scale up the use of IPs as a form of technology dissemination, extension advice and innovative marketing. The project IPs in Uganda will serve as one of the learning centers. Under this collaboration, several disciplines in the College of Agricultural and Environmental Sciences, Makerere University will be involved. They will contribute their expertise to solving farmers' bean production problems through the mobile extension system, while their understanding of IP functionality will also be enhanced. This is expected to contribute to University curriculum changes including understanding the practical relevance of IPs during student training and research.

Co-PI Ricardo Maria and Sostino Mocumbe (IIAM) are following up initial meetings held by research team members with: (1) IITA (Dr. Steve Boahen - Regional Coordinator; Carlos Malita - SEMEAR project manager; and Ana Covinhas - Communications officer); (2) NCBA CLUSA (Dr. Carlos Sanchez - Regional Director); and (3) FAO (Mr. Omar - representative in Gurúè). Communication with Rowland Chirwa (CIAT/PABRA) focuses on research objectives and activities, and identification of potential bases for collaboration vis. seed varieties. We continue to learn about relevant existing and emerging conservation agriculture approaches and technologies (e.g., how upland farming practices can be improved for reducing erosion and quality of lowlands where rice and bean are grown). We will continue to network with PABRA, the AGRA Soil Health Program and CABI (Ricardo Maria is involved with both programs), McKnight Foundation which has programs with an integrated multi-functional intensification emphasis, Africa RISING which focuses on maize-legume based systems in the Eastern Highland of Africa, the Bill and Melinda Gates Foundation, and IFDC.

Project researchers will continue to build collaborative relationships with two African based networks under PABRA (the Pan-African Bean Research Alliance): the Eastern and Central Africa Bean Research Network (ECABREN) and the Southern Africa Bean Research Network (SABREN). The project team, particularly collaborating research institutions in Uganda and Mozambique, will identify partnering and networking activities to ensure that appropriate public and private sector institutions can engage in follow-up adaptive research and field validation, in addition to technology transfer, in FTF countries and regions so that research outputs are disseminated on a wide scale for quantifiable developmental impact.

VII. Leveraged Resources

The project team is exploring opportunities to collaborate and coordinate research efforts with CGIAR scientists (IITA, CIAT and ICRISAT in the USAID-funded SEMEAR project in Mozambique), the AGRA Soil Health Program, McKnight Foundation, Africa RISING, the Bill and Melinda Gates Foundation, and IFDC. We are identifying how such opportunities will complement and coordinate with planned activities described in the Workplan of this Legume Innovation Lab project.

VIII. Timeline for Achievement of Milestones of Technical Progress

(Milestones of Progress = attached)

Appendix 1: Workplan for Training/Capacity Strengthening - FY 2017

Degree Training

Trainee #1

First and Other Given Names: Naboth
Last Name: 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
If enrolled at a US university, will Trainee be a 'Participant Trainee' as defined by USAID? No
Host Country Institution to Benefit 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
Projected Completion Date: May 2019
Training status: (active, completed, pending, discontinued or delayed): Active
Type of USG Support (full, partial or indirect) for training activity: Partial

Trainee #2

First and Other Given Names: Prossy
Last Name: Kyomuhendo
Citizenship: Uganda
Gender: Female
Training Institution: Makerere University
Supervising Legume Innovation Lab PI: Moses Tenywa
Degree Program for training: M.S.
Program Areas or Discipline: Soil Science and Crop Production
If enrolled at a US university, will Trainee be a 'Participant Trainee' as defined by USAID?
Host Country Institution to Benefit from Training: Makerere University
Thesis Title/Research Area: Limiting Nutrients and Lime Requirements for Bean Production
Start Date: January 2014
Projected Completion Date: January 2017
Training status: (active, completed, pending, discontinued or delayed): Active
Type of USG Support (full, partial or indirect) for training activity: Partial

Trainee #3

First and Other Given Names: Stewart
Last Name: Kyebogola
Citizenship: Uganda
Gender: Male
Training institution: Makerere University
Supervising Legume Innovation Lab PI: Onesimus Semalulu
Degree Program for training: M.S.
Program Areas or Discipline: Soil Science and Crop Production
If enrolled at a US university, will Trainee be a 'Participant Trainee' as defined by USAID?
Host Country Institution to Benefit from Training: National Agricultural Research Laboratories
Thesis Title/Research Area: Effect of integrating organic with inorganic fertilizers on bean yield on three contrasting soils of Masaka district
Start Date: July 2014

Projected Completion Date: January 2017
Training status: (active, completed, pending, discontinued or delayed): Active
Type of USG Support (full, partial or indirect): Partial

Trainee #4

First and Other Given Names: Jafali
Last Name: Matege
Citizenship: Uganda
Gender: Male
University to provide training: Makerere University
Supervising Legume Innovation Lab PI: Richard Miiro
Degree Program for training: M.S.
Program Areas or Discipline: Agricultural Extension Education
If enrolled at a US university, will Trainee be a 'Participant Trainee' as defined by USAID?
Host Country Institution to Benefit from Training: Makerere University
Thesis Title/Research Area: Gender Dimensions of Bean Farmers' Decision Making for Soil Fertility Management in Masaka and Rakai Districts, Uganda
Start Date: July 2014
Projected Completion Date: August 2017
Training status: (active, completed, pending, discontinued or delayed): Active
Type of USG Support (full, partial or indirect): Partial

Trainee #5

First and Other Given Names: António José
Last Name: Rocha
Citizenship: Mozambique
Gender: Male
Training institution: University of Hawaii - Manoa
Supervising Legume Innovation Lab PI: Russell Yost
Degree Program for training: M.S.
Program Areas or Discipline: Agronomy and Tropical Soils
If enrolled at a US university, will Trainee be a 'Participant Trainee' as defined by USAID? Yes
Host Country Institution to Benefit 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
Type of USG Support (full, partial or indirect) for training activity: Full

Short-term Training:

Name of training program: Agro-Input Dealer Training
Type of training: Fertilizer application
Description of training activity: Equip agro-input dealers with skills for appropriate fertilizer application in quantity, quality and method of application
Location: Kampala
Duration: 3 days
When will it occur? Jan 2017
Participants/Beneficiaries of Training Activity: 30

Anticipated numbers of Beneficiaries (male and female): 15 M and 15F
PI/Collaborator responsible for this training activity: Dr. O. Semalulu
Approximate budget allocation from USAID funds for training: US\$ 6000
List other funding sources that will be sought (if any): Private sector
Training justification: Meets project goal

Name of training program: Field Extension Workers Training
Type of training: Soil fertility problem diagnosis
Description of training activity: Empower frontline field extension workers with skills for appropriate soil fertility problem diagnosis
Location: Masaka
Duration: 3 days
When will it occur? Jan 2017
Participants/Beneficiaries of Training Activity: 30
Anticipated numbers of Beneficiaries (male and female): 15 M and 15F
PI/Collaborator responsible for this training activity: Dr. O. Semalulu
Approximate budget allocation from USAID funds for training: US\$ 5000
List other funding sources that will be sought (if any): n.a.
Training justification: Meets project goal

Name of training program: Innovation Platform Leadership and Group Management
Type of training: Training of farmer innovation platform leaders in leadership and group management skills in order to facilitate uptake of project practices and technologies
Description of training activity: Empower Innovation Platform leaders at the Apex and the farmer group leaders to use sound governance and leadership skills to keep a strong farmer base with capacity to absorb the technologies developed in the project
Location: Masaka & Rakai
Duration: 6 days, split into 3 offerings
When will it occur? March 2017
Participants/Beneficiaries of Training Activity: 45
Anticipated numbers of Beneficiaries (male and female): 25 M and 20 F
PI/Collaborator responsible for this training activity: Dr. R. Miiro
Approximate budget allocation from USAID funds for training: US\$ 8000
List other funding sources that will be sought (if any): n.a
Training justification: Meets project goal

Name of training program: Workshop for sharing research findings with communities, agriculture development organizations, and District Agricultural Department
Type of training: Soil research and participatory action research findings
Description of training activity: increase awareness of soil fertility problems, responses for integrated soil fertility management and challenges and opportunities for improving bean productivity in Gurùè
Location: Gurùè
Duration: 2 days
When will it occur? September 2017
Participants/Beneficiaries of Training Activity: 25
Anticipated numbers of Beneficiaries (male and female): 15 M and 10F
PI/Collaborator responsible for this training activity: Ricardo Maria and District Agricultural Department
Approximate budget allocation from USAID funds for training: US\$ 4000

List other funding sources that will be sought (if any): Optimizing Fertilizer Recommendation in Africa (OFRA).

Training justification: Meets project goal

Name of training program: Developing Soil Quality indicators and Decision Guides corresponding to soils and bean crop requirements

Type of training: Use innovative farmers to support clustering soils and developing decision guides

Description of training activity: Empower innovative farmers, field extension and researchers in identifying soil quality indicators and matching with crop requirements. The training will draw on generalized scientific soil classification and sharpen the focus to match local soil groupings.

Location: Gurùè

Duration: 6 days, including field and office activities

When will it occur? July 2017

Participants/Beneficiaries of Training Activity: 59

Anticipated numbers of Beneficiaries (male and female): 45 M and 14 F

PI/Collaborator responsible for this training activity: Ricardo Maria

Approximate budget allocation from USAID funds for training: US\$ 9000

List other funding sources that will be sought (if any): n.a.

Training justification: Meets project goal

Equipment (costing >\$5,000):

Specific Type of Equipment to be purchased:

Justification for equipment to achieve Workplan objectives:

Institution to benefit from equipment:

Institution to purchase equipment:

Amount budgeted for equipment item:

Appendix 2: Budget Narrative (SO2.1)

a. Personnel Cost

Salaries – (\$97,460) this includes: Graduate Research Assistant stipend and tuition at ISU, Hawaii, and Makerere; a software specialist at Hawaii; and technicians at NARL and IIAM.

Fringe Benefit – (\$13,709) institutional rates are applied at ISU and Hawaii; these vary according to personnel type.

b. Travel – (\$101,957) this includes: travel to Lead PI and U.S.-based Co-PIs to Uganda and Mozambique for field research and meetings; travel to the U.S. by Africa-based Co-PIs to collaborate on analyses and writing; and travel by the GRAs to Uganda and Mozambique for field research.

c. Equipment (\$5000 Plus) – N/A

d. Supplies – (\$51,044) this includes: research materials to conduct interviews and for communication and extension activities (ISU); research materials and analyses of soil and plant samples (Hawaii); field experiment inputs and supplies, soil analyses, farmer workshops and trainings, and use of communication media (Makerere, NARL, and IIAM); and fuel and maintenance for vehicle (IIAM).

e. Training

Degree – (\$7,303) this includes: tuition for the GRAs at ISU and Makerere (tuition at Hawaii is not charged to the grant, but covered by the institution).

Non-Degree – these costs are incorporated in the supplies budget for Makerere, NARL and IIAM.

f. Other – (\$9,349) this includes: phone calls and DHL (all institutions); dissemination workshop (Makerere)

g. Total Direct Cost – (\$280,822)

h. Indirect Cost - (\$50,201) institutional rates on applicable categories of expenditure are applied (26% at ISU, 24% at Hawaii, and 10% at Makerere, NARL and IIAM).

i. Indirect Cost on Subcontracts (First \$25000) – N/A

j. Total Indirect Cost – (\$50,201)

Total – (\$331,023)

Grand Total - \$331,023

Notes:

- The split in total direct costs is U.S. (16.05%) and HC institutions (83.95%)
- Breakdown in cost share contributions (in-kind & cash) by the U.S. (100% - \$25,245 by ISU and \$8,5889 by Hawaii) and Host Country institutions
- Total budgetary attribution to institutional capacity building (29.78%)

FY 2017 WORK PLAN

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

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:

1. Gelson Tembo, University of Zambia
2. Lawrence Mapemba, Lilongwe University of Agriculture and Natural Resources, Malawi
3. Fredy Kilima, Sokoine University of Agriculture, Tanzania
4. Allen Featherstone, Kansas State University
5. Kara Ross, Kansas State University

I. Project Problem Statement and Justification

Unlike maize, pulses are not traditional staples in Zambia, Malawi and Tanzania. The average annual per capita consumption of pulses between 2000 and 2011 in Tanzania, Malawi and Zambia is respectively 21.0 kg, 14.4 kg and 2.1 kg respectively. In terms of direction, the per capita consumption in Zambia is flat while Tanzania's is declining and Malawi's is increasing. It is important, however, to recognize that the foregoing represent averages across the country and food choices vary across ethnic and socio-economic lines. The market opportunities for grain legumes may differ from these average indicators in the focus countries.

The need to identify the potential demand profiles for grain legumes in the focus countries provide the justification for this research. The results would provide insights into how the legume industry in the different countries may be organized to improve smallholder producers' wellbeing. For example, by identifying consumer preferences for different types of legumes by specific socio-economic and demographic characteristics, it may be possible to develop well-structured value chains commencing from breeders through producers to distributors and retailers to maximize value addition at each of the stages. For example, information about consumer preferences may inform market segmentation and support a focus in the breeding programs being done by National Agricultural Research scientists and their international collaborators to increase payoff and impact. These focused breeding activities may facilitate the development of production clusters to serve specific markets on a national or regional basis, and in so doing, improve the market opportunities accessible to smallholder producers.

The project's fundamental problem is, thus, is to develop a new understanding of the forces and factors shaping and influencing consumers' food choice decisions and use this to facilitate improvements in legume value chains. We envisage this improvement to go from the breeder through the producer and the extension agent to the non-governmental organization working to enhance producers' lot and the industry association staff working to improve the wellbeing of industry members. The project has been structured to use both primary data to elicit information about consumer preferences about legumes and where they fit in food hierarchies as well as

secondary data collected by organizations such as the World Bank and national government agencies in the focus countries.

We see the empirical results from the research foundations insights into how industry stakeholders in the focus countries (private businesses, non-governmental organizations, producers, traders, processors, etc.) and public institutions (research institutes, universities, extension, government, etc.) may be engaged in a search for value creation and expansion opportunities as well as solutions to challenges preventing value chain effectiveness. We also plan to use the results from our analysis of industry capacity gaps to carefully develop and deliver outreach programs aimed at enhancing strategy development, management and decision-making. In the end, the project will provides innovative and unique pathways that bring smallholder producers and other stakeholders into specific alliances to help smallholder producers improve their economic wellbeing.

The project's geographic scope covers Zambia, Malawi and Tanzania; all Feed the Future focus countries. These countries reflect 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. The results from this research hopes to provide insights into legumes may be used to the principal objectives of the Feed the Future initiative – reducing poverty, increasing incomes and improving nutrition.

II. Project Activities for the Work plan Period (October 1, 2016 - September 30, 2017)

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

Five theses have been completed and seven more are under way and are expected to be completed this coming fiscal year. Studies completed so far have indicated that gravy quality and tradition/culture are important attributes for legume consumption across the three countries. Zambian consumers are more affected by price and size of the bean compared to Malawian and Tanzanian consumers. In Malawi, gravy quality, cooking time, grain size and tradition/culture influence consumption of the top four popular beans. Results from the Malawi survey also indicate that common beans may not be considered “poor man's meat” as households residing in high income areas consume more beans than households residing in low income areas. Results from the three surveys will be shared with our public and private institution partners to encourage their participation in developing outreach programs informing consumers about the multiple benefits of bean consumption and educating upstream chain actors on the consumer preferred bean characteristics.

In addition to these analyses, we are organizing a community outreach project – a bean recipe contest - to encourage consumers to develop innovative ways to consume beans as a main dish instead of a sauce or relish. This contest is focused on urban consumers in Malawi and will give us some practical insights into what factors influence consumers, at least urban Malawi consumers, to consume beans as a main dish. Outcomes of this objective will increase the consumption of beans in urban areas and improve market condition for producers and bean supply chain.

Collaborators

- Mr. Chance Kabeghe, IAPRI, Zambia
- Mr. Simon Mwale, CCARDESA, Botswana
- Dr. Jim Kelly, PI, SO1.A3 (MSU)
- Mr. Kennedy Muimui, ZARI, Zambia
- Dr. Eliud Birachi, CIAT
- Dr. Susan Nchimbi-Msola, Sokoine University of Agriculture
- Dr. Rowland Chirwa, CIAT Malawi
- Others in the CIAT/SABRN research community

Approaches and Methods

Objective 1 employed a survey method to collect consumer information and uses stated preference (Discrete Choice Experiment) method to elicit consumer preferences among alternative legume products in each country. We are analyzing the data using STATA® and standard econometric modeling. We will meet with our private and public institution partners in the respective countries in this fiscal year to share the results and develop strategies in delivering effective outreach in attempt to execute the recommendations from the Objective 1. Each country is planning a national conference and three regional meetings to disseminate the findings from the Objectives 1 and 2. These events will take place in the first half of the upcoming fiscal year. Malawi is hosting a bean recipe contest in Lilongwe between the end of September and the end of October. This event is being organized by the US PIs, Malawian PI and principal leaders of the legume industry in Malawi.

Period	Activity	Specific Responsibility
November 2016	Complete policy brief based on consumption report, distribute to collaborators, industry stakeholders, country USAID missions and policymakers for comment, finalization and rollout process discussion.	Research Team with each HC PI leading their country initiative
October 2016		US PIs and Malawi PI Leading
October 2016	Consumption report distributed to Legume Innovation Lab partners, regional CG partners, country USAID missions and country policy makers.	US PIs and HC PIs Leading
November-December 2016	Report rollout in each country to present lessons learned from Objective 1 and 2 with HC PIs coordinating with local agencies and partners to maximize rollout impact.	Research Team with each HC PI leading their country initiative
August 2017	Complete final policy briefs based on lessons learned from outreach programs and gaps identified in downstream activities.	US PIs and HC PIs Leading

Objective 2: Conduct situation analyses for legume production and marketing/distribution systems with a view to identifying the nature and extent of the gaps in their value chains.

Collaborators

- Mr. Gerald Mgaya, Managing Director, Tanmush, Tanzania
- Ms. Grace Mijiga Mhango, Vice President, Malawi Grain Traders and Processors Association
- Mr. Chance Kabeghe, IAPRI, Zambia
- Mr. Simon Mwale, CCARDESA, Botswana

Approaches and Methods

Objective 2 used secondary data to determine the situation of bean production in the focus countries and focus group interviews to assess gaps in the downstream segment of the legume industry. Econometric modelling and analyses were used to determine the production situation. These analyses were used as training opportunities for MS students in the HC countries who are working on the project as part of their degree completion requirements under HC PI supervision and mentorship.

There are two components to Objective 2: (1) Situation analyses of primary production; and (2) Situation analyses of downstream activities. The first component of Objective 2 has been completed with the help of our MS students in the respective HC institutions. The specific output of the reports describe and compare the state of bean/cowpea production in the selected countries to identify the different paths that may be used to improve performance in each country. Additionally, three MS theses on the subject coming from the host countries. HC PIs are overseeing students' research activities. With the delay in the completion of the Zambia situation analysis, this has pushed back the completion of the comparison report of the three countries. We anticipate the report of the country comparison situation analyses of primary production to be completed by the end of October 2016.

The second component of Objective 2 involves the situation analyses of downstream activities. These analyses will be conducted with secondary quantitative data from SABREN and primary qualitative data from focus group interviews conducted with industry stakeholders after the national and conference and regional meetings. The results and implications from the consumer study will help guide the assessment in downstream capabilities and reveal gaps in these activities and downstream relationships. Therefore, this second component of Objective 2 will be completed at the beginning of 2017. The results from the situational analyses and Objective 1 will inform the outreach programs planned for this fiscal year including the national conference and regional meetings in each of the three countries. Results from the second component of Objective 2 will be used in the development of outreach programs to address the gaps identified by the industry. The table below provides a schedule of activities planned for FY2017 in association with Objective 2.

Period	Activity	Specific Responsibility
October 2016	Complete country comparison situation analyses of primary production for the three focus countries.	US PIs and HC PIs Leading
March 2017	Complete a situation analyses of downstream activities and report on chain activities in the focus countries.	Research Team with each HC PI leading their country initiative

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.

Collaborators

- Local trade associations
- Government departments of agriculture and food

Approaches and Methods

HC PIs are on track in their recruitment of MS students. They have each recruited at least two MS students for FY2017 in line with the plan. Each HC PIs have recruited at least one graduate student for the Master of Agribusiness (MAB) program at Kansas State University.

The results from the first two objectives would provide information for developing effective curricula to address the capacity and knowledge gaps in the legume supply chain in the three focus countries. We will work closely with industry stakeholders using innovative engagement methods to identify their strategic management challenges and develop the appropriate curricula to address the identified gaps. We plan to employ multiple pedagogies in delivering the training and exercises that aim to improve skills and knowledge to enhance stakeholder capabilities. We also plan on using multiple delivery format to reach the most people in the legume industry in the three countries. To ensure sustainability of the training programs, we plan to train local stakeholders as trainers so that they can continue delivering the training programs after this project ends. Host country PIs have the responsibility to work with the industry, faculty and/or students to identify the knowledge and capacity gaps and publicize it with date, time and location.

Period	Activity	Specific Responsibility
October – November 2016	Begin planning for training workshops in each country in the FY2017. HC PIs will coordinate with local agencies to maximize participation in workshops.	Research Team
February - September 2017	Conduct a training workshop in each HC country.	US PIs and HC PIs Leading
October 2016 – September 2017	Work with local policymakers to undertake public education initiatives about the value for nitrification in their respective countries	HC PIs with US PIs support

III. Contribution of Project to USAID Feed the Future Performance Indicators

The close collaboration between the project and industry stakeholders will allow us to build the Feed the Future performance indicators into our engagements. For example, we expect the capacity building initiatives to contribute to productivity across the whole legume supply chain, from breeders to retailers. To this end, we envisage the project contributing to Indicator #1 (number of people in our degree training programs) and #2 (number of people in short-term training – our seminars, workshops and other engagement initiatives). Because our efforts will include helping the legume industry stakeholders enhance their management capability and decision-making skills, the project will also contribute to Indicator #4. We will endeavor to facilitate public-private partnerships – e.g., between NARS’ breeders and the industry in using our information to streamline product development and commercialization. Therefore, we see the project contributing to Indicator #5.

IV. Outputs

Three specific outputs will be delivered within this work plan period:

- A draft policy brief on how the results from the consumer research may be employed to facilitate public policy in support of the legume industry in the focus countries. It will be circulated for discussion among the stakeholders in each country by the first half of FY2017. (The final policy brief is scheduled to be completed in the second half of FY2017).
- A report of the situation analyses of downstream activities and report on chain activities in the three focus countries.
- One national conference and three regional meetings to disseminate the results from the DCE survey and situational analyses in each country.
- Industry training workshops addressing knowledge and capacity identified in the industry.

V. Engagement of USAID Field Mission(s)

Despite the high turnover that is the reality of the Missions, we have been lucky to have national staff who are already familiar with our work. We have met and briefed USAID/Zambia Mission about this project and its expected outputs and impacts. The Director of the Economic Growth Office in Ghana with whom we have been working on another project is being transferred to Malawi as the Deputy Director of the Mission and this will provide us an improved access to the Mission in Malawi. We will continue to explore ways of leveraging our collective resources to enhance the effective impact of this project and those being undertaken by the Missions through associate awards or similar structures.

VI. Partnering and Networking Activities

The nature of the project requires effective partnerships to make it work. To this end, we have built, and will continue to nurture, our relationships with the breeders and the CG institutions in the regions. Specifically, as our results come in, we will share them with our in-country breeders and Legume Innovation Laboratory scientists to explore how information emanating from our research may be incorporated into their own research initiatives to enhance consumption of legumes. We continue to explore partnerships with public and private institutions to facilitate the dissemination of the results even as we explore ways of improving the effectiveness of planned public outreach initiatives.

VII. Leveraging of CRSP Resources

We have been successful in getting some Legume Innovation Laboratory funding to undertake institutional capacity building in Malawi. These resources will allow us to expand the depth of our outreach and capacity building effort through the research community at LUANR and the grain legume community in Malawi. In this coming fiscal year, we are hoping to be successful in obtaining similar funding opportunities for Tanzania and Zambia so that we can offer outreach and capacity building programs for the research community and grain legume community in those countries. We will continue to explore other opportunities from other institutions in our efforts to leverage our resources to expand our impact and reach.

VIII. Timeline for Achievement of Milestones of Technical Progress

See Milestones for Technical Progress Worksheet

Appendix 1: Work Plan for Training and Capacity Building (FY 2016)

Degree Training:

The project's degree training is limited to MS in agricultural economics and Master of Agribusiness (MAB). We proposed sponsoring two students per year in the three HCs for the MS program and four MAB across the three countries. The tables below provide the situation of degree awarding training programs for the project. None of the beneficiaries are receiving full support under the project. The MS students are receiving a stipend to support their contributions to the research and outreach efforts of project staff. The MAB students receive a full scholarship for tuition and books but are responsible for their program related travel expenses. This has slowed down our recruitment effort. We are exploring some options on how this may be addressed.

Please note: The project is not purchasing any equipment costing more than \$5,000.

	Student 1	Student 2
First and Other 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	Lawrence D. Mapemba	Lawrence D. Mapemba
Degree Program for training	Masters degree	Masters
Program Areas or Discipline	Agricultural economics	Agriculture And A
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	LUANAR	LUANAR
Thesis Title/Research Area	Household Demand for Common Beans in Lilongwe District of Malawi: A Censored Regression Approach	Assessing the impact of various attributes in determining the demand for common beans in Lilongwe district
Start Date	2015	2015
Projected Completion Date	September 2016	September 2016
Training status	Active	ACTIVE
Type of CRSP Support for training activity	Partial	PARTIAL
First and Other Names	Billy Mark	Chitete
Last Name	Dzimhiri	Moses
Citizenship	Malawian	Malawian
Gender	Male	Male
Training Institution	Lilongwe University of Agriculture and Natural Resources (LUANAR)	Lilongwe University of Agriculture and Natural Resources (LUANAR)
Supervising CRSP PI	Lawrence D. Mapemba	Lawrence D. Mapemba
Degree Program for training	Masters	Masters
Program Areas or Discipline	Agribusiness Management	Agricultural and A
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	LUANAR	LUANAR
Thesis Title/Research Area	Do commodity exchanges improve efficiency of bean markets in Malawi: A case of AHLGX and ACE	Market Structure, Competition and the Role of Smallholder Farmers in Beans Marketing S
Start Date	2016	2016
Projected Completion Date	September 2017	September 2017
Training status	Pending	Pending
Type of CRSP Support for training activity	PARTIAL	PARTIAL

	Student 1	Student 2
First and Other Names	Ocran	Ezekiel
Last Name	Chengula	Swema
Citizenship	Tanzania	Tanzania
Gender	Male	Male
Training Institution	Sokoine University of Agriculture	Sokoine University
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 Agriculture Food Security and Cooperatives	Sokoine University
Thesis Title/Research Area	Market Participation Among Smallholder Bean Farmers In Tanzania	Common Beans At Preference in Dar E
Start Date	September, 2013	September 2015
Projected Completion Date	November 2016	November 2016
Training status	Active	Active
Type of CRSP Support for training activity	Partial	Partial
First and Other Names	Elizabeth	Rameck
Last Name	Medard	Rwakalaza
Citizenship	Tanzania	Tanzania
Gender	Female	Male
Training Institution	Sokoine University of Agriculture	Sokoine University
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
Thesis Title/Research Area	Not yet decided	Not yet decided
Start Date	April 2016	April 2016
Projected Completion Date	September 2017	September 2017
Training status	Active	Active
Type of CRSP Support for training activity	Partial	Partial

	Student 1	Student 2
First and Other Names	Jackson	Mabvuto
Last Name	Jacob	Zulu
Citizenship	Tanzania	Zambian
Gender	Male	Male
Training Institution	Sokoine University of Agriculture	University of Zambia
Supervising CRSP PI	Fredy T. M. Kilima	Gelson Tembo
Degree Program for training	M.Sc.	Master of Science
Program Areas or Discipline	Agric. Econ.	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	Sokoine University of Agriculture	University of Zambia
Thesis Title/Research Area	Not yet decided	Consumer Preferences in Lusaka, Zambia. A
Start Date	April 2016	April 2015
Projected Completion Date	September 2017	March 2017
Training status	Active	Active
Type of CRSP Support for training activity	Partial	Partial
First and Other Names	Isabel	Nandi Nomsa
Last Name	Sakala	Jama
Citizenship	Zambian	Zambian
Gender	Female	Male
Training Institution	University of Zambia	University of Zambia
Supervising CRSP PI	Gelson Tembo	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	Not yet decided	Not yet decided
Start Date	June 2016	June 2016
Projected Completion Date	July 2017	July 2017
Training status	Active	Active
Type of CRSP Support for training activity	Partial	Partial

	Student 1	Student 2
First and Other 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?		
HC Institution to Benefit from Training	University of Zambia	
Thesis Title/Research Area	Not yet decided	Not yet decided
Start Date	January 2015	August 2016
Projected Completion Date	May 2017	December 2018
Training status	Active	Active
Type of CRSP Support for training activity	Full	Full
First and Other Names	Furaha	
Last Name	Rashid	
Citizenship	Tanzanian	
Gender	Male	
Training Institution	Kansas State University	
Supervising CRSP PI	Vincent Amanor-Boadu	
Degree Program for training	MAB	
Program Areas or Discipline	Agribusiness	
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID?		
HC Institution to Benefit from Training		
Thesis Title/Research Area	Not yet decided	
Start Date	January 2017	
Projected Completion Date	May 2019	
Training status	Active	
Type of CRSP Support for training activity	Full	

Short-Term Training

Training Type	Workshop	Workshop
Description	Identifying the Different Governance Structures in Value Chains	Closing the Knowledge Gaps in the Legume Industry
Location	Zambia; Malawi; Tanzania	Zambia; Malawi; Tanzania
Duration	1 day	1 day
Dates	TBD	TBD
Participants/Beneficiaries	Agri-food sector stakeholders, faculty, students	Agri-food sector stakeholders, faculty, students
Anticipated Attendance	30 per country (50% male)	50 per country (50% male)
Responsible PI	U.S. PI	U.S. PI
Other Funding Sources	Not yet.	Not yet.
Justification for Training	In anticipation of building value chains in the legume industry, this workshop seek to prepare stakeholders for what it takes to build successful and manage successful value chains.	In response to identified capacity and knowledge gaps in the legume supply chain in the three focus countries, workshops will be developed to closed those gaps and mitigate strategic management challenges.

FY 2017 WORKPLAN

Project Code and Title: S03.1 - Legumes, Environmental Enteropathy, the Microbiome and Child Growth in Malawi

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

Mark Manary MD, Helene Roberson Professor of Pediatrics

Washington University School of Medicine in St. Louis

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

- Ken Maleta MBBS PhD, Professor in Community Health, University of Malawi College of Medicine
- Chrissie Thakwalakwa PhD Lecturer in Community Health, University of Malawi College of Medicine
- Indi Trehan MD, Assistant Professor of Pediatrics, Washington University School of Medicine in St. Louis

I. **Project Problem Statement and Justification:**

Each year millions of children in Africa die from malnutrition and even more are stunted due to nutritional and absorption deficiencies, interventions to help children affected and at risk are urgently needed to improve the lives of these children. Environmental enteric dysfunction (EED), a pervasive chronic subclinical gut inflammatory condition is prevalent amongst these children and places them at high risk for stunting, malabsorption, and poor oral vaccine efficacy. EED is characterized by T-cell infiltration of the intestinal mucosa leading to a chronic inflammatory state with increased intestinal permeability, translocation of gut microbes, micro- and macronutrient malabsorption, poor weight gain, stunted physical and cognitive development, frequent enteric infections, and decreased response to enteric vaccines. EED often develops within the first three years of life, a high-risk period marked also by the transitions from exclusive breastfeeding to 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. Legumes provide just such an opportunity, as their protein content is significantly higher than cereals, and they are rich in dietary fiber, starch, minerals, vitamins, and antioxidants.

II. Project Activities for the FY 2017 Workplan Period (October 1, 2016 – September 30,

2017)

We will complete all components of two randomized, controlled clinical trials investigating the effect of cowpea or common bean consumption on infant and young child growth and gut health.

Objective 1:

Completion of intervention delivery and specimen collection in infants with a dietary legume.

Collaborators:

University of Malawi, College of Medicine

Approaches and Methods:

Evaluate changes in childhood anthropometry (height-for-age and weight-for-height z scores), biomarkers of EED (lactulose:mannitol and a panel of human mRNA messages predictive of EED) and the characteristics of the microbiome (population taxonomy from phyla to genus, and the collective metabolic capacity expressed as Kyoto Encyclopedia of Genes and Genomes (KEGG) categories) after inclusion of either cowpeas or common beans as an integral component of complementary feeding for 6-11 month-old rural Malawian children.

Study population. Approximately 300 healthy children aged 6-11 months in villages surrounding Mitondo in the Chikwawa District of southern Malawi and Llmela in Machinga District were randomized to receive a legume-based complementary food made from cowpeas, common beans or an isoenergetic amount of corn flour, a traditional Malawian complementary food. These villages are very similar in that the residents are subsistence farmers growing maize on small plots, live in mud huts with thatch roofs, and use boreholes or nearby streams as their water source.

These infants were recruited between the ages of 5.5 and 6.5 months, and their participation will last for 6 months. Enrollment was ongoing, and extended over a 9 month period and involved health surveillance assistants, midwives, and other local health staff and village leaders to maximize outreach into the community. Given our extensive prior experience working in this community and our excellent working relationship with the Ministry of Health and District Health Officers in this area, we have been successful with subject retention.

In addition to consuming legumes daily, these children were tested for EED using a dual sugar test at the ages of 6, 9 and 12 months of age. Stool samples were collected at 6, 6.5, 7.5, 9, 10.5 and 12 mo of age suitable for microbiota and microbiome analyses.

At the onset of Oct 2017 there will only be 15 children remaining in the study, and their participation is scheduled to be completed by 15-Oct-16. Thus the bulk of the work associated with this study is sample analyses and data analyses. Urine tests for lactulose and mannitol are done monthly in batches, so the September 2016 batch and October 2016 batch will be sent to the lab at Children's Nutrition Research Center in Houston. Data are tabulated and processed upon receipt of the results. Analyses of stool samples for 16s and metagenomic sequencing will be ongoing through March 2017, and data analyses will follow thereafter.

Objective 2:

Analyses of complementary foods

Collaborators:

Elizabeth Ryan PhD, Assistant Professor,
Department of Environmental and Radiological Health Sciences,
Colorado State University, Fort Collins, CO

Approaches and Methods:

Dr. Ryan's lab will deliver a comparative analysis of food composition as well as a comparative analysis of small molecules and metabolite pathways. This includes all known toxins and contaminants as well as bioactive small molecules for the cowpea and common bean supplements fed to the children in Malawi. This will identify the 40 major nutrients (macro and micronutrients) as well as hundreds of other small molecules. This information is helpful and necessary to understand the feasibility of operational implementation of this complementary feeding.

Objective 3:

Completion of intervention delivery and specimen collection in young child project

Collaborators:

University of Malawi

Approaches and Methods:

Evaluate changes in childhood anthropometry (height-for-age and weight-for-height z scores), biomarkers of EE (lactulose:mannitol and a panel of human mRNA messages predictive of EE) and the characteristics of the microbiome (population taxonomy from phyla to genus, and the collective metabolic capacity expressed as Kyoto Encyclopedia of Genes and Genomes (KEGG) categories) after inclusion of either cowpeas or common beans as an integral component of complementary feeding for 12-24 month-old rural Malawian children.

Study population. Approximately 300 healthy children aged 12-24 months in villages surrounding Mitondo in the Chikwawa District of southern Malawi and Llmela in Machinga District were randomized to receive a legume-based complementary food made from cowpeas, common beans or an isoenergetic amount of corn flour, a traditional Malawian complementary food. These villages are very similar in that the residents are subsistence farmers growing maize on small plots, live in mud huts with thatch roofs, and use boreholes or nearby streams as their water source.

These infants were recruited between the ages of 12-24 months, and their participation will last for 12 months. Enrollment occurred in 3 month period and involved health surveillance assistants, midwives, and other local health staff and village leaders to maximize outreach into the community. Given our extensive prior experience working in this community and our excellent working relationship with the Ministry of Health and District Health Officers in this area, subject retention was successful.

Eligible children were screened by the research supervisors and physicians from our team. Specific exclusion criteria were severe or moderate acute malnutrition, severe developmental delay or congenital malformations (including congenital heart disease) or any other known chronic disorder. After a thorough, tiered informed consent process presented to the community and parents, written as well as oral consent will be sought from the primary caretaker, who is almost always the mother or another matriarchal figure. Attempts will be made to engage any paternal figures in the household in the consenting process as well in order to maximize compliance with the study interventions and decrease attrition. Any caretakers reluctant to participate were not be encouraged to do so, and any participant desiring to leave the study after enrollment was allowed to do so without coercion. This method of informed consent has been used successfully by the research team in the past, and been endorsed by the University of Malawi College of Medicine Research and Ethics Committee and the Washington University Human Research Protection Office.

In addition to consuming legumes daily, these children were tested for EED using a dual sugar test at enrollment and after 3, 6, 9 and 12 months of feedings. Stool samples were collected at 10 time points during the 12 months of participation and these fecal samples are suitable for microbiota and microbiome analyses.

In October 2017 78 children will be remaining in this study, and their participation will be complete by 15-Dec-16. Most of the work in 2017 associated with this objective is sample analyses and data analyses. Urine tests for lactulose and mannitol are done monthly in batches, so the September-December 2016 batches will be sent to the lab at Children's Nutrition Research Center in Houston. Data are tabulated and processed upon receipt of the results. Analyses of stool samples for 16s and metagenomic sequencing will be ongoing through May 2017, and data analyses will follow thereafter.

Objective 4 : Increase the capacity, effectiveness and sustainability of agriculture research institutions which serve the bean and cowpea sectors in Malawi.

Collaborators:

University of Malawi

LUANAR

While completing Study Aims, the PI and his research team will promote sustainable research through relationships with the Malawi College of Medicine and with colleagues at LUANAR. The research team recognizes how integral it is that local Malawi institutions be equipped to initiate and conduct operational health, nutrition and agriculture studies to improve the health and

wellness of its population, and extensive training and support will be offered. Chrissie Thakwalakwa of the College of Medicine, who received her PhD with support from the LIL, completed her charge to develop the study procedures, guidelines and materials and has acted as an administrative supervisor for the clinical trial, she has been under the guidance of the PI and his research team. The Agriculture Department at LUANAR, led by Vernon Kambambe and Agnes Mwangwela, were engaged developing formulations and recipes using cowpeas and common beans, the PI and his team trained the **only** two student LUANAR food scientists on the development processes used in the Washington University food science labs.

Trainees

Chrissie Thakwalakwa – PhD, Malawi College of Medicine -**completed**

Tereza Ngoma from LUANAR to develop recipes lead a food quality workshop - **completed**

Ulemu Chimimba from LUANAR to develop recipes -**completed**

Yankho Kaimila PhD candidate Malawi College of Medicine

Oscar Divala - PhD candidate Malawi College of Medicine

III. Contribution of Project to USAID Feed the Future Performance Indicators:

This project supports the US Government’s Feed the Future commitment to a multifaceted approach to nutrition and sustainably reducing global poverty and hunger. EE is estimated to cause about one third of the child stunting seen worldwide and the causes of EE are multifactorial. Our project aligns with these goals: developing a dietary intervention for children at risk for malnutrition and enteropathy using legumes, a local and common Malawian crop, is an opportunity to harness a local crop to resolve widespread condition afflicting children across the developing world. In the first year of the project we will set forth the methodology and training to develop a food that can treat this condition, and also train local universities and students on the methods to conduct this kind of research.

IV. Outputs:

- Report on nutrient properties and food safety of the cowpea and common bean complementary foods
- Clinical trial results

V. Engagement of USAID Field Mission(s)

Continued communication, engagement and collaboration are planned with Crispin Magombo from the FTF team at the USAID mission in Lilongwe, Malawi.

VI. Partnering and Networking Activities:

The PI and his team will work with the Ministry of Health and the College of Medicine to understand the results from the clinical trial and how they might be implemented in an operational setting.

VII. Leveraged Resources:

Ken Maleta is a lead member of the Investigation of Lipid Nutrient Supplements (iLiNS) project, a large Bill and Melinda Gates Foundation-supported effort in Malawi. He provides a direct link between this legumes project and any other international nutrition programs in Malawi. Equipment will be shared with the iLiNS project, reducing the costs. All results will be presented at international nutrition and food research meetings focused on FTF themes, which will allow an opportunity to synergize with other projects.

Samples collected through the clinical trials will be assessed for serum metabolomics at Johns Hopkins University to better understand EED.

VIII. Timeline for Achievement of Milestones of Technical Progress:

See attached Milestones

Appendix 1: Workplan for Training and Capacity Strengthening (FY 2017).

Degree Training:

1. William Cheng, USA, Male
Washington University in St. Louis, MA in Biological Sciences
Supervisor: Mark Manary
Participant Trainee: Yes
Host Country Institution to Benefit from Training: College of Medicine
Research Area: Assisting with the completion of the clinical trial
May 2016 – March 2017
Training status: Ongoing
Type of LIL Support: Indirect
2. Theresa Ngoma, Malawi, Female
LUANAR, MSc in Food Science and Technology
Supervisors: Mark Manary, Ken Maleta, Indi Trehan
Participant Trainee: Yes
Host Country Institutions to Benefit from Training: LUANAR
Research Areas: Development of common bean and cowpea flour recipes ; Production and quality control of common bean and cowpea flour recipes
January 2015 – December 2015
Training status: Active
Type of LIL Support: Direct
3. Ulemu Chimimba, Malawi, Female
LUANAR, MSc in Food Science and Technology
Supervisors: Mark Manary, Ken Maleta, Indi Trehan
Participant Trainee: Yes
Host Country Institutions to Benefit from Training: LUANAR
Research Areas: Development of common bean and cowpea flour recipes ; Production and quality control of common bean and cowpea flour recipes

January 2015 – December 2015

Training status: Active

Type of LIL Support: Direct

4. Yankho Kaimila, Malawi, Female

University of Malawi College of Medicine, PhD in Epidemiology

Supervisors: Mark Manary, Ken Maleta, Indi Trehan

Participant Trainee: Yes

Host Country Institutions to Benefit from Training: LUANAR

Research Areas: Clinical trial of flours to improve EED and stunting; Laboratory techniques to measure biomarkers of EED

August 2015 – July 2017 (estimated)

Training status: Active

Type of LIL Support: Direct

5. Oscar Divala, Malawi, Male

University of Malawi College of Medicine, PhD in Epidemiology

Supervisors: Mark Manary, Ken Maleta, Indi Trehan

Participant Trainee: Yes

Host Country Institutions to Benefit from Training: LUANAR

Research Areas: Clinical trial of flours to improve EED and stunting; Laboratory techniques to measure biomarkers of EED

August 2015 – July 2017 (estimated)

Training status: Active

Type of LIL Support: Direct

Short-term Training: Staff Field Training

Type of training: Field training for research activities

Description of training activity: Training study research nurses, drivers, research assistants and staff on the field study guidelines. Trainees will receive training in "Good Clinical Practice" guidelines, anthropometric data collection skills, biological sample collection methods and community engagement.

Location: Malawi College of Medicine

Duration: 1 week

When will it occur? ongoing

Participants/Beneficiaries of Training Activity: Research team

Anticipated numbers of Beneficiaries (male and female): 10

PI/Collaborator responsible for this training activity: Indi Trehan and

Ken Maleta List other funding sources that will be sought (if any): None

Training justification: this training is necessary to conduct the research projects, having a knowledgeable and capable staff is imperative to conducting this research.

Short-term Training Food safety course

Type of training: In country course on food safety for agronomists and food processors (open enrollment)

Description of training activity: A sets of seminars and field experience set up to run over 1 week are arranged through the school of public health at the College of Medicine, University of Malawi

Location: Malawi College of Medicine

Duration: 1 week

When will it occur? ongoing

Participants/Beneficiaries of Training Public and private sector individuals in Malawi. Anticipated numbers of Beneficiaries

(male and female): 75

PI/Collaborator responsible for this training activity: Indi Trehan and

Ken Maleta List other funding sources that will be sought (if any): None

Training justification: this training will heighten awareness of food safety issues and how they can be minimized.

FY 2017 WORKPLAN

Project Code and Title:SO4.1 - Impact Assessment of Dry Grain Pulses CRSP investments in research, institutional capacity building and technology dissemination for improved program effectiveness

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

Mywish Maredia, Professor, Agricultural, Food and Resource Economics (AFRE), Michigan State University

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

Eric Crawford (Co-PI), Agricultural, Food and Resource Economics, Michigan State University
US and HC PIs/collaborators of other Legume Innovation Lab Projects

I. 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.

The proposed research contributes towards evidence-based rigorous ex ante and ex post assessments of outputs, outcomes and impacts with the goal of assisting the Legume Innovation Lab program and its Management Office (MO) to achieve two important goals--accountability and learning. Greater 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 Legume Innovation Lab and generating knowledge outputs will ultimately help increase the overall impact of such investments.

II. Planned Project Activities for the Workplan Period

Objective 1:

Provide technical leadership in the design, collection and analysis of data for strategic input and impact evaluation

Collaborators:

Juan Osorno (NDSU), Julio Martinez (ICTA), and Byron Reyes (CIAT)

Nicole Mason and David DeYoung, Michigan State University

Approaches and Methods:

Following activities from previous years will be expanded and / or completed in FY 17.

1a. Analysis of baseline study in Guatemala: A baseline survey of more than 500 farm households to study the constraints and opportunities for research to contribute to increased productivity of climbing beans in Guatemala was conducted in 2015 jointly with the SO1.A1 project team under their objective ‘*Genetic improvement of climbing black beans for the highlands of Central America.*’ Data cleaning and organization is completed and a poster paper highlighting the preliminary results of this survey was presented at the Pan African Legume Conference in Zambia in March 2016. In FY 17, this project plans to complete the data analysis and generate a working paper for wider dissemination. This will be a joint activity with the SO1.A1 team (Juan Osorno (NDSU), Julio Martinez (ICTA)), and Byron Reyes (CIAT). The analysis will focus on the current status of the climbing bean/maize intercropping production system (i.e., the *milpa* system) in the highlands of Guatemala. Data concerning cultivated area, production practices, production problems/constraints, seed quality and culinary preferences along with the socio-demographic characteristics of farm households will be analyzed using descriptive and econometric techniques to help establish priorities for the climbing bean breeding program.

1b. Analysis of existing data for strategic insights to guide impactful research on legume based farming systems: The movement towards sustainable intensification as promoted by many donor funded projects, including USAID’s FTF programs in some countries, is based on the premise that integrating legumes in crop rotation and as intercropped with cereals can have much needed soil fertility and nutrition benefits to farmers adopting these practices. There is, however, little empirical evidence documenting these claims. As part of FY 17 workplan, this project plans to continue rigorous panel data analyses to provide strategic insights on following question: What are the productivity, nutrition, and income effects of the adoption of legume based intensification technology (such as legume-cereal intercropping and rotation).

Existing panel datasets from LSMS-ISA surveys in Tanzania, Uganda and/or Malawi will be used to address these questions. In the case of Malawi, the LSMS-ISA data can be used to explore how subsidies not just for maize inputs but also for legume seed (which started being included in the Malawi FISP input packs a few years ago) affect long-term adoption and incomes, and not only adoption in the year of the subsidy but in subsequent years.

The PI will collaborate with Nicole Mason from MSU AFRE Department on this activity. She has experience working in East and Southern Africa, and expertise in conducting panel data analysis using rigorous econometric methods.

Objective 2: Conduct ex ante and ex post impact assessments

Collaborators:

Robert Shupp, David DeYoung and Nathalie Mensope, Department of Agricultural, Food and Resource Economics (MSU), Byron Reyes and J.C. Rubyogo, CIAT, Paul Kusolwa and Fulgence Mishili, SUA, Tanzania, Francis Kusi, SARI, Ghana, Ilboudo Dieudonne and Clementine Dabire, INERA, and researchers from SO1.A4, SO1.B1 teams

Approaches and Methods:

In FY 17, following research studies and activities will be conducted under this objective.

2a. Sustainability of legume seed system constraints and opportunities to guide policies and programs: Two studies were initiated/completed in FY 15 (Tanzania and Ghana) under this broad theme and the plan is to continue/extend this work in FY 17 as described here.

- i. *Willingness of small holder farmers to pay for quality seed:* This will be an expansion of the study conducted in Tanzania in previous years to assess farmers' willingness to pay for quality seed over grain. The methodology/ approach to address this research question consists of first conducting field experiments in farmers' fields to demonstrate the value of planting different types of seeds of the same vs. grain saved from previous harvest (representing different years of recycled seed) or purchased from the market, and then conducting bidding experimental auctions (BEA) to test farmers' willingness to pay for different types of seeds (i.e., certified seed, quality declared seed and recycled seed). In FY 17, the plan is to complete the analysis of this study conducted in Ghana for cowpea, and expand this research in Nicaragua for beans. The study in Nicaragua will be conducted in collaboration with CIAT and INTA.

The geographic focus will be the Northwest of Nicaragua, described in

Table 1. The specific number of villages per municipality will be determined later on, as we depend on the villages where potential collaborators work. In these municipalities, as in most of the country, the first season (Primera) goes from May to July and the second season (Postrera) goes from August to November. Because of budget limitations, the DEMO and BEA will focus on one municipality in each department (for a total of two municipalities) and selecting ten villages in total.

Table 1. Proposed study sites and number of villages, Nicaragua

Municipality	Department	
	Jinotega	Madriz
La Concordia	5-8 villages (TBD)	n.a.
Yalaguina	n.a.	2-5 villages (TBD)

Notes: TBD=to be determined; n.a.=not applicable

Interest from other legume innovation lab country collaborators (INERA in Burkina Faso and NSS in Haiti) to conduct similar WTP studies has been expressed. However, this research will be expanded to these additional two countries contingent upon budget availability.

- ii. Case study on community based seed system: The BTD project in Nicaragua used Community Seed Banks (CSB) to multiply and disseminate improved varieties of *Apta* (i.e., Quality Declared Seed) bean seed to farmers. Between 2011 and 2013, existing CSBs were supported or new CSBs estimated in 234 communities. An estimated 16,065 farmers obtained seed from the CSBs representing 23% of farmers cultivating beans on 10 MZ (7 hectares) or less. A study of the cohort of CSBs established in the first year of the BTD project reinforce the importance of seed marketing training, production of quality seed, inclusive transparent operations, and experience leadership as factors contributing to the longevity, and thus sustainability, of CSBs. While these results were important, the study was limited to a time period in which the CSBs received external financial and technical support.

To further understand the factors contributing to sustainability of CSBs, and specifically, after external financial support ends, we propose a follow up study in collaboration with CIAT, of the CSBs that participated in the BTD project. Specifically, the study will interview representative of the 34 CSBs from the first cohort that operated all three years in the BTD project (agricultural seasons 2011-13). An additional 34 CSBs will be selected

using a proportional selection method of location and years of operation of the additional 114 CSBs operating at program end 2013, but not included in the original study because they began operations in 2012 or 2013.

A structured questionnaire will be developed to collect data on the operation of CSBs after 2013 without direct external support of the BTD project. Seed production and dissemination data, as well as descriptions of changes in the leadership and operations of the CSBs will be collected. Additionally, any collaborative agricultural or non-agricultural group activities not related to seed production that continue among the CSB members will be documented to identify community impacts beyond the strengthening of the local seed systems.

2b. Adoption study in Haiti: In collaboration with the SO1.A4 team, this proposed study was initiated in FY 16 and will be completed in FY 17. The study is designed to generate systematic and rigorous evidence on the use of improved bean varieties by farmers in Haiti. Specific objectives of this study are:

- a. 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.
- b. 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
- c. 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.'
- d. 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.

Activities in FY 17 will mostly focus on objectives b, c and d. Specifically, it will include:

1. *Bean seed supply chain assessment* to get a good understanding of the relative importance of the formal and informal bean seed channels, major players involved in each, how the bean seed flows within and between the formal and informal channels, and types of bean seed varieties available in the system. This will require different methods, approaches and sources of information as outlined below:

- i. Bean seed source patterns (how farmers are linked with upstream seed supply chain), types of seed varieties grown by farmers, how farmers use the harvested grain, and how they are linked with the supply chain downstream. This information will be obtained from the farm surveys conducted in FY 16.
 - ii. Seed/grain market analysis: Since a bulk of seed planted by farmers are procured from the market and sold after harvest, the plan is to do a systematic assessment of the bean varieties available in the market, pricing patterns, sourcing areas, and seed quality management procedures followed by the seed/grain vendors. The plan is to piggyback on the existing market information system infrastructure managed by NASS called Systeme D'information Sur Les Marches Argricoles (SIMA), and collect bean seed samples and information from bean vendors from whom the seed samples are collected. The plan is to do this seed sample and information collection from bean vendors at least 6 times in each market for the 12 month period starting in August 2016. A sub-set of the seed samples collected from the markets will be subjected to seed quality test and DNA fingerprinting for varietal identification. The sampling plan and the logistics of doing this seed/grain market analysis study are to be further developed with input from NASS and NSS, and will be contingent upon budget availability.
 - iii. Key informant interviews with major institutional players involved in the formal bean seed system in Haiti. This includes agro-dealers, international and national NGOs, IICA, FAO, donor funded programs (e.g., Change Life), Ministry of Agriculture and NSS. A combination of face-to-face or phone interviews and emails or online survey will be used to gather information on the scope, scale and size of seed production, multiplication and distribution efforts by these players. For a sub-sample of organizations in each category, the plan is to also request or collect bean seed samples promoted by these different entities and seed programs and conduct DNA fingerprinting analysis and seed quality tests. The methodology for this sub-component is still to be developed, and will also depend on budget availability.
2. *DNA fingerprinting*, which is routinely used by plant breeders and is becoming widely available and affordable, offers a reliable method to accurately identify varieties grown by farmers. The use of this method can thus increase the accuracy and credibility in the interpretation of results of adoption and impact studies based on household surveys. We thus plan to supplement the data collection approaches outlined under objectives a and b with DNA fingerprinting of bean seed samples collected from farmers, markets and different nodes of the formal and informal seed supply chain. This component of the Haiti study will be done in close collaboration with the SO1.A4 team. Protocols for collecting seed samples, labeling, handling, shipping and storage of seeds from the point of collection to NSS facilities in Haiti, and then shipping these seeds to Puerto Rico (where seeds will be germinated and DNA extracted), and from there the shipment of DNA samples to lab facilities where DNA fingerprinting will be conducted will be worked out with SO1.A4 team. Cost estimates have been provided for the DNA analysis, which range from \$10-15/sample depending on the sample size. Across the farmer survey, market survey and the different nodes of the supply chain, we anticipate collecting a large number of seed samples (more than 5000). We will thus need to come up with a strategy to sub-sample the collected samples for DNA analysis. The number of seed samples that will be DNA fingerprinted will be based on available budget and a scientifically meaningful sampling method. Since this component was not originally planned and budgeted for this study, we have requested the Management Office for additional support.

The DNA analysis will include bean seed samples (preferably breeder seeds) of all the released and/or promoted varieties in Haiti and neighboring countries either through private sector, Zamorano, UPR, CIAT or other breeding programs in the region (e.g., DR, USA, Mexico, Guatemala). Also, any known improved landraces introduced or indigenous varieties in Haiti will be included in the reference library as long as the source of these seeds can guarantee its identity. Dr. Emmanuel Prophete is compiling a list of all the varieties (improved, introduced in Haiti) that will potentially be included as the reference materials for DNA fingerprinting.

3. *Assessment of bean varietal adoption by farmers and seed system analysis.* The output of this study will be reflected in reports (followed by peer reviewed publications) that will be generated based on the data and results from data collection and analysis of objectives 1-3. This output will be generated in FY 17 and will include:
 - i. Overview of the bean seed system in Haiti (different players, formal and informal channels of seed supply)
 - ii. Importance of different sources of seed for farmers
 - iii. Estimates of the adoption and prevalence of different types of bean seed varieties in the seed system in Haiti.
 - iv. Adoption outcomes of targeted seed distribution efforts (e.g., BTD)
 - v. Assessment of seed system constraints and opportunities for improvement

2c. Follow-up survey in Burkina Faso for impact assessment of biocontrol IPM research:

Cowpea (*Vigna unguiculata*) is an important staple in Burkina Faso as well as many other countries in West Africa. Among the major cowpea pests affecting the crop are the legume pod borer (*Maruca vitrata*), flower thrips (*Megalurothrips sjostedti*), bruchids (*Callosobruchus maculatus*), and pod-sucking bugs, for which conventional plant breeding has not been effective and the use of pesticides has economic, health and environmental limitations. Through support from the predecessor CRSP and the current Legume Innovation Lab, the SO1.B1 project team has developed alternative strategies to control these insect pests and reduce the levels of pesticide used on the crop. One of these strategies includes implementing a comprehensive bio-control program. As part of this strategy, the SO1.B1 team has recently released bio-control agents in selected locations in Burkina Faso where baseline data were collected by this project in 2012. The sample design covers a total of 560 households distributed across 56 villages and 10 provinces. In FY 17, the plan is to conduct a follow-up survey (in collaboration with INERA) of the same farmers in 56 communities to be able to evaluate the impacts of bio-control research using difference-in-difference methodology. The baseline data collected in 2012 will serve as the ‘before’ scenario, which will be compared with an “after” scenario in 2017.

The main purpose of this proposed impact evaluation study is to measure the farm level effects of bio-control IPM strategy to control *Maruca vitrata*. Data will be collected on: (1) the incidence and severity of damage caused by biotic (particularly insects) and abiotic stresses; (2) the use of insecticides; farmers' knowledge/awareness about beneficial insects to control cowpea pests; (3) pesticide management practices; (4) toxic health effects from pesticide use (misuse); and, (5) use of labor during cowpea production. Other economic indicators include the quantity of cowpea grain produced, revenues from grain sales, input and transportation costs, and relative importance of cowpea as a source of income and food security.

Objective 3: *Build institutional capacity and develop human resources in the area of impact assessment research*

Collaborators: NARS and CIAT partners

As in previous years, this project will address the objective of institutional capacity building and human resource development through the following activities planned in FY 17:

- a. Research activities under objectives 1 and 2 will involve host country PIs/collaborators in the planning and conduct of field data collection as much as possible. During the data analysis phase, HC collaborators will be given opportunities to visit MSU and get some hands-on training by working jointly with US PIs and collaborators with the goal of generating scholarly outputs.
- b. Activities planned under this project will involve graduate students in the planning and conduct of field research and write-up of research results. These students will be recruited from within the Department of Agricultural, Food and Resource Economics at MSU (see the details on trainees in the Training section).

III. Contribution of Project to USAID Feed the Future Performance Indicators:

None

IV. Outputs:

Specific outputs to result from this project by the end of FY 17 include:

- a. Completion of two manuscript for publication in academic journals and/or presentations at professional meetings
- b. Completion of impact briefs based on published papers

V. Engagement of USAID Field Mission(s)

No specific plans for engagement of USAID Field Mission(s) are envisioned in FY 17. Project activities in host countries will mainly involve data collection, accessing secondary data, and information gathering through stakeholder interviews. Data collection will be done in collaboration with HC partners in countries where Legume Innovation Lab is already engaged and where activities are occurring in concurrence with USAID country or field missions.

VI. Partnering and Networking Activities:

All the activities occurring in specific countries through field research will involve collaboration with host country institutions and partners. Host country institutions will not only be involved in the planning and design of data collection efforts, conducting surveys, data entry and report writing, but also in the dissemination of results to broader audience and stakeholder groups. Opportunities will be sought to present papers based on this project's research results in national and international policy and professional forums.

Results emanating from this impact assessment research project will be published in the form of Impact Briefs and will be posted on the Legume Innovation Lab website. They will be also shared with appropriate USAID mission offices through the Legume Innovation Lab Management Office and host country partners.

VII. Leveraged Resources:

The Master Card Foundation has awarded a scholarship to a Ghanaian student for a two year M.S. degree in the Department of Agricultural, Food and Resource Economics at MSU under the mentorship of M. Maredia. This project will leverage this scholarship opportunity to undertake and complete the WTP study in Ghana planned under Objective 2 (activity 2a).

In addition, the project PIs will be actively engaged in identifying opportunities to partner with other international impact assessment and Grain Legume research programs/projects and seek for opportunities to leverage resources to achieve common research goals.

VIII. Timeline for Achievement of Milestones of Technical Progress:

See the attached excel file

Appendix 1: Workplan for Training and Capacity Strengthening (FY 2016)

Degree Training:

First and Other Given Names: Edward

Last Name: Opoku

Citizenship: Ghana

Gender: Male

Training Institution: Michigan State University

Supervising CRSP 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 will assist in the WTP of quality cowpea seed in collaboration with SARI, Ghana

Start Date: Fall 2015

Projected Completion Date: Fall 2017

Training status (Active, completed, pending, discontinued or delayed): Active

Type of CRSP Support (full, partial or indirect) for training activity: Indirect

First and Other Given Names: Sean

Last Name: Posey

Citizenship: USA

Gender: Male

Training Institution: Michigan State University

Supervising CRSP 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: (TBD) The student will assist in various research activities planned under objectives 1 and 2

Start Date: Fall 2016

Projected Completion Date: Fall 2018

Training status (Active, completed, pending, discontinued or delayed): Pending
Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Brian
Last Name: Bartle
Citizenship: USA
Gender: Male
Training Institution: Michigan State University

Supervising CRSP 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: (TBD) The student will assist in various research activities planned under objectives 1 and 2

Start Date: Fall 2016

Projected Completion Date: Fall 2018

Training status (Active, completed, pending, discontinued or delayed): Pending
Type of CRSP Support (full, partial or indirect) for training activity: Partial

Equipment (costing >\$5,000): **None**