LEGUME INNOVATION LAB FOR COLLABORATIVE RESEARCH

ON GRAIN LEGUMES

FY 2016 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:

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

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

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I. Project Problem Statement and Justification:

With approximately 11 million habitants, Guatemala is mostly a rural country, with 60% of the population living in farms and 50% of the population being indigenous. Maize is the main staple food in most households with a per capita consumption of ~100 kg per year, followed by beans with ~13 kg per year. However, consumption trends are different in rural vs. urban areas. Since few other sources of protein are available especially in rural areas, this amount is not enough to ensure an acceptable nutritional quality, especially within poor households. As expected, the lack of protein intake has reduced the nutritional quality in many households, and significantly affecting children.

Beans are grown on 31% of the agricultural land and mostly in the low to mid-altitude regions (0-1500 masl) in a monoculture system. Contrastingly, intercropping (locally known as Milpa) is the main production system in the highlands, where maize-bean is the most common crop association. The system uses climbing beans that grow around the corn stalks. Two main methods are used: direct planting, in which both maize and beans are planted simultaneously, and relay, in which the maize is planted first and

the beans are planted at a later date in order to avoid strong competition between the two crops. Unfortunately, on-farm productivity of these climbing beans is approximately one third of their genetic yield potential, mostly due to the lack of improved cultivars that are able to withstand biotic and abiotic stresses. Fungal and bacterial diseases as well as pests are the main cause for yield reductions. In addition, production is made with almost no inputs of fertilizers and/or other chemicals. Historically, climbing beans worldwide have received less attention and breeding efforts in comparison with the bush-type beans commonly grown in the lowlands, as shown by the significant yield gap between regions. In addition, there are genetic and environmental interactions among species (maize, bean, squash, etc.) not well understood within the intercropping system that affect crop performance and hence, seed yield. The legume Innovation Lab has been involved in collaborative bean breeding research targeting lowland agro-ecologies in Central America, but research for the highland bean production systems is still lacking. A significant seed yield differential between the lowlands and the highlands can be observed, especially in Guatemala.

There is an existing collection of approximately 600 accessions of climbing beans collected across all bean production regions in Guatemala. This collection is kept by ICTA and has been characterized morphologically and with few molecular markers (6 SSR primers). In addition, some field notes concerning disease resistance (natural pressure) and other agronomic traits of economic importance have been collected as well. Initial results suggest that ½ of the collection consist of duplicates. In addition, some initial crosses among climbing beans and selections have been made by Dr. Fernando Aldana (ICTA-Quetzaltenango) and the rest of the ICTA group. These lines will be used intensively in this project.

II. Planned Project Activities for the Workplan Period (October 1, 2015 – September 30, 2016)

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

Collaborators:

NDSU: Juan M. Osorno and Phil McClean.

ICTA: Julio Cesar Villatoro, Fernando Aldana, Edgardo Carrillo.

Approaches and Methods:

1.1: Farmer's field testing of 12 selected accessions (ICTA) and other early-generation genetic material (final testing year): The bean breeding program at ICTA has planted a selected a group of 12 genotypes that include accessions from the germplasm collection and crosses made by Dr. Fernando Aldana that offer agronomic traits of interest such as plant growth type, seed yield, disease resistance, earliness, and seed quality, among others. Field trials were planted in farmer's fields during the 2014 growing season and replanted again this year in April and May 2015 at 10 locations representing five departments where there is significant production of climbing beans (final report from 2014 trials is available under request). Most locations are tested under the common intercropping system (Milpa) and few under monoculture. A final third year of field testing during FY16 is needed in order to find the most appropriate genotype(s) to be considered as future varieties. The trials are planted using a Randomized Complete Block Design (RCBD) with 2 or 3 replications depending on space and resources at each location. The local variety commonly grown by the grower is used as the check.

An effort to collect all the following agronomic data will be made within each plot at all locations:

- Days to emergence: Bean seedlings counted 20 days after planting
- Vigor: Visual scale of 1-9 where 1 is best and 9 is worst.
- Early disease symptoms: CIAT scale 1-9 will be used for any disease naturally occurring at any of the locations.
- Days to Flowering: Number of days after planting in which 50% of the plants in a plot have at least 1 flower.
- Pod distribution: Classified either as columnar (even pod distribution across all plant) or pyramidal (uneven pod distribution with most pods around the higher part of the plant).
- Climbing aggressiveness: Classified as low, medium, or high depending on a visual estimate of plant biomass (leaf, stems, and pods)
- Disease symptoms (natural pressure): CIAT scale 1-9 will be used for any disease naturally occurring at any of the locations.
- Days to maturity: Days after planting when at least 50% of the plants within a plot are ready for harvest.
- Seed yield: Weight in g of seeds after threshing and converted to kg/ha.
- 100-seed weight: the weight in g of 100 seeds collected randomly for the seeds obtained from each plot.

Once all the data is collected at the end of the year, decisions will be made about selecting a smaller number of lines for testing in FY16 at farmer's fields across 10 locations again. The number of entries to be tested in the following year will depend on this year's results. The same field testing protocol will be applied for this new cycle of field testing. In addition, we'll keep monitoring the phenotypic heterogeneity of the lines tested (objective 1.3).

1.2: Breeding pipeline (ICTA/NDSU): a group of 28 F6 bolonillo lines and 23 selected accessions of climbing beans (bolonillo, piloy, piligua, etc.), were evaluated and harvested at the ICTA stations in Chimaltenango and Quetzaltenango last year (2014) and seed was increased during the off-season at San Jeronimo. Phenotypic evaluation of this material allowed the selection of 130 lines with potential. 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 2015 at ICTA-Quetzaltenango for field evaluation under Milpa conditions and phenotypic selection will be practiced again. Selected F9 lines will be planted and evaluated again in FY16 based on the same traits previously mentioned.

1.3: Genetic purification of selected material (ICTA): As explained Technical Project Description, phenotypic variation has been detected within accessions and breeding lines. Some individual plant selections were made last year within the 28 F_6 breeding lines and will be tested again this year for homogeneity at the ICTA-Chimaltenango and Quetzaltenango stations. In addition, visual evaluation for phenotypic heterogeneity will be made across all field testing locations in order to have a better estimate of genetic variability within each line tested. If genetic heterogeneity is visually detected, plants with apparent superior performance (e.g. disease resistance, seed yield, pod distribution, seed quality, climbing aggressiveness, earliness, etc.) will be tagged to be harvested as a single plant selection. The seed from each individual plant selected will be used in the future for: i) seed increase, and ii) further evaluations.

1.4: Field evaluation of Bolonillo-TEXEL (ICTA): One of the improved lines selected by Dr. Fernando Aldana at advanced breeding stages (known as Bolonillo-Texel) was planted in ~20 grower's fields during FY15 (final report available under request). Each field consist of ~400 m^2 planted with Bolonillo-Texel and growth next to or near the variety or varieties the grower normally uses. The same experiment will be repeated in FY16 in order to obtain robust data across years and location about the agronomic performance of Bolonillo-Texel. An attempt to measure the same traits mentioned above will be measured across all locations or at least, a subset of them. 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 Bolonillo-Texel should be released or recommended for all the highland ecosystem or if the new variety seems 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 Guatemalan seed system. If Bolonillo-Texel has good acceptability it could be released sooner, which would allow for a significant impact of this project earlier than planned by releasing an improved variety of climbing bean thanks to the previous efforts made by the ICTA bean breeding project.

1.5: Second crossing block (ICTA): A first set of 23 potential parents (see objective 2.3) were planted in the greenhouse at the ICTA station in Chimaltenango during the 2015 growing season. The use of an offseason growing cycle in the lowlands (e.g. San Jeronimo) was used to advance 2 generations per year. The first generation of single crosses during FY15 has encountered some difficulties in regards to flowering synchronicity in spite of planting the material at staggered planting dates. Therefore, some crosses planned initially won't be accomplished and will have to be attempted again during FY16. A minimum of 40 parental combinations are expected to be produced. All this material constitutes the first batch of genetic material towards the creation of 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.

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

Collaborators:

NDSU: Juan M. Osorno and Phil McClean.

ICTA: Julio Cesar Villatoro, Fernando Aldana.

Approaches and Methods:

2.1 Evaluation of core collection with the 6k SNP chip (NDSU): The cold storage at ICTA-Chimaltenango where the climbing bean germplasm collection is kept is in very bad condition, mostly affected by bruchids and rodents. Because of this, and before embarking into the genotyping efforts, it was decided to do a field seed increase of the 600 accessions at ICTA-Chimaltenango during 2014 in order to obtain a fresh batch of seed for the molecular analyses and also to renovate the seed from the cold storage. Harvested seed has been cleaned and conditioned and will be shipped to NDSU once a phytosanitary certificate is obtained from the Guatemalan Ministry of Agriculture. Therefore, we are behind our proposed timeline in this regard. The phytosanitary certificate was finally obtained in Mid-July and seed is expected to arrive to NDSU during the last week in July 2015. Seed from each accession of the climbing bean collection will be processed for DNA extraction and SNP genotyping. The timing is actually

perfect since it will coincide with the arrival of the three new students that will work with these accessions (Objective 4.1).

Initially, the core collection of approximately 300 accessions will be evaluated with the set of ~6000 Single Nucleotide Polymorphism (SNP) markers available from the BeanCAP project (www.beancap.org) funded by USDA-NIFA. This set of markers is highly precise, reliable, and allow higher resolution and differentiation among genotypes compared to SSR markers. With the goal of having a better understanding of the organization of the genetic diversity of this group, we will extract DNA of the core 300 accessions and screen them with the 6k beancap chip and do a genetic diversity study of possible genetic relationships among the accessions.

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 it 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. In addition, a random group of 20 accessions previously identified as duplicates based on the SSR data will be also screened in order to confirm these results or evaluate the need to include more of these duplicates in the screening. Some of the results found in this study will aid in the planning and designing of the crossing block during FY2016.

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 could be used as a thesis topic to identify candidate regions associated with disease resistance genes for example.

2.2 Assessment of the intra-accession variability (NDSU): A Genetic assessment of variation within the 10 selected lines used in objective 1.1 and 1.2 will be made in order to account for the heterogeneity

at the molecular level not only among but within accessions and possibly, extrapolate that information to the rest of accessions. In addition, this information will be compared with the data obtained from visual evaluation of the phenotypic heterogeneity in the field.

Preliminary phenotypic observations in the field suggest that there is a high amount of genetic heterogeneity (heterozygocity) within accessions. Therefore, 20 plants from 10 random accessions will be planted in the greenhouse at NDSU and DNA will be extracted, for a total of 200 DNA samples/individuals. These genotypes will be also screened with a subset of INDEL markers developed in the NDSU bean molecular genetics lab (Moghaddam et al., 2013). The INDEL markers were developed from polymorphic SNPs, but their advantage is that they can be easily reproduced by PCR and visualized in an agarose gel. Since the main goal is to assess intra-accession variability, this will be easily detected by looking at the bands in the gels. Polymorphic Information Content (PIC) and other genetic parameters will be estimated.

2.3 Field evaluation of the ICTA collection of climbing beans (ICTA/NDSU): As mentioned before, the entire collection of climbing beans from ICTA was grown during 2014 at the ICTA station in Chimaltenango to allow a re-evaluation of the material and also the production of a newer batch of seed. Each accession was planted in short rows (~2 m) mostly for phenotypic observation. The project director (Juan M. Osorno) and co-PI (Phil McClean) spent few days along with ICTA personnel (Julio Villatoro and Fernando Aldana) evaluating the entire collection. The following traits were recorded: disease reaction under natural conditions (Ascochyta, Rust, Anthracnose) and pod distribution (upper vs. homogeneous distribution). A total of 23 accessions were selected based on the best combination of all these agronomic attributes. These accessions are currently being grown in the greenhouse at ICTA-Chimaltenango and used for crosses. In addition, it was decided to do another seed increase of the entire collection at ICTA-Chimaltenango during the 2015 growing season in order to do a final round of phenotypic evaluation in case something was missed in the previous year.

All this information will allow a better understanding of the organization of the genetic diversity within this core collection for future use and research. The results obtained in this first phase will allow making informed decisions about the potential parents for the following set of 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: Gustavo Mejia, Julio Cesar Villatoro, Fernando Aldana.

MSU: Mywish Maredia, David DeYoung, and Byron Reyes.

Approaches and Methods:

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

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

Collected data has been entered into a digital format (Excel) by ICTA personnel and is currently under revision and filtering of errors. Therefore, during FY16, data will be analyzed using the proper statistical tools and results will be summarized. Results of this survey will be shared not only within the project but with other projects currently working in Guatemala (e.g. Masfrijol) and government agencies interested. No field activities are planned for this objective during FY16.

3.2 Seed increase of samples collected during the survey (ICTA/NDSU): During the deployment of the survey, growers were asked to provide a small seed sample of the variety or varieties they commonly grow in their farms. Therefore, a seed increase has been planned during the 2015 and 2016 growing seasons at the ICTA-Chimaltenango station. This will provide an opportunity to do a phenotypic evaluation

of the germplasm collected during the survey and possibly to identify genetic material of interest for the breeding pipeline (Objective 1.2). In addition, the specific location from where each seed sample was obtained is available and therefore, some geographical diversity analyses are possible in the near future. Even more, the new germplasm collected during the survey could be compared with the original germplasm collection via SNP analysis (Objective 2.1) and try to establish some genetic similarities and hence, some possible geographical origin for the original germplasm collection since all the passport data was lost several years ago. We foresee this study as a good research topic for one of the students coming to do their M.S. training at NDSU (Objective 4.1).

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

4.1. Graduate Students:

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

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

4.2. Bean workshop at NDSU for ICTA personnel:

As described in the technical project description, a bean workshop has been proposed for the third year of this project. The goal of this training/workshop will be to show the visiting group how bean production is made in North Dakota (the largest producer in the U.S.) and also to receive training on plant breeding, plant pathology, molecular markers, and other genomic tools that could help in the breeding process. Activities will include field tours to breeding nurseries, commercial farming operations, and bean industries in the region. Priority will be given to ICTA personnel working on legumes, followed by other Guatemalan personnel from other government agencies and NGOs. Candidates from other bean programs from the region will be also considered if funds are available. We have budgeted funds to support 6 participants but additional funds could be sought to support additional participants (i.e. capacity strengthening grants). The workshop will be 1 week long during the month of August 2016. Other Legume Innovation Lab projects will be welcome to attend if they are willing to cover the cost for their participants.

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. Farmer's field testing of 12 selected lines (ICTA).
   - 1.2. Breeding pipeline (ICTA/NDSU).
   - 1.3. Genetic purification of selected material (ICTA).
   - 1.4. Field evaluation of Bolonillo-TEXEL (ICTA).
   - 1.5. Second crossing block (ICTA/NDSU).

2. **Objective 2:**
   - 2.1. Evaluation of core collection with the 6k SNP chip (NDSU).
   - 2.2. Assessment of the intra-accession variability (NDSU).
   - 2.3. Second field evaluation of the ICTA collection of climbing beans (ICTA/NDSU)

3. **Objective 3:**
   - 3.1. Tabulation of grower's survey data and statistical analyses (ICTA/MSU/NDSU).
   - 3.2. Seed increase of samples collected during the survey (ICTA/NDSU)

4. Objective 4:

4.1. Three graduate students at NDSU (ICTA-NDSU).

4.2. Bean workshop for ICTA personnel at NDSU (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. S01.A4). Therefore, some collaboration among projects is expected. The personnel from EAP-Honduras (J.C. Rosas) have also expressed their willingness 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.

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

Degree Training:

First and Other Given Names: Carlos Raul
Last Name: Maldonado
Citizenship: Guatemalan
Gender: Male
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: Geographical comparison of 2 germplasm collections in Guatemala

Start Date: August 2015

Projected Completion Date: December 2017

Training status (Active, completed, pending, discontinued or delayed): Delayed
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 in Guatemalan climbing bean germplasm collection.

Start Date: August 2015

Projected Completion Date: December 2017

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

Short-term Training:

Name of training program: NDSU Bean Workshop

Type of training: Informal Training
Description of training activity: Hands-on workshop on bean production, agronomy, breeding, genomics, and pathology.
Location: North Dakota State University, Fargo-ND.
Duration: 7 days (including travel)
When will it occur? August 2016

Participants/Beneficiaries of Training Activity: ICTA personnel, other Guatemalan government agencies, and NGOs, other bean programs from Central America and the Caribbean, other Legume Innovation Lab programs.
Anticipated numbers of Beneficiaries (male and female) 6 selected participants

PI/Collaborator responsible for this training activity: Juan M. Osorno and Phil MClean

Approximate budget allocation from USAID funds for training: $15,000

List other funding sources that will be sought (if any): Capacity Strenghtening Grants, other Legume Innovation Labs.

Training justification: North Dakota is the largest producer of dry beans in the U.S. and it is very important for bean researchers in developing countries to see and experience how bean production is accomplished in the region. In addition, the bean breeding program at NDSU has a lot of expertise that will be shared with the group as well. Many concepts and methods could be applied in their home countries in the future.

Equipment (costing >$5,000)**:**

None.

FY 2016 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 Plant Research Lab, Michigan State University

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

Kelvin Kamfwa, University of Zambia
Kennedy Muimui, ZARI, Zambia
Wayne Loescher, MSU
James Kelly, MSU
Tim Close, U.C. Riverside

Phil Roberts, U.C. Riverside

Maren Friesen, MSU, Plant Biology

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 hear and drought.

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

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

II. Project Activities for the FY 2016 Work plan Period (October 1, 2015 – September 30, 2016)

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

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

In response to altered starting times, and preliminary results, we have adjusted the 2015-2016 work plan.

Having identified conditions that result in substantial photosynthetic phenotypic differences between selected parent lines, in the 2015-2016 work year, we will focus on building rapid, high throughput methodology for mapping QTLs associated with these properties using the DEPI platform. The key question we will ask is: how can we reliably (with high statistical power) probe photosynthetic responses in RIL and GWAS lines?

Greg Austic (MSU)

Dan TerAvest (MSU)

Robert Zegarac (MSU)

Donghee Hoh (MSU)

Kelvin Kamfwa (MSU/U. Zambia)

Wayne Loescher (MSU)

James Kelly (MSU)

Phil McClean (NDSU)

Stanley Nkalubo (NaCRRI, Uganda).

Approaches and Methods:

1) Test a range of developmental times to determine the smallest plants and most rapid protocols that show consistent, strong phenoptypes (Target date: Feb, 2016).
2) Extend these assays to common bean GWAS genotypes (Target date: April, 2016)
3) Test selected lines to determine the feasibility of QTL mapping using DEPI approach (Target Date: June, 2016).
4) Establish growth populations for initial QTL analyses in Zambia with collaborator Kamfwa (Target Date: March, 2016).

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

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

Collaborators:

Kelvin Kamfwa (U. Zambia)

Wayne Loescher (MSU)

Phil McClean (NDSU)

Stanley Nkalubo (NaCRRI, Uganda).

Approaches and Methods:

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

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

Training and initiation of field research at UC Riverside and NDSU. We are expecting a new student, Isaac Osei-Bonsu, a Legume Scholars Program, from Ghana to join the project. Isaac will initially work on the with the UC Riverside or NDSU groups to help train and interpret data from

common bean and cowpea field trials set up with our collaborators in NDSU and UC Riverside. The student team will be immediately supervised by Greg Austic, Dan TerAvest and Jeffrey Cruz (USA, Kramer lab).

The goals for 2015-2016 year:

5) Transferring 15 PhotosynQ MultispeQ units to Zambia and initiating first field trials (Sept 2015-Jan. 2016).

6) Training of four students in Zambia in the use of PhotosynQ platform (Target Date: Jan. 2016).

7) Testing of field measurement protocols in Zambia (Target Date: Jan., 2016)

8) Development of rapid cowpea and common bean phenotyping protocols in DEPI chambers (Target Date: Feb., 2016)

9) Initial feasibility study of cowpea lines for QTL mapping in DEPI (Target Date: March, 2016)

10) Initial feasibility study of cowpea lines for QTL mapping in UC Riverside (Target Date: Sept. 2016)

11) Initial feasibility study of common bean lines for QTL mapping at NDSU (Target Date: Sept. 2016)

12) Detailed study of selected cowpea or bean lines for phenotypes under simulated environmental conditions (Target date: Oct, 2016)

13) Use DEPI results from outcome 12 to determine which sets of lines are most promising for QTL mapping (Target date: March-April, 2016)

14) Assessment of field performance of PhotosynQ platform in Zambia (Target date: Oct, 2016).

Objective 3) Development of Data Management Plan:

As a part of the development process, we proposed to modify the PhotosynQ platform to meet the needs of the project. Our initial work shows at least one area (data privacy) that needs urgent further development.

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 annonymization layers into the PhotosynQ platform. This effort will not require additional funds because we were able to obtain first year support for student Donghee Hoh and expectation of the arrival of our new Legume Scholars student, allowing us to use allocated funds to support a web programmer.

Collaborators: Greg Austic (MSU)

Specific goals:

15) Develop privacy layers for PhotosynQ platform and inform/train LIL researchers in their use (Target Date: Feb. 2016)

16) Further development and refinement of data management layers (Target Date: September, 2016).

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 2015 and 2016 following FTF guidelines.

IV. Outputs:

1) Establishment of first proofs of concept for QTL mapping of photosynthetic properties in cowpea and common bean in controlled simulated environments;
2) Establishment of a working phenotype group in Zambia2)
3) Development and implementation of a Data Management Plan for PhotosynQ that includes critical privacy layers
4) Training of two graduate students at MSU and 4 at U. Zambia

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:

1) 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 MultiSpec sensor for the platform is being 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". In addition the social networking aspects of the PhotosynQ platform are being developed under a grant from USAID through the MSU Global Center for Food Safely Innovations.

2) MAGIC and GWAS populations and on-going field trials by Tim Close, Phil Roberts and Phil McClean are supported by grants from USAID.

VIII. Timeline for Achievement of Milestones of Technical Progress:

(Complete the "Milestones for Technical Progress" form for the FY 2016 workplan period. These milestones of progress should be viewed as specific benchmarks toward achievement of research, outreach and institutional capacity building objectives by the respective participating institutions, plus be considered as specific "deliverables" for incremental payments under Fixed Term Contracts with sub-subcontracted institutions in the project. Please be reminded that success in achieving milestones will also be reported at the end of each fiscal year and be a criterion for evaluation of project performance by the TMAC and USAID. Uncompleted milestones from a previous year must be carried over and reported. It is therefore important that the milestones be clearly identified (in terms of their

size/scale/scope and target location), quantity (to the extent possible), logistically feasible, and with the responsible institution(s) identified for completing each Milestone.)

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

Degree Training:

The project will contribute to the training of the following:

Degree Training:

First and Other Given Names: Kelvin

Last Name: Kamfwa

Citizenship: Zambian

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: University of Zambia

Thesis Title/ Research Area: Genetic dissection of biological nitrogen fixation in common bean using genome-wide association analysis and linkage mapping.

Start Date: August 2008

Projected Completion Date: November 2015

Training Status: Active

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/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

Degree Training:

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: First year graduate student

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

Short-term Training:

Type of training: Training of researchers in use of PhotosynQ platform
Description of training activity: There will be four levels (or phases) of training: 1) In the first phase, students will be trained at MSU in the basic science and technology behind photosynthesis measurements, the PhotosynQ and DEPI platforms, as well as the use of these technologies for assessing plat health and mapping genetic bases of phenotypes.

2) In phase 2, these students will develop educational modules that will allow them to transfer this knowledge to students and researchers in US and HC. These will immediately be useful for distance (internet) based training in U. of Zambia. We will focus on both undergraduate and masters students at U. Zambia under the direction of Kelvin Kamfwa. Special efforts will be made to ensure that this aspect of training will be gender balanced, especially focusing on a pool of 5-10 female students currently enrolled in the program.

3) Students will travel to NDSU and US Riverside to train researchers in the use of the technology.

4) In the next year's work, HC students will train researchers and students in their respective HCs.

Location: MSU, NDSU, UC Riverside, Zambia, Uganda.
Duration: 9 months
When will it occur? From Jan, 2015 through Sept, 2016

Participants/Beneficiaries of Training Activity:

The on-site training at MSU will immediately benefit students Kelvin Kamfwa, Issac Dramadri and Donghee Hoh..

The second-level training will benefit up to 20 undergraduate and masters students at U. Zambia.

Anticipated numbers of Beneficiaries (male and female) 10 male and 10 female students

PI/Collaborator responsible for this training activity: D. Kramer and Kelvin Kamfwa.

List other funding sources that will be sought (if any): We plan to seek funding from NSF or Gates Foundation to establish a network of educators around the world to make educational

modules for the PhotosynQ platform. Each of these modules will target a different audience (region, education level) and topic (scientific or technological focus or issues). The current project will be a model for these efforts.

Training justification

Training is at the heart of the project, as it aims to bring new technologies for plant breeding to the world.

Equipment (costing >$5,000)**: None**

FY 2015 – 2016 WORKPLAN

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 2015-16

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. Assemble a common nursery across participating countries of about 80 lines considering the differential information for ANT (CIAT), ALS (CIAT), CBB (MSU), and rust (MSU/SABRN). Collaboration with S01.A4 will be explored.
2. Assemble a drought nursery of 60 lines and develop the drought screening protocol to be used. Collaboration with S01.A4 will be explored.
3. Seed increase in each country. Each participant country will receive 100 seeds of each line and increase them.
4. Screen the disease nursery to different pathogens in greenhouse in Zambia. The races to be used will be determined from objective 2.
5. Initiate selection for disease resistance in field and under screen house inoculation condition in Zambia.
6. Screen the disease nursery to different pathogens (rust, ANT, and ALS in screenhouse and field conditions in Uganda. The races to be used will be determined from objective 2.
7. Continue with selection for disease resistance under screenhouse inoculation condition in Uganda.
8. Screen the disease nursery to CBB in North Platte, NE.
9. Screen a subset of the Andean panel and NIFA root rot lines to terminal drought in Scottsbluff, NE.
10. Screen the drought nursery in Uganda and Zambia to intermittent drought stress.
11. Screen the drought nursery in Nebraska to terminal drought stress.
12. Cross sources of resistance for angular leaf spot (ALS), rust, anthracnose, common bacterial blight, and drought tolerance into large seeded lines with contrasting colors in Uganda, Zambia, Nebraska and Michigan.
13. Few selected climbers in each country will be crossed to sources for ALS, ANT, CBB, and rust resistance.
14. Use of markers identified in objective 3 to make selections in each country
15. Screen Andean lines for cooking time using a pin drop (Mattson cooker) method.
16. Canning evaluation of climbing sugar beans from Uganda
17. Evaluate Andean elite lines for micronutrient bioavailability in MI and NE.
18. Evaluate three non-destructive, high throughput methods to measure cooking time and seed chemical composition.
19. 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.

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. Continue with the collection of isolates of ANT, ALS, CBB, and Rust in different production regions of Uganda.
3. Increase seed of the differentials for ANT, ALS and rust in Zambia and Uganda
4. Race characterization of ANT and ALS in Zambia. Rust characterized at UNL.
5. Initiate race characterization of ANT, ALS and Rust in Uganda.
6. Utilize the mobile nursery protocol to determine the effectiveness of rust resistance genes in genotypes in Zambia and Uganda**.**
7. 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 and Uganda.
8. Select the most informative genotypes for each country/location to include in future mobile nursery evaluations in individual countries and /or locations.
9. Increase seed of these selected genotypes for inclusion in the mobile nursery.
10. Choose the most relevant races of ANT, ALS and rust and strains of CBB for screening breeding nurseries in Zambia.
11. Choose the most relevant races of ANT, ALS and rust and strains of CBB for screening breeding nurseries in Uganda.
12. 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.
13. 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 bioavailablity 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 bioavailablity in Michigan, Uganda, and Zambia.

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 extensively rely 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 (e.g., Urrea, Kelly).

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, Kelvin Kamfwa in plant breeding, genetics and biotechnology will conduct field research on BNF on genetic population(s) in Michigan and Zambia. A Masters student Grady Zuiderveen from the US will be involved in GWAS for anthracnose resistance. 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. Conduct short term training for Ms. Blessing Odogwu in marker research to detect rust resistance in Ugandan breeding lines at MSU and UNL. 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.
3. Provide short term training of graduate students, collaborators, and visiting scientists on phenometrics at MSU.

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 and 2015 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 bioavailablity 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 chl 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 accessing SNP Markers developed through that program.

- 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.
- USAID funded Feed the Future Project: Development and dissemination of multiple pathogen and drought resistant/tolerant nutritionally enhanced bean varieties for the semi-arid and other regions of Uganda –PI-M.A. Ugen, NaCRRI, Uganda.
- Bean utilization project funded by ASARECA: Utilization of Bean Innovations for Food Security and Improved Livelihoods in Eastern and Central Africa - PI-M.A. Ugen, 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-ARS FTF Dry Bean project which is genotyping and phenotyping the Andean Diversity Panel for numerous traits in multiple locations in the U.S. and Africa.
- 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.
- Ugandan MS student in Food Science at MSU funded through MasterCard will work on the project.
- 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 and FY15 have been completed for each objective listed in the workplan.*

Training/Capacity Building Workplan for FY 2015 – 2016

Degree Training:

First and Other Given Names: Kelvin

Last Name: Kamfwa

Citizenship: Zambian
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: University of Zambia

Thesis Title/ Research Area: Genetic dissection of biological nitrogen fixation in common bean using genome-wide association analysis and linkage mapping.

Start Date: August 2008

Projected Completion Date: December 2016
Training Status: Active

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

Degree Training:

First and Other Given Names: Grady

Last Name: Zuiderveen

Citizenship: US
Gender: M
Training Institution: MSU

Supervising Legume Innovation Lab PI: James D. Kelly
Degree Program for training: MS
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: SNP marker development for major resistance genes

Start Date: August 2013

Projected Completion Date: August 2015
Training Status: Pending

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

Degree Training:

First and Other Given Names: Jesse

Last Name: Traub

Citizenship: US
Gender: M
Training Institution: MSU

Supervising Legume Innovation Lab PI: 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 differences among *Phaseolus vulgaris* cultivars differing in drought tolerance.

Start Date: August 2013 on Legume Innovation Funding

Projected Completion Date: December 2015

Training Status: Current graduate student with University Distinguished Fellowship from MSU for his first and final years of study FY11 and FY15 at MSU.

Type of Legume Innovation Lab Support (full, partial or indirect): Partial – one year funding FY14

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 will 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: Drought and Disease Screening methods
   Description of training activity: Take staff through drought screening protocol, isolation and inoculation techniques for ALS, Rust, CBB
   Location: National Crops Resources Research Institute, Namulonge, Uganda
   Duration 7-10 days
   When will it occur: Between November 2015- March 2016
   Participants/Beneficiaries of Training Activity: Research and technicians and Ugandan PI
   Anticipated numbers of Beneficiaries (male and female) 10 (6 males and 4 females)

   PI/Collaborator responsible for this training activity James Kelly/ Jim Steadman/Carlos Urrea/ Stanley Nkalubo

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

   Training justification: Understanding the different screening methods and how they are applied for the different stresses is important to avoid escapes and useful phenotypic data.

3. Short term training for Borlaug LEAP Fellow, Ms. Blessing Odogwu in marker research to detect rust resistance in Ugandan breeding lines at MSU and UNL. December 2015

FY 2016 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 (BCMV), *Bean Common Mosaic Necrosis Virus* (BCMNV) and BGYMV. Regional performance trials will be conducted in Central America and the Caribbean to measure the durability of the resistance when exposed to different genera and ecotypes of bruchids.

The 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. 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 soils, high temperature).

Improved black, red mottled, white and small red bean germplasm lines and cultivars have been released in Central America and the Caribbean during the first few year 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 common bacterial blight, bruchids and other important traits have been identified. Resistance to BCMV, BGYMV, larger seed size and improved agronomic traits, would increase the potential adoption of tepary beans. Interspecific crosses with common beans could be used to introgress these traits into 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 *nod*C, *rec*A y *atp*D 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 will assist this effort through the development of the populations and information needed to identify improved markers for traits such as the *Ur-11* gene for rust resistance.

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 Workplan Period (October 1, 2015 – September 30, 2016)

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. Bruchid resistant Andean bean lines with BCMV and BCMNV (*I* + *bc-1*^{2}) resistance have already been developed. Considerable progress has also been made toward the development of black beans that combine bruchid and virus resistance. During FY16, a small group of lines selected in Puerto Rico for bruchid resistance will be tested in Central America and Haiti to evaluate the durability of resistance when exposed to different ecotypes of *Acanthoscelides obtectus* and other genera (*Zabrotes subfasciatus*) of bruchids.

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 UPRM.

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 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 screenhouse 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 FY16:

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 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).
- Conduct the third cycle of recurrent selection for resistance to terminal drought.
- Characterize the variability of *Phaeoisariosis griseola* isolates from Guatemala and Honduras.
- Validate in Honduras the resistance to ALS found in the Middle American and Andean Diversity Panels.
- Test the performance of bruchid resistant lines when exposed to natural infestation and other ecotypes y genera 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 by the end of the five-year extension period. 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 *Rhizoboium* 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)
- Conduct field trials to test the performance of elite lines selected from the second cycle of recurrent selection for enhanced biological nitrogen fixation.
- Test the performance 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 root 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
- 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 F_4 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.

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 interespecific (tepary bean x common bean) populations to establish symbiosis with *Rhizobium* and/or *Bradyrhizobium* using *nod*C, *rec*A y *atp*D genes will be studied.

Additional sources of disease resistance will be evaluated using the CIAT tepary bean collection (about 250 accessions). These accessions will be evaluated for CBB and BCMV.

Breeding and introgression of BGYMV res., *I* 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.
- F_1 Pv x Pa hybrids were completed during FY14 from crosses between selected parents above at ARS-TARS.
- Embryo rescue was initiated from the BC_1F_1 generation material through collaboration with the U. of Saskatchewan.

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.

- 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 CIAT tepary bean germplasm collection (~250 lines) were evaluated for response to NL3 at the UPR (FY15) using leveraged ARS-FTF funds. Evaluate RILs to identify genes and markers for resistance.
- The CIAT tepary bean germplasm collection was evaluated for BGYMV in Honduras - Multi-location testing of improved tepary bean breeding lines. BGYMV Resistant lines crosses with tepary beans 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 *I* gene for BCMV, the *Ur-11* gene for rust, *Phg-1* gene for angular leaf spot, the *Co-4*^{2} for anthracnose, and the new Xa11.4 QTL for CBB 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 gene developed
- Populations will be developed for subsequent development of improved markers for BGYMV resistance genes and QTL (*Bgp*, SW12, and *bgm*).
- 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 Ph.D. and M.S. degree students will be provided a broad range of training in conventional and molecular plant breeding techniques so that they can assume roles of leadership in

bean research programs in the target countries. Informal training of technicians should improve the reliability and quality of bean research conducted in host countries.

Informal training

- In-service training will be provided 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 workshop will be held in Honduras in November 2015 to train technical personnel concerning topics related to the production, processing and storage of bean seed. Special emphasis will be placed on the breeder and basic seed stocks so that bean research and seed programs in Central America and Haiti can become more self-reliant.

- In collaboration with the Penn State University CRIB Project, a workshop concerning abiotic stress will be held in Honduras in December 2016. The latest advances in the development of bean with greater tolerance to abiotic stress will be discussed. Research techniques used to screen beans for resistance to abiotic stress will also be discussed.

- 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 possible 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 has received funds from the USDA that are being used to support a graduate student from Nicaragua (Ana Vargas). He 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. 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. We also proposed to strengthen the capacity to produce *Rhizobium* inoculant that should increase bean yield in low N soils.

VIII. Timeline for Achievement of Milestones of Technical Progress:

Please refer to the document describing milestones

Training/Capacity Building Workplan for FY 2016

<u>Long-term training</u>:

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: Aug. 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: Julian
Last Name: Colley Pabón
Citizenship: US Puerto Rico
Gender: M
Training Institution: University of Puerto Rico
Supervising CRSP PI: Consuelo Estevez de Jensen Degree Program for training: M.S.
Degree Program for training: M.S.
Program Areas or Discipline: Plant Pathology
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: Resistance to Macrophomina phaseolina
Start Date: January. 2015
Projected Completion Date: December. 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: Pablo

Last Name: Pizarro

Citizenship: Ecuador

Gender: M

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: Evaluación de la resistencia a gorgojos de grano *Acanthoscelides obtectus* y *Zabrotes subfasciatus* en frijol común.

Start Date: Jan. 2015

Projected Completion Date: Dec. 2015

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: Tatiana

Last Name: Escobar Vados

Citizenship: Honduras

Gender: F

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: Evaluación de la resistencia a gorgojos de grano *Acanthoscelides obtectus* y *Zabrotes subfasciatus* en frijol común.

Start Date: Jan. 2015

Projected Completion Date: Dec. 2015.

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: Jason

Last Name: Rizo

Citizenship: Nicaraguan

Gender: M

Thesis Title/Research Area: Evaluación de líneas de frijol tolerantes a baja fertilidad.

Start Date: Jan. 2015

Projected Completion Date: Dec. 2015.

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: Johan

Last Name: Gabor

Citizenship: Ecuador

Gender: M

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: Evaluación de líneas de frijol tolerantes a baja fertilidad.

Start Date: Jan. 2015

Projected Completion Date: Dec. 2015.

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: José Manuel

Last Name: Martínez

Citizenship: El Salvador

Gender: M

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: Caracterización de razas de *Pseudocercospora griseola* y la resistencia a la mancha angular del frijol.

Start Date: Jan. 2015

Projected Completion Date: Dec. 2015.

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: Luís Alonso

Last Name: Peñate

Citizenship: El Salvador

Gender: M

Thesis Title/Research Area: Caracterización de razas de *Pseudocercospora griseola* y la resistencia a la mancha angular del frijol.

Start Date: Jan. 2015

Projected Completion Date: Dec. 2015.

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: Luis

Last Name: Monserrate

Citizenship: Ecuador

Gender: M

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:Evaluación de germoplasma de frijol por la resistencia a la mancha angular.

Start Date: Jan. 2015

Projected Completion Date: Dec. 2015.

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: Henry

Last Name: Espinoza

Citizenship: Ecuador

Gender: M

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: Evaluación de germoplasma de frijol por la resistencia a la mancha angular.

Start Date: Jan. 2015

Projected Completion Date: Dec. 2015.

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: Juan

Last Name: Nuñez

Citizenship: Honduras

Gender: M

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: Evaluación de germoplasma de frijol para la tolerancia a altas temperaturas.

Start Date: Jan. 2015

Projected Completion Date: Dec. 2015.

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: To be determined (TBD)

Last Name: TBD

Citizenship: TBD

Gender: TBD

Training Institution: North Dakota State University Supervising CRSP PI: Phil McClean and Juan Osorno Degree Program for training: Ph.D.

Program Areas or Discipline: Plant breeding and genetics

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

Host Country Institution to Benefit from Training: TBD

Thesis Title/Research Area: TBD

Start Date: TBD

Projected Completion Date: TBD

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: To be determined (TBD)

Last Name: TBD

Citizenship: TBD

Gender: TBD

Training Institution: North Dakota State University Supervising CRSP PI: Juan Osorno and Phil McClean Degree Program for training: Ph.D.

Program Areas or Discipline: Plant breeding and genetics

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

Thesis Title/Research Area: TBD

Start Date: TBD

Projected Completion Date: TBD

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

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? - 2016

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.

Type of training: Workshop

Description of training activity: A workshop will be held in Honduras to train technical personnel concerning topics related to research for improving the tolerance of common bean to abiotic stresses (drought, heat and low fertility).
Location: Honduras
Duration: One week

When will it occur? - December 2015

Participants/Beneficiaries of Training Activity: Technicians working for bean research programs in Central America and Haiti.

Anticipated numbers of Beneficiaries (male and female): 20

PI/Collaborator responsible for this training activity: Juan Carlos Rosas and James Beaver

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

Training justification: Trainees will improve their skills in conducting field and laboratory research to screen germplasm and breeding lines for tolerance to abiotic stress factors. This should improve the quality and reliability of research conducted in host countries

Equipment (costing >$5,000)**:** None during FY-16

FY 2016 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 Batieno, Institut de l'Environment et des Recherches Agricole (INERA), Koudougou and Kamboinse, Burkina Faso

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

Ndiaga Cisse, Centre National Recherches Agronomie, Bambey, Institut Senegalais de Recherches Agricole (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. Planned Project Activities for the Workplan Period (October 1, 2015 – September 30, 2016)

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 is being applied in FY15 and will be applied during FY16 to parents and derived mapping populations focusing on the QTL discovery phase. 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 send 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 FY14 and FY15 (short-term training workshops and adoption).

1.1 Aphid resistance: We will test the genetic relatedness of five sources of cowpea aphid (*Aphis craccivora*) resistance. Field observations in Africa and California indicate differential effects of resistance sources on aphid populations from different cowpea production areas. Cowpea lines IT97K-556-6, KvX295-2-124-99, an IITA wild donor line (TVNu1158), UCR01-11-52/SARC1-57-2, and 58-77 representing a set of resistance donor genotypes plus known susceptible control lines were seed-multiplied in 2014 and again in spring 2015. 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 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 FY15 starting in July. Following additional seed increases, the tests will be conducted in main season FY16 to provide a minimum of 2-3 years of data. 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 if, as expected, aphid biotypes are delineated on the cowpea resistance sources. Samples of aphids will be collected and stored for DNA and RNA

extraction (using RNAlater kits), with a view to developing 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 will be compared. In Burkina, we have an F2 population between a susceptible elite line and resistance donor KvX295-2-124-99. For QTL mapping, this population is being advanced to F3 families in FY15 and will be phenotyped and genotyped in FY16. From the wild donor IITA line TVNu1158 a RIL population has been developed for mapping QTL and seed increase is underway in FY15. We plan on phenotyping and genotyping this population in FY16. This work is being planned 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 Tvx3236. 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 FY15 and FY16 workplan periods. This will provide multiple years and locations of phenotyping data. Additional germplasm lines will be included in the screening sites to search for more sources of resistance in both FY15 and FY16. 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 Tvx3236 were intercrossed in all combinations by Dr. Cisse in FY14; these populations are being advanced to F3 in FY15 and to F6 in FY16 and phenotyped. 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 will be advanced to F4 in FY16. 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 will phenotype the three F7 populations for thrips tolerance in the FY15 workplan main season using the previously described experimental protocols. This will provide a second year of phenotyping data. The F3 families will be SNP genotyped using bulked leaf disks from 20 plants per family. Depending on progress, we will focus on the IT97K-499-35-derived population for improvement. In Ghana, to match the genotyping and phenotyping data of the Thrips /aphid/Striga populations, leaf samples of 272 single seed families have been sampled for SNP genotyping and the plants currently been giving the needed care and protection to produce enough seeds for phenotyping. The FY16 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 will combine Striga and Thrips will be further evaluated. The seeds of the selected families will be increased to enable availability of 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, F3) on F3 plants are being genotyped and phenotyped in FY15 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 FY16 to provide validated QTL mapping data. Additional potential tolerance donor lines are included in the initial phenotyping screens in FY15, including those in the pedigree of resistance donor IT86D-716, to broaden the knowledge base and potentially identify additional sources of tolerance. Two existing F2 populations generated from resistance donor IT86D-716 with parents Kvx771-10 and IT98K-205-8 enable combining Striga resistance with pod-sucking bug tolerance. The parents have been genotyped through LGC Genomics and the F2 and F3 populations will be phenotyped in FY15 and FY16 for pod bug resistance in Burkina Faso, in collaboration with Dr. Dabire. The F2 were advanced to F3 in FY15 to provide screening resources for FY15 and FY16. 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 FY15. 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 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.

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 Moussa Local, Gourgou 3, 7 and 11, Nafi, and IT98K-205-8). We are genotyping Burkina Faso BC5 and Ghana BC2 progenies in FY15 and our plan for FY16 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 will be 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 they will be 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 screenhouse 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 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 FY15 –FY16.

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 are being 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 FY15 and FY16 seasons using sites at Bambey. The Foundation Seed will be used by Certified Seed producers in the main season 2016, with training inputs from Dr. Cisse. BC4F3 lines of Melakh with Striga resistance will be available for evaluation during FY 16 main season.

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 are being 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 are being re-evaluated in FY15, 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 2015 or 2016 depending on the committee meeting schedule. Breeder Seed of the best lines chosen for release submission based on main season 2014 and off-season 2015 performance data will be

produced at Saria during the main season 2015 (June – October). The Breeder Seed will be used to initiate Foundation Seed production in the FY16 off-season and start Certified Seed production in the FY16 main season.

In California, we will field test advanced breeding lines for release potential, based on performance data collected in 2015. 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 will conduct on-farm yield strip trials in a Tulare Co. farmer's field to assess commercial yield performance. 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.

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 will use the same format for the workshop in FY16, to be held in Livingstone, Zambia in February preceding the World Cowpea Conference. The molecular breeding approach is complex and requires a combination of hands-on experience with self-generated data sets, augmented with periodic intensive training workshops to improve knowledge, skills and problem-solving. The technologies underlying the genotyping capability are in a state of frequent enhancement and upgrade, requiring periodic training input. Thus both young breeder trainees new to the programs and experienced breeders from the HC NARS are in need of this training. Training materials and protocols 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 MS 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.

F3s will be generated from thrips resistance sources intercrosses (Senegal).

Data from phenotyping 3 F7 populations with Sanzi donor parent (Ghana).

Genotyping data from F3 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).

Two 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 2016, the UC-R PI and Co-PI will make a field visit to HC Senegal to review and coordinate field based phenotyping activities. During this HC trip, we will arrange to visit the Senegal USAID mission. 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 and Ghana, following field visits in 2014 to Burkina and 2015 to Ghana (planned), 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. Batieno (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 Promise project of CARE International which seeks to introduce improved quality cowpea varieties as well as IPM strategies for cowpea production to farmers.

VII. Leveraging of CRSP 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 has been extended to November 2015. The cowpea component of this project is led by UC Riverside (Roberts and Close) and includes 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 is applying 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 are being targeted 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, has been approved for funding for four years commencing in summer 2015. In the cowpea objective, UCR ($260,000) will contribute SNP genotyping work and guide its application in cowpea breeding, while INERA–Burkina Faso ($519,396) and SARI-Ghana ($319,271) will contribute trait discovery and breeding line development plus cowpea seed system development. These projects provide excellent leveraging for CRSP activities described here to be used for cowpea modern breeding. The projects also link us to the GCP-Integrated Breeding

Platform project which is developing a 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 (Roberts and Close) has 2015 pending applications for cowpea funding with NSF/BREAD and USDA-NIFA 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. Batieno.

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

Kirkhouse Trust provided funding for SARI to improve the field resistance of five cowpea lines using MABC. These lines are current being evaluated in multilocation on-farm 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.

Training/Capacity Building Workplan for FY 2016

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: 12/2016

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 two of these workshops were held in March 2014 and March 2015 at UCR. We will convene next year’s training workshop immediately preceding the Pan-African Grain Legume and World Cowpea Conference.
Location: Livingston, Zambia
Duration 3 days
When will it occur? February 2016

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 (costing >$5,000)**:** None requested during this period.

FY 2016 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, University of Illinois at Urbana-Champaign (UIUC)

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

Dr. Manuele Tamò, IITA-Benin (HC-PI)
Dr. Clémentine Dabiré-Binso, INERA-Burkina Faso (HC-PI)
Mr. Laouali Amadou, INRAN-Niger (HC-PI) (Requested replacement for Dr. Ibrahim Baoua)
Dr. Ibrahim Baoua, University of Maradi (collaborator with INRAN; no direct funding)
Dr. Stephen Asante, SARI, Ghana (HC-PI)
Dr. Haruna Braimah, CRI- Ghana (HC-PI)
Dr. Julia Bello-Bravo, UIUC (US Co-PI)
Mr. Eustache Biaou, INRAB-Benin INRAN-Niger (Requested replacement for Mr. Leonard Hinnou)

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 uguiculata* [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. virata* 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 FY16/17) 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 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, 2015-September 30, 2016)

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":

IPM-omics = ***define the pest problems*** + ***appropriate solutions*** + ***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 4-years 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. **Omics** 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 follows "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 flora (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 tool.

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 limited 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.

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 created 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 Ehtiopia 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. 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. 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. 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 FY16 (and FY17) we will heavily focus on pathways for "pass off" of our educational content to other groups that can integrate these materials into their educational and extension programs.

It is important to note that we have recently 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 a developed 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) GIS systems – 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 4.1 - 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 UIUC to determine pest movement patterns within regions (on cowpeas and alternative host plants). We will also develop interfaces to summarize our findings in a visual format.

Collaborators:

Dr. Brad Coates, USDA, Iowa State University (Genomics)

Dr. George Czapar, UIUC (GIS systems)

Dr. Phil Roberts, UCR (Genomics)

Dr. Baoua Ibrahim, University of Maradi (Pest Insect Biology)

Approaches and Methods:

The following activities will occur in FY16 (Step 4.2 in our Program logic 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 indentify each species as well as the host plants where they are known to occur. We also will work with SO1.A5 on the collection of insects from their field tests. This information will be placed up against GIS data (at UIUC) to better understand the impact of environmental parameters on the pest biology. 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 increase to upwards of once a week (where appropriate) both in cowpea fields and on wild alternative host plants. Samples of these insects will be sent back to UIUC for SNP and microsatellite analyses. For example, in Burkina Faso the sampling is done through different agro ecological zones of Burkina Faso (Pobé, Kamboinsé and Bobo Dioulasso). 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 ultimate 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 UIUC 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 receive 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 $1000 in travel and $1000 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 $1000 in supplies and costs. Both at SARI and CRI the following budget will be used for these activities: (1) $1000 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 $66,497.00 in salaries and in $29,705.00 benefits along with $13,200 supplies will benefit this section and the development of the interface to make the outputs available to the rest of the community). 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 feed 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 4.3 of the our Impact Pathways we will (a) have novel *Maruca* parasitoids available for inoculative releases; b) new information available to better target thrips parasitoid releases; (c) prototype deployment devices for pod bugs egg parasitoids available for validation with farming communities; (d) endophytic strains of *Beauveria bassiana* available for testing in all countries; (e) *Maruca* virus available for integration into IPM packages at FFF sites.

During this phase we propose (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 4.2 for this section: (a) novel *Maruca* parasitoids from Asia introduced to the IITA laboratories for initial screening; (b) scale-up the rearing and release of the thrips parasitoid in all participating countries; (c) sex and aggregation pheromones for pod sucking bugs investigated; (d) PCR techniques developed for detecting endophytic strains of *Beauveria bassiana* in the different tissues of cowpea; e) feasibility of storing *Maruca* virus both as liquid and solid substrate investigated (IITA).

Collaborators:

Dr. Ramasamy Srinivasan, AVRDC, Taiwan (Biocontrol agents of *M. vitrata*)

Dr. Rousseau Djouaka, IITA, Benin (Molecular biology)

Dr. Ousmane Boukar, IITA, Nigeria (Resistant varieties)

Dr. Phil Roberts, UCR, USA (Resistant varieties)

Approaches and Methods:

During FY16 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 start new ones for *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 established 9 months ahead of 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 start elucidating 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 two localities in Benin (Dassa and Glazoue), 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 FY16. (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 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) $1000 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) $5000 in salaries, (2) $500 in benefits, (3) $1000 in travel, and (4) $1000 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. This section some level each of the Steps 1-3, in the impact pathway, should occur within this year. In terms of Program Logic, step 4.1 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) $10000 in salaries, (2) $1000 in benefits, (3) $1000 in travel, and (4) $3000 in supplies. For INRAN the following funds will be used for scaling of solutions activities: (1) $5500 in salaries, (2) $550 in benefits, (3) $2000 in travel, and (4) $1500 in supplies.

Collaborators:

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

Dr. Mywish Maredia, MSU

Dr. Byron Reyes, MSU

Approaches and Methods:

(1) Direct release into the environment and natural establishment - In FY16, 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 and establishment impact on cowpea crops and their expected positive impacts on cowpea farming systems and cowpea farmers themselves.

(2) Educational solutions – As part of 4.3 in our impact pathway, ICT training packages and content will be made available through online and in country training, available packages undergoing third year of test of FFF for impact through collaborative organizations. Over F13-14 we 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). 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, have a new "App" for easy access and download for our educational materials. The Android App has been approved by UIUC legal team and has been released. 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, 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 $7000) direct spendable will be used for these activities, including $1500 (non-degree training) of which will be used in INRAB personnel time to train IITA staff of these assessment approaches. Another $2000 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."* This section some level each of the Steps 1-3, in the impact pathway, should occur within this year. In terms of Program Logic, step 4.3 and 4.4 will occur (see cell 19J and K of the Impact pathway template as well): 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, 3) technician training on biocontrol agent production and release. Both at SARI and CRI $1100 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 not a Postdoctoral fellow at Yale University, previously supported by a Howard Hughes Fellowship, and will have published all of her thesis papers by the end of FY16. 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 incoming students have been identified, including several undergraduate trainees. We will continue to train students at the B.S,/B.Sc., M.S. and Ph.D. levels – each country will train students at different degree-levels depending on needs and opportunities. The UIUC program will be potentially receiving another MS student to attend UIUC, however, and this is expected to occur at the end of FY15. The Legume Scholars Program will support this female MS student.

We will continue with the students: (1) one BS student will be partially supported at SARI in Ghana (entomology - $1500), (2) one BS student will be partially supported at CRI in Ghana (entomology - $1500), (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 assistant on the assessment studies - $5000 for this partial support), (3) one PhD student will be partially supported at INERA (entomology - $5000), (4) one honors or MS student will be partially or fully supported at INRAN in Niger (entomology $2950), and (5) three more PhD or MS students will be partially/fully supported at IITA in Benin (entomology – partial support for each student at $5000 per student). This brings a total of eight students. The UIUC program will be actively looking to find another MS or PhD student from one of the HC to attend UIUC, however, this will not occur in FY15, as it will not be possible to bring in a student (from an admissions prospective) until the fall of 2015. Additionally, such a student, if identified, would be supported by UIUC funds.

Short-term training – We will be developing tools for short term training and testing these. We see developing 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 efforts in FY14-15 is that "piggy backing" on other educational programs or existing extension/education networks it likely to provide us with the most "cost effective" to 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 for each of these countries and initiate new animations where the educational content is needed), make available that 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 with Bluetooth), (2) we will promote and perform ICT training sessions for our collaborators and outside groups like NGOs, other government and international organization (such training sessions will occur online three times per year and one in-country once per year). 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 UIUC to support activities to develop and implement training materials and sessions. An additional $6005.00 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 minimal 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 $5000 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 FY16. IITA will use $11,300 of their budget for these activities.

Capacity building awards. INRAN and INERA both applied for and were granted capacity building awards in FY15. The details of these awards and activities were outlined in their proposals and approved by the TMAC.

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 another 1 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 and we expect to lay these data over known GIS data.

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 will be presented on IPM-omics at the Innovation Lab Workshop to be 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. Thus, we have already begun 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 will be handed to NARS programs for testing, use and deployment 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 ones – 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 UIUC will be used for UIUC faculty, staff and/or students to visit with IITA and/or NARS scientists in the course of the FY16 along with potentially one UIUC team member attending the PanAfrican Grain Legume and World Cowpea Conference). 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 UIUC team will leverage funds from the ADM Institute for the Prevention of Postharvest Losses, endowment funds, and funds from the Chancellor's Office (UIUC). Additionally, the MO, IITA and UIUC 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 2013 – 2014 (use format below)

Degree Training:

First and Other Given Names: Viviana
Last Name: Ortiz Londono
Citizenship: Columbian
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? Yes
Host Country Institution to Benefit from Training: Columbia
Thesis Title/Research Area: To be determined
Start Date: Continuation (Started Fall 2015)
Projected Completion Date (Summer 2017)
Training status (Active, completed, pending, discontinued or delayed): Pending the student accepting the position at UIUC and the full scholarship she will receive
Type of Innovations Lab Support (full, partial or indirect) for training activity: Direct from Legumes Scholar Program

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 fras 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: tbd

Last Name: tbd
Citizenship: Benin
Gender:

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: Performance of Therophilis javanus 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: tbd

Last Name: tbd
Citizenship: Benin
Gender:

Training Institution: IITA

Supervising CRSP PI: Tamò

Degree Program for training: BSc
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: Competition between Therophilis javanus and Phanerotoma syleptae

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: 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: Fuseini

Last name: Abdulai

Citizenship: Ghanaian

Gender: Male

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: September 2014

Program completion Date: Fall 2015

Training Status During Fiscal – Year 2014: Undergraduate

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

Training Status During Fiscal – Year 2015: Undergraduate

Type of Legume Innovation Lab Support: Partial

First name: Mariam

Last name: Derra

Citizenship: Burkina Faso

Gender: Female

Discipline: Entomology

Host Country Institution to benefit from Training: INERA

Supervising Legume Innovation Lab PI: Dabire

Start Date of Degree Program: September 2014

Program completion Date: TBD

Training Status During Fiscal – Year 2014: Graduate student

Type of Legume Innovation Lab Support: Partial

First name: Edouard

Last name: Drabo

Citizenship: Burkina Faso

Gender: Male

Discipline: Entomology

Host Country Institution to benefit from Training: INERA

Supervising Legume Innovation Lab PI: Dabire

Start Date of Degree Program: September 2014

Program completion Date: TBD

Training Status During Fiscal – Year 2014: Graduate student

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 2015

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 220 (equally split between males and females) to benefit

PI/Collaborator responsible for this training activity: Dabire 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 Benin and others virtually or during other training opportunities/thrips
Duration: Several hour 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 FY15 we will have trained 200 individuals from NGOs/government agencies/private sector firms and we expect these groups (and out online systems) to impact >5000 people to our materials. 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.

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

List other funding sources that will be sought (if any): ADM Institute for the Prevention of Postharvest Loss and the Chancellor's office

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 FY14

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, Dabire, 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

FY 2016 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
Julia Bello-Bravo - University of Illinois at Urbana- Champaign
Barry Pittendrigh - University of Illinois at Urbana-Champaign
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
Venâncio Salegua - Institute of Agriculture Research of Mozambique

I. Project Problem Statement and Justification

Poor soil fertility is a major factor in low bean yields in Uganda and Mozambique, important Feed the Future focus countries. Both countries have weak and uneven extension systems and rural social and economic institutions, limiting widespread access to improved crop management information, quality inputs and credit, with Mozambique particularly problematic. 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 will be based on enhancing smallholder farmers' capabilities in diagnosing and finding solutions to important yield constraints, and helping to remove barriers to access various types of soil amendments.

Project research activities focus on key common bean production regions – in Masaka and Rakai districts in south-central Uganda and in Gurue district in northern Mozambique. To understand potentially limiting soil nutrients, the team analyzed physical and chemical properties of soil samples collected from farmers' fields representing the three predominant soil types used to grow beans in the study communities in each country. Results guided nutrient omission studies (NOS), using soils from farmers' fields, which revealed effects of specific nutrients (N, P, K, Mg, Ca, S, and micronutrients) on bean plant growth and development. The NOS in Uganda showed that low P availability limits bean growth on red, black and stony soils. The NOS in Gurue is being repeated due to problems experienced in early 2015. Complementing the NOS is the lime requirement study (addressing low pH, Ca and Mg availability, and Al toxicity). Researcher-managed field trials in Masaka and Rakai districts during the 2014-B and 2015-A seasons demonstrated the importance of seeding for denser stands in all soil types, that addition of P, Ca, and Mg nearly doubled bean yield in black soil, and the effect of adding Rhizobia, seed fungicide, and a foliar fungicide is contingent on rainfall. With high rainfall levels, one NARO foliar fungal resistant bean variety had the best yield in all management systems while farmers preferred a variety that produced almost no yield in the 'innovative farmer' management system. A third season field trial will be conducted in Rakai during 2015-B. In Gurue, field trials during the 2014-2015 rainy season were adversely affected by farmer activities, compromising results. Field

studies during the 2015 dry season in lowland fields will be done to determine which nutrients are most limiting bean yield. Specifically, a nutrient omission study will be conducted at six sites in Mipuagiua, providing results on the influence of soil fertility and nutrient additions on leaf tissue nutrient concentrations and bean yield. Results will guide treatment design of subsequent field trials in Gurue during the 2015-2016 rainy season and 2016 dry season.

Two multistakeholder innovation platforms (IPs) are emerging in Masaka and Rakai districts with assistance of the project team. Members across the value chain share interests, concerns and strategies to address bean productivity and marketing constraints. In 2016, IP members will be engaged in field trials that demonstrate the impact of improved management practices and technologies (MPT) for bean production. In Gurue, farmer research group activities will test site-specific MPT. Both approaches will engage producers and other stakeholders in social learning, stimulate interest among community members in the demonstrations and trials, and contribute to subsequent widespread use of MPT that are proven to be 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 in the short term and improvements in soil fertility in the long term. We are assessing the effectiveness of innovative communication approaches and technologies to engage farmers with diverse characteristics and other key stakeholders in widespread dissemination and adoption of appropriate diagnostic and decision support aids.

II. Project Activities for the Workplan Period (October 1, 2015 – September 30, 2016)

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

Approaches and Methods

Our interviews and soil surveys document that smallholder farmers recognize the role of a variety of soil-related characteristics that impact bean yield in their production systems: soil color, particle size, soil texture, topsoil depth, rocks, slope, water holding capacity, plant vigor, previous yield results, weeds, etc.

Farmers in Uganda and Mozambique currently use a variety of management practices and technologies (MPT) to maintain or increase bean productivity, with significant variation by location regarding type and extent of use - reflecting awareness, availability, access and affordability. Our baseline farming system and socioeconomic surveys are providing detailed community-wide profiles of farmers' acreage and number of fields, practices of field selection and preparation, crop and variety selection, purchase of good quality seeds, planting methods and spacing, use of various types of inputs (manure, inorganic fertilizers, foliar sprays, pesticides, herbicides), intercropping and rotation patterns, weeding, incorporating crop residues in soil (rather than burning), mounding ridges, mulching, and fallow. Methods and criteria of problem identification and management practices utilized by farmers to date is also important. These analyses guide the research team in its observations and learning how farmers use existing knowledge to help determine crop system needs and to improve conditions.

Analysis of relevant data from the household baseline survey in Masaka and Rakai is progressing well and is expected to be completed in late 2015. Additional cleaning of household baseline survey data from Gurue occurred in June, permitting the team to proceed with comprehensive analysis during late 2015 and early 2016.

Obj. 1a. Continue collection of primary data in Gurue (lead researcher: R. Maria)

1a.1. Monitor field experiments with selected farmers in Gurue (rainy and dry seasons) (also: R. Yost, A. Lenssen)

1a.2. Document farmers' knowledge, attitudes, and practices (also: R. Yost, A. Lenssen, R. Mazur, V. Salegua)

Milestones

Oct. 2015 – Mar. 2016

1.1 - Reports on farmers' participation in field experiments in Gurue

Apr. 2015 – Sept. 2016

1.2 - Reports on farmers' knowledge, attitudes, and practices in Gurue

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

Collaborators:

Jalia Namakula, GIS specialist, NARL, Uganda

Cassamo Sumila - Institute of Agriculture Research of Mozambique

Approaches and Methods

The institutional support system for selected 'cash crops' plays a significant role in farmers' ability and interest in making investments in crop production and soil fertility enhancement. 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 – for soybean, pigeon pea, sunflower, pineapple, cotton, and tobacco. In contrast, common bean production and sales appear to be almost exclusively driven by domestic market actors. Initiatives by Maputo-based 'market women' during the past five years has helped increase market prices for common beans. If/when the support for other crops is reduced or eliminated, or the market prices for other crops decline significantly, common bean production will be viewed as being more lucrative. In Uganda, the two major cash crops are currently affected by disease - banana bacterial wilt and coffee rust; cassava, sweet potatoes, and groundnuts are also widely produced. In both countries, farmers indicated that post-harvest storage is a highly ranked problem. Some farmers try to avoid bruchid damage by using strong chemicals (at least 1 in 10 farmers are using chemicals, some of which are known to be hazardous to human health), while most farmers in Mozambique use nothing.

The existence and strength of farmers' groups varies significantly. In Uganda, some farmer groups formed for projects often don't persist after project support ends (e.g., government extension); others have consolidated and grown into cooperatives. The emergence of two multistakeholder Innovation Platforms in Masaka and Rakai indicates strong interest in coordination across the value chain from inputs to markets. In Mozambique, farmers groups (associations, forums and federations) are the principal mechanisms to access training and other support. Some associations are able to effectively engage in collective marketing, while others are not. This has significant implications for farmers' decisions to prioritize cultivation of specific crops, including beans, as they take into account the potential for earning needed income.

Building on information obtained during participatory rural appraisals, the baseline household survey is providing a detailed profile of key social, cultural, economic, institutional and contextual factors which shape farmers' decision making – individually and collectively. These include: farmers' sources, credibility, and uses of information about bean crop and soil fertility management; problem diagnoses and solutions adopted; assets and flows of key resources

(production materials, labor, money, etc.); gender and other roles (who makes or negotiates which types of decisions, alone or with others); resource constraints (material, labor, financial, etc.); food security; market sales; decision making processes (timing, stages, sequencing); and risk management strategies. Contextual factors analyzed include availability, accessibility and affordability of key resources (natural, physical, financial); value chain development (input and output markets); group and network size and strength; and collective action experience. In Masaka and Rakai, this is complemented by qualitative research using in-depth interviews with farmers to understand how and why they make decisions about production and soil fertility. Together, these analyses can explain current knowledge, attitudes, practices, and subsequent processes of information dissemination, training, utilization, and support to stimulate and sustain widespread change. Characterizing and modeling farmer decision-making processes will provide insight into which households are more able and likely to make fundamental changes and why.

Obj. 2a. Characterize resources and actions to increase bean crop productivity and marketing, and to improve soil fertility (lead researchers: R. Mazur, R. Miiro, V. Salegua, E. Luvaga)

2a.1. Continue analysis of household survey data regarding farmers' resources, management practices and investments, and marketing

2a.2. Document roles and collaboration among members of multistakeholder innovation platforms

Milestones

Oct. 2015 - Mar. 2016

2.1 – Reports on farmers' resources and actions for management practices and investments to increase bean crop productivity and marketing, and improve soil fertility

2.2 – Reports on activities and successes of members of multistakeholder innovation platforms in promoting improved bean crop management practices, investments and marketing

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. Saleguam E. Luvaga)

2b.1. Continue analysis of household survey data to model farmers' decision making

2b.2. Identify specific information and knowledge gaps to be addressed

Milestones

Apr. 2016 – Sept. 2016

2.3 – Models of farmer decision making vis. management 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
Jalia Namakula, GIS specialist, NARL, Uganda
Stanley Nkalubo, bean breeder, NaCRRI, Uganda
Clare Mukankusi, bean breeder, CIAT, Uganda
Manuel Amane - Institute of Agriculture Research of Mozambique

Approaches and Methods

To improve soil management decision making, diagnostic criteria and aids will be developed with and for farmers who have varying levels of education. These aids will be based upon field-observable soil classification characteristics in diverse agroecologies in Masaka district, Uganda and Gurue district, Mozambique. Utilizing farmer experience and input from soil scientists and crop systems agronomists, we draw from results obtained during the first two years of our project and the global knowledge base of appropriate practices and technologies, soil and cropping systems management strategies and options appropriate for various smallholder farm systems.

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 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. Our soil survey results documented that the Limyufumyufu (red) soils were strongly acidic in the 15-30 cm depth, while available P, K, Ca, and Mg likely were limiting bean growth, and this was confirmed with scientist-managed field research in Masaka over two rainy seasons. Additionally, Al^{+3} levels were often significant in red soil, further constraining potential root growth for water and nutrient extraction, and improved systems that included the addition of limestone proved highly effective, doubling bean yields. With reference to results from the lime requirement study, Limyufumyufu soil had this regression equation $y = 0.1285x + 5.5014$. Considering that the recommended pH for beans ranges from 5.8 - 6.5, this equation can be used to calculate the amount of lime required to raise pH from one level to another. For example, raising pH from 5.02 (which is the initial pH of this soil type) to 6 will require 3.88 tons of $CaCO_3$, while raising the pH to 6.5 will require 7.77 tons of $CaCO_3$

A question remaining to be answered is exactly how much lime is required to moderate the effects of low pH, Ca, and Mg on red soil and the profitability of lime addition. Results from the lime requirement study provide good starting points on this for both red and stony soils. Results for the Luyinjayinja (black, stony) soil samples were more similar to those of Limyufumyufu than for Liddugavu soils; both had low pH and concentrations of available nutrients. Additionally, these soils typically had a zone of higher clay concentration that likely limits hydraulic conductivity, increasing water logging of top soil during a wet period. These factors limit root growth in topsoil and subsoil. Results from our January 2014 soil survey and biweekly monitoring of bean fields in Uganda documented that numerous specific soil sites had reasonable nutrient availability and soil quality, yet farmers still experienced low and unsatisfactory bean yields. Scientist-managed research on black soil confirmed that improving stand density by higher seeding rates and timely weeding improved yield when availability of the three most limiting nutrients was increased by fertilization. When rainfall was excessive in April 2015, the single foliar application of a strobilurin fungicide greatly decreased incidence of angular leafspot on leaves and anthracnose lesions on pods, significantly improving yield and quality of yield of NABE14, NABE15, and K132. The farmer preferred variety NABE4, which is preferred for home food consumption, was highly susceptible to diseases and yields were poor in all systems, even with the application of the foliar fungicide. On the red soil, greater stand density, more timely weeding, addition of limestone to ameliorate excessively low pH, and the application of P and K more than doubled bean yield compared to the management system used by farmers. Analysis of soil samples obtained from farmers in Gurue will yield similarly useful results and provide insights regarding nutrient limitations in bean productivity, particularly when complemented by results from bean harvest.

The nutrient omission studies provided new information on the relative importance of nine nutrients for bean growth and development on Liddugavu, Limyufumyufu, and Luyinjayinja soils from Uganda. Results are being used in scientist-managed field studies comparing different

application rates of chicken manure, P, and N. The N addition rates were included because current NARO fertilizer recommendations for bean in Uganda include use of N fertilizer, since N fixation by beans is generally low. Additionally, the previously untested solution strategies of using seed fungicide and a single foliar fungicide application for disease management were highly successful in the recent wetter-than-normal rainy season. Diagnostic aid development is based on results from the nutrient omission studies and scientist-managed studies. Numerous photographs were taken of bean plants shortly after emergence, flowering, and just prior to harvest in scientist-managed studies that show well the key nutrient deficiency symptoms and bean yield potential under greater stand density, improved weed management, with and without application of limiting nutrients, and with and without application of a foliar fungicide. We anticipate including a number of comparative photographs showing the results of management practices that make a difference in bean production and profitability. Development of diagnostic aids requires the inclusion of farmers' input during all developmental phases, not just during testing.

In Gurue, visual observations of the nutrient omission experiment at Tetete and the measured results from Lioma indicate that wet 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 is 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. Experiments are planned to include a pigeon pea rotation in the bean rotation system to provide increased N input.

Local Mozambique rock phosphate materials are available in Nampula, and this may be an effective way to provide low cost, locally available P. The acid, low Ca soils of Gurue are, in fact, ideal to stimulate rock phosphate dissolution and availability. In addition, rock phosphate applications can provide both P and Ca that can increase soil health and productivity. The residual effects of the rock phosphate would like increase both pigeon pea and bean access to P as soil productivity and health are improved. We will also determine the calcium carbonate equivalent of locally available limestone.

Diagnostic criteria provide implicit comparisons of 'what if' scenarios. Readily observable characteristics will be compared, often in a dichotomous series. These criteria will provide farmers with information on improved practices to achieve particular objectives, and enable farmers to weigh 'trade-offs' between alternative approaches or practices. We have determined for black soil in Masaka that P, Ca, and Mg availability often are inadequate for bean production and that increased stand density, timely weeding in conjunction with addition of these limiting nutrients can more than double bean yield. The development of the diagnostic aid will be done using photographs from the NOS and scientist-managed field studies that documented differences in bean development, bean leaf health, and subsequent bean yields. Photographs taken during the course of the nutrient omission and scientist-managed field studies will comprise an important component that allows farmers to quickly note important differences between the aforementioned management practices. In subsequent years, images will be available from productive innovative farmer fields where the criteria were used, providing direct comparison of bean growth, development, and yield between management systems used. Additionally, comparisons will be done between innovative farmers and a control (not selected) farmer group where diagnostic criteria were not used as a second level of comparison.

Farmer research groups will be formed and supported to engage producers in field experiments that test and demonstrate the impact of variations in farmer-recommended improved MPT for bean production. Farmer research group activities will generate practical results, engage farmers in social learning, stimulate interest among other community members in the trials and demonstrations, and eventually contribute to widespread adoption of proven management

practices and technologies (MPT). Farmer-assisted field research trials will be conducted in each district comparing MPT recommended by productive and innovative farmers with those indicated as relevant based on analyses of soil samples and the nutrient omission studies. These research trials will enable us to confirm nutrient limitations on farmers' fields and improved systems that address the most critical limiting soil nutrients and management practices. Given inherent precipitation, soils, and other differences between Masaka district (beans are planted in both rainy seasons) and Gurue district (beans are planted in the singular rainy season and in the subsequent dry season), we have the opportunity for a robust comparison of our overall methodology. Farmers will be surveyed annually after each cropping cycle to determine impact of using diagnostic criteria on bean productivity, soil quality, and potential for sustainable adoption.

The farmer assisted research will include data collection on initial, annual (pre-planting and post-harvest), and final key soil chemical and physical properties from samples taken at depths of 0-15 cm and 15-30 cm. Initial properties determined typically will be those documented in the nutrient omission and scientist-managed studies that impacted bean growth and development. Bean stand density, yield, yield components (pods/m^2, seed/pod, seed weight), and seed protein will be determined in fields under both management systems and for the non-selected farmer control group. Additionally, timing and intensity of foliar disease development will be assessed, providing relevant results for deployment of newer, more disease resistant varieties as one component of the overall strategy to improve bean production. Statistical analyses used with data from the farmer assisted research will include paired-T tests within selected farmer groups, and analysis of variance with appropriate mixed models, and nonparametric tests, depending on the specific parameter.

The formation and support of farmer research groups will be essential to the success of our efforts to develop and test the effectiveness of diagnostic and decision support methods and aids. Groups and social networks play key roles in experimentation and adoption of new management practices and technologies, involving changes in beliefs, knowledge, and behavior. Researchers and farmers will create a continuous community learning environment - a 'community of practice' in which farmers 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.

Based upon insights gained from socioeconomic research on farmer decision making, integrated soil and crop management decision tools appropriate for varying levels of formal education will be developed and tested in various contexts and evaluated for their effectiveness over multiple years. For sustained utilization, we must ensure that the tools are useful and accessible to diverse populations (low education/literacy, socioeconomic characteristics, etc.). This is accomplished in part by including an array of relevant stakeholders, including smallholder farmers.

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. Complete field studies of bean management systems and soil fertility

3a.2. Analyze results and recommended solutions

Milestones

Oct. 2015 – Mar. 2016

3.1 – Completed field studies on bean crop management systems

3.2 – Analyses and recommendations for bean crop management systems

Obj. 3b. Develop Diagnostic Methods and Aids

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

3b.1. Engage farmers in a participatory assessment of the draft initial diagnostic and decision support aid

3b.2. Finalize initial diagnostic and decision support aid

Milestones

Oct. 2015 - Mar. 2016

3.3 - Participatory assessment of preliminary diagnostic and decision support aid

Apr. 2016 – Sept. 2016

3.4 – Refined and field tested diagnostic and decision support aid

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
Dorival Freitas, Gurue District Agricultural Extension Officer, Mozambique
Cassamo Sumila - Institute of Agriculture Research of Mozambique

Approaches and Methods

To realize our goals, we are 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. Farmers described strengths and weaknesses of current information providers and existing agricultural information dissemination systems in Uganda and Mozambique. In Uganda, groups are especially important as sources of valued information, along with fellow farmers and NAADS/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. We are contacting potential information providers to assess their capacity and willingness to develop and deliver messages concerning beans and soil fertility.

The project is engaging producers and other stakeholders, women and men, in testing innovative communications 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 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.

To begin engaging local learning and information dissemination systems, we are 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. The Masaka District Agricultural Officer recently learned and used the triple bag method to verify its effectiveness; he is enthusiastic for the project team to train others. In June 2015, we demonstrated these methods during meetings with 30 members of the two IPs in Uganda using established extension training methods, a live

action video, and a newly developed animated video. In Gurue, our communication research is comparing the effectiveness of different combinations and sequences of training media for learning the procedures involved. Beans stored using anaerobic and conventional storage methods will be compared by IP members in Uganda and farmer group members in Gurue in late 2015. Positive results will enhance the perceived value of the project activities and encourage community members to participate in future learning and information dissemination opportunities focused on bean production and soil fertility. Training materials will be refined, further tested, and distributed to a sample of farmers for evaluation of learning processes. This initial engagement will guide subsequent development of messages regarding crop and soil management practices and technologies, and dissemination through information systems effectively and efficiently.

As crop system management diagnostic and decision support aids are being developed by project researchers working in a participatory manner with farmers and other stakeholders, we will identify the most appropriate media and methods for dissemination, pre-test them, revise as appropriate, prepare for initial dissemination, evaluate their effectiveness, and provide recommendations for more widespread dissemination by relevant organizations. Dissemination, training and support will target priority decision-making points for individuals and groups. Optimum levels of training and follow-up support will be determined to identify efficient use of resources (extension personnel, material, financial); this will facilitate development projects being able 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 and sustainable resources. Monitoring and evaluating the impacts of project activities will involve collecting and analyzing baseline data and periodic monitoring of indicators.

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

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

4a.1. Analyze results of field test of prototype message/media

4a.2. Develop new message and align with appropriate media

Milestones

Oct. 2015 - Mar. 2016

4.1 – Analyses of effectiveness of prototype media and training strategies

Apr. 2016 – Sept. 2016

4.2 – Message and media for dissemination of initial diagnostic and decision support aid

Obj. 4b. Refine Content and Information Dissemination System

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

4b.1. Engage farmers and other key stakeholders in a participatory process of assessing the message and media for the initial diagnostic and decision support aid

4b.2. Identify priority issues and strategy for development of new messages

Milestones

Apr. 2016 – Sept. 2016

4.3 – Participatory assessment of message and media for initial diagnostic and decision support aid

4.4 – Foci and strategy for development of messages and media for dissemination of additional 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 is training four graduate students in academic programs in U.S. institutions and in research activities in host countries. Specific research foci and affiliations follow:

- one M.S. student from Uganda is studying Sustainable Agriculture and Sociology at Iowa State University and conducting research on farmers' perceptions, knowledge and socioeconomic factors influencing decision making for integrated soil fertility management
- one M.S. student from Mozambique is studying Communication at Iowa State University and conducting research on innovative socio-technical approaches for dissemination of information for diagnosis and decision support
- one Ph.D. student from Mozambique is studying soils/crops at the University of Hawaii and conducting research on alternative management practices for improving bean production

One M.S. student studying Agronomy at Iowa State University has been conducting M.S. thesis field research in Uganda as part of this project, focusing on practical methods to alleviate constraints limiting common bean production in Masaka, Uganda. The student receives stipend and tuition scholarship from ISU, not this project. The student's research is testing the management strategies in replicated, researcher-managed studies.

Three graduate students are receiving training at Makerere University in M.S. programs that contribute directly to project objectives:

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

Additionally, short-term training needs are identified as research activities continue. In Uganda, this includes training technicians from Makerere University and from NARL, students, extension workers and some lead farmers in Masaka and Rakai in field soil characterization. One specific area concerns enhancing farmer decision making in soil fertility management through use of the refined indigenous soil classification system. In addition, a Ph.D. student supervised by Richard Miiro has joined the field research team, under private funding; he is studying how Innovation Platforms may enhance member participation in decision-making. Further, the Bean Program of the National Crops Resources Research Institute (NaCRRI), through its Pre-cooked Beans Project with CIAT, is joining the bean Innovation Platform. They will contribute resources for promoting relevant technologies as our team project addresses soil improvement issues.

Two scientists from IIAM will participate in a training session in Uganda on identifying and characterizing soil 'catenas' in the two countries. This activity is anticipated to assist in the understanding and documentation of the high importance of geomorphology and topography of soils and its importance in the farmer's classification or grouping of soils of the project villages.

A follow up training workshop will be held in Gurue, Mozambique for personnel with IIAM, Instituto Medio Agropecúario de Gurue (IMAPEG), UniZambeze (the new University of Zambézia)

to learn and survey local indigenous soil types and classifications that farmers use in their decision-making for bean production. The training will occur at IMAPEG and in two communities where our team is currently working. The objective is to expand and build on the baseline survey previously conducted in the Gurue region by combining indigenous farmer knowledge of soil classification and management with scientist knowledge of soil genesis, classification, and fertility.

Milestones

Oct. 2015 - Mar. 2016 and *Apr. 2016 – Sept. 2016*

5.1 - Students continue/complete graduate studies programs

5.2 - Short-term training of key technical staff

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 expected to produce the following outputs:

- Characterization of smallholder bean farmers' agricultural motivations, current knowledge and practices, problem diagnoses, and livelihood and risk management strategies (by end 2015)
- Models of farmer decision making strategies that reflect influences of social, cultural, economic, institutional and contextual factors are developed and refined (by 2016)
- Innovative diagnostic aids using observable characteristics that enable farmers to make site-specific management decisions are developed and validated (by 2016)
- Process for identifying alternative strategies and management practices for improving cropping system productivity and soil fertility is developed (by 2017)
- Effective and efficient methods and media for information dissemination to intermediate and end users are developed and assessed (by 2017)
- Capacity building through applied research-based training is conducted (2013 onwards)
- Research results published in peer-reviewed literature and at the Legume Innovation Lab website hosted by the Management Office at Michigan State University (2015 onwards)

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 2015 in Mozambique, project PIs Russ Yost (University of Hawaii) and Ricardo Maria (IIAM) met with USAID staff members Karelyn Cruz (Agriculture Development Officer), Paula Pimentel (Agricultural Research & Technology Transfer Advisor), and Surendra Bhatta in Maputo on February 17, and Karelyn Cruz and Ryan Fong (GIS Specialist) on June 19. These meetings provided great opportunities to discuss project objectives and activities in the context of recent and current USAID programs in Mozambique. In Uganda, the project Lead PI has met regularly since 2004 with USAID Mission agricultural development staff, and will continue to do so during future travel there to communicate the focus and approach of project activities and explore bases for collaboration. On June 12, 2015, project researchers Rob Mazur, Eric Abbott, Andy Lenssen (all ISU), Moses Tenywa, Richard Miiro (both Makerere University),

Onesmus Semalulu (NARL), and two MS students (Makerere University) met with USAID's Andrew McKim (Feed the Future Coordinator) and Simon Byabagambi (Agronomist/ Program Management Specialist) in Kampala. The PI and Co-PIs subsequently met with Martin Fowler (Agriculture and Livelihoods Advisor) and Robert Anyang (Deputy Chief of Party of the USAID Uganda Feed the Future 'Commodity Production and Marketing' project), as recommended. We are also following up on a meeting with William Luyinda (Program Manager) and Mary Arach of AKORION (ICT for Agriculture). Our very enthusiastic discussion with Mark Tamale, General Manager of Buddu Broadcasting Services in Masaka, 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

The project team is maintaining and strengthening research collaboration with CIAT scientists. Co-PI Andy Lenssen and Lance Goettsch have coordinated with Steve Beebe (Cali) and Clare Mukankusi (Kampala) on two studies. One involves the determination of biological nitrogen fixation of bean in the three management systems on red and black soils. A non-nodulating bean line (BAT 477) was planted in each of the four replicates, allowing the comparison of N acquired by symbiotic nitrogen fixation (SNF) and through uptake of N from soil. The results ^{15}N:^{14}N from bean leaf samples will allow the calculation of N_{fixed} to N_{soil}. Additionally, Goettsch and Beebe have a separate study on red soil comparing growth, development, and yield of a newly released germplasm from CIAT (ALB91) that is to soluble Aluminum in acid soils with NABE 4, the most preferred bean variety by smallholder farmers in Masaka.

Co-PI Ricardo Maria (IIAM) is following up with Rowland Chirwa (CIAT/PABRA) and Steve Boahen (IITA) to discuss research objectives and activities, and identify potential bases for collaboration. 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 (where PI Rob Mazur met with program officers in February), 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 (SABRN). 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 will continue to explore opportunities to collaborate and coordinate research efforts with CGIAR scientists, the AGRA Soil Health Program, McKnight Foundation, Africa RISING, the Bill and Melinda Gates Foundation, and IFDC. We will identify how such opportunities would complement and coordinate with planned activities described in this Workplan of the 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 2016

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: M.S.
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? Yes
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 2013
Projected Completion Date: December 2015
Training status: (active, completed, pending, discontinued or delayed): Active
Type of USG Support (full, partial or indirect) for training activity: Full

Trainee #2
First and Other Given Names: Lance
Last Name: Goettsch
Citizenship: United States
Gender: Male
Training institution: Iowa State University
Supervising Legume Innovation Lab PI: Andrew Lenssen
Degree Program for training: M.S.
Program Areas or Discipline: Agronomy
Host Country Institution to Benefit from Training: Makerere University
If enrolled at a US university, will Trainee be a 'Participant Trainee' as defined by USAID? No
Thesis Title/Research Area: Practical Methods to Alleviate Constraints Limiting Common Bean Production in Masaka, Uganda
Start Date: August 2013
Projected Completion Date: May 2016
Training status: (active, completed, pending, discontinued or delayed): Active
Type of USG Support (full, partial or indirect): Partial

Trainee #3
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: August 2016
Training status: (active, completed, pending, discontinued or delayed): Active
Type of USG Support (full, partial or indirect) for training activity: Partial

Trainee #4
First and Other Given Names: Sostino
Last Name: Mocumbe
Citizenship: Mozambique
Gender: Male
Training institution: Iowa State University
Supervising Legume Innovation Lab PI: Eric Abbott
Degree Program for training: M.S.
Program Areas or Discipline: Communications
If enrolled 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: Socio-technical Approaches for Dissemination of Information and Decision Support Aids
Start Date: July 2014
Projected Completion Date: December 2016
Training status: (active, completed, pending, discontinued or delayed): Delayed
Type of USG Support (full, partial or indirect): Full

Trainee #5
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 2016
Training status: (active, completed, pending, discontinued or delayed): Active
Type of USG Support (full, partial or indirect): Partial

Trainee #6
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: August 2017
Training status: (active, completed, pending, discontinued or delayed): Active
Type of USG Support (full, partial or indirect): Partial

Trainee #7
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: Ph.D.
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: August 2014
Projected Completion Date: September 2017
Training status: (active, completed, pending, discontinued or delayed): Pending
Type of USG Support (full, partial or indirect) for training activity: Full

Short-term Training:
Type of training: Short-term field based.
Description of training activity: Field soil characterization
Location: Masaka and Rakai Districts
Duration: 3 days
When will it occur? September 2015, February 2016
Participants/Beneficiaries of Training Activity: Soil technicians from Makerere University and from National Agricultural Research Laboratories, MS students, district extension workers and some lead farmers
Anticipated numbers of Beneficiaries (male and female): 10 males, 10 females
PI/Collaborator responsible for this training activity: Professor M. Tenywa and Dr. O. Semalulu
List other funding sources that will be sought (if any):
Training justification: We need to create a community of practice on soil characterization and analysis closer to the farmers.

Type of training: Short-term

Description of training activity: understanding the indigenous soil classification system in a catenary concept
Location: Masaka
Duration: 3 dates
When will it occur? September 2015
Participants/Beneficiaries of Training Activity: Technicians, students and farmers
Anticipated numbers of Beneficiaries (male and female): 10 males, 10 females
PI/Collaborator responsible for this training activity: Prof. M. Tenywa and Dr. O. Semalulu
List other funding sources that will be sought (if any)
Training justification: Farmers describe their soils using the indigenous soil classification system. Early scientific soil classification was based on the catenary concept and more recently, the USDA and FAO World's Soil Reference systems which combine field observations with laboratory analytical data. There is need to develop a system that combines the farmer indigenous with the scientific systems to make better use of both systems at farm level.

Type of training: Short-term
Description of training activity: learn and survey local indigenous soil types and classifications that farmers use in their decision-making for bean production
Location: Gurue
Duration: on a recurrent basis, with field research in October 2015
When will it occur? On a recurrent basis (backstopping and other resources via internet)
Participants/Beneficiaries of Training Activity: staff from government research institutes (IIAM, IMAPEG, UniZambezi and Ministry of Science and Technology)
Anticipated numbers of Beneficiaries (male and female): 24 male, 6 female
PI/Collaborator responsible for this training activity: Ricardo Maria
List other funding sources that will be sought (if any):
Training justification: expand and build on the baseline survey previously conducted in the Gurue region by combining indigenous farmer knowledge of soil classification and management with scientist knowledge of soil genesis, classification, and fertility.

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:

FY 2016 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 2011in 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, 2015 - September 30, 2016)

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

Work continues this fiscal year on the identification and analyses of the principal factors affecting legume consumption in the study areas. One thesis has been completed and three more are under way and should be completed this coming fiscal year. The completed thesis confirmed that beans are very low on the food hierarchy in Zambia, receiving a lower income effect than even fruits and vegetables have. Preliminary indications are that the results might only be slightly different in Tanzania and Malawi. The principal reason for this may be the continued perception that beans are a "poor man's meat" and, as such, an increasing income situation leads to a lower allocation of income share. The preliminary indications suggest a broader campaign to develop outreach initiatives in collaboration with governments to alter this image of beans and help bring its value for nutrition characteristics front and center in consumer decision choices about food. The public and private institution partners of the project will be engaged in this fiscal year to drive this initiative forward as we complete the work on the analyses and confirm the position of beans and the principal factors influencing its relative position across the countries. From the scientific contributions perspective, we will complete work on comparing the factors across countries in order to shape the relative messages for more effective engagement with government and private policymakers.

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.

Period	Activity	Specific Responsibility
October 2015	Begin planning for report rollout in each country in the winter. HC PIs will coordinate with local agencies and partners to maximize rollout impact.	Research team
December 2015	Complete cross country comparison analyses on legume consumption in the focus countries.	US PIs and HC PIs Leading
December 2015	Complete draft of policy brief based on consumption report, distribute to collaborators, industry stakeholders, country USAID missions and policymakers for comment, finalization and rollout process discussion.	Research Team with each HC PI leading their country initiative
January 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

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. The approach used is econometric modelling and analyses to determine the production situation. This effort is being used as training opportunity 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 currently been completed with the help of our MS students in the respective HC institutions except for Zambia. Because of the delay in completing the contract for Zambia, we had some challenges recruiting students in FY2015. This challenge is not anticipated in FY2016, and we expect to be have the situation analysis for Zambia completed in the first half of FY2016. We used the World Bank's nationally representative Living Standards Measurement Study-Integrated Survey on Agriculture (LSMS-ISA) data for Malawi and Tanzania and we will use the Food Security Research Project (FSRP) dataset for Zambia to conduct the situation analyses of primary production in the three countries. The specific output will be reports describing and comparing 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. We are anticipating the report of the country comparison situation analyses of primary production to be completed by December 2015. The results from these analyses and Objective 1 results would inform the outreach programs planned for this fiscal year in the partner countries. The table below provides a schedule of activities planned for FY2016 in association with Objective 2.

Period	Activity	Specific Responsibility
November 2015	Complete the situation analysis of primary production for Zambia and complete the country comparison report	US PIs and HC PIs Leading
November - December 2015	Conduct focus interviews in the HC countries	US PIs and HC PIs Leading
November - December 2015	Begin planning for workshops in each country in the spring. HC PIs will coordinate with local agencies to maximize impact of workshops.	Research Team
April 2016	Complete a draft situation analyses of downstream activities and report on chain activities in the focus countries.	Research Team with each HC PI leading their country initiative
May 2016	Conduct workshops in each HC country to present lessons learned from Objective 1 and 2 and identify	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 two MS students in line with the plan. We also have graduated one student already enrolled in the Master of Agribusiness (MAB) program at Kansas State University. The recruitment information for Academic Year 2016 is already out with HC PIs and they are working with industry stakeholders in their respective countries to identify potential candidates.

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
January 2016	Begin planning for training workshops in each country in the FY2016. HC PIs will coordinate with local agencies to maximize participation in workshops.	Research Team
February - September 2016	Conduct a training workshop in each HC country.	US PIs and HC PIs Leading
October 2015 – September 2016	Work with local policymakers to undertake public education initiatives about the value for nitration 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 quarter of FY2016. (The final policy brief is scheduled to be completed in the first half of 2016).
- A report of the situation analyses of downstream activities and report on chain activities in the three focus countries.
- One day workshops 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. 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	Marynia	Emily
Last Name	Mazunda	Malunga
Citizenship	Malawian	Malawian
Gender	Female	Female
Training Institution	LUANAR, Malawi	LUANAR, Malaw
Supervising CRSP PI	Dr L. Mapemba	Dr L. Mapemba
Degree Program for training	Master of Science	Master of Scienc
Program Areas or Discipline	Agribusiness Management	Agribusiness Ma
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	Situation analysis of post-production segments of Malawian legume industry	
Start Date	May 2014	August 2015
Projected Completion Date	October 2015	October 2017
Training status	Active	Active
Type of CRSP Support for training activity	Partial	Partial
First and Other Names	Charles	Ezekiel
Last Name	Lungu	Swema
Citizenship	Zambian	Tanzania
Gender	Male	Male
Training Institution	Sokoine University of Agriculture	Sokoine Universi
Supervising CRSP PI	Fredy T. M. Kilima	Fredy T. M. Kilir
Degree Program for training	Master of Science	M.Sc.
Program Areas or Discipline	Agribusiness Management	Agric. Econ.
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?	N/A	N/A
HC Institution to Benefit from Training	Sokoine University of Agriculture	Sokoine Universi
Thesis Title/Research Area		
Start Date	September 2015	September 2015
Projected Completion Date	October 2016	October 2016
Training status	Active	Active
Type of CRSP Support for training activity	Partial	Partial

First and Other Names	Mabvuto	Chalwe
Last Name	Zulu	Sunga
Citizenship	Zambian	Zambian
Gender	Male	Female
Training Institution	The University of Zambia	Stellenbosch Uni
Supervising CRSP PI	Gelson Tembo	Gelson Tembo
Degree Program for training	Master of Science	Master of Scienc
Program Areas or Discipline	Agricultural Economics	Agricultural Eco
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	The University of Zambia	The University o
Thesis Title/Research Area		An Analysis of C common beans: A Malawi, Tanzani
Start Date	September 2015	September 2015
Projected Completion Date	September 2017	September 2017
Training status	Active	Active
Type of CRSP Support for training activity	Partial	Partial

Short-Term Training

Training Type	Workshop	Workshop	
Description	Identifying the Different Governance Structures in Value Chains	Closing the Knowledge Gaps in the Legume Industry	Business Development and Entrepreneurial Action
Location	Zambia; Malawi; Tanzania	Zambia; Malawi; Tanzania	Zambia; Malawi; Tanzania
Duration	1 day	1 day	1 day
Dates	TBD	TBD	TBD
Participants/Beneficiaries	Agri-food sector stakeholders, faculty, students	Agri-food sector stakeholders, faculty, students	Agri-food sector stakeholders, faculty, students
Anticipated Attendance	30 per country (50% male)	50 per country (50% male)	50 per country (50% male)
Responsible PI	U.S. PI	U.S. PI	U.S. PI
Other Funding Sources	Not yet.	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.	In response to participant feedback from the workshops done last fiscal year, we are going to deliver this workshop again in all three countries.

FY 2016 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

II. 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 enteropathy (EE), 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. EE 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. EE 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 EE 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 2016 Workplan Period (October 1, 2015 – September 30, 2016)

We will complete the clinical 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:

Enrollment, 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 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 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 LImela in Machinga District will be 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 will be recruited between the ages of 5.5 and 6.5 months, and their participation will last for 6 months. Enrollment will be ongoing, and extend over a 9 month period and involve 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 are optimistic about community engagement and subject retention.

Eligible infants will be screened by the research supervisors and physicians from our team. Specific exclusion criteria will be 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 will not be encouraged to do so, and any participant desiring to leave the study after enrollment will be 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.

Objective 2:

Develop and test the acceptability of two sets of 3-4 recipes that include either cowpeas or common beans for use 12 – 35 month old rural Malawian children in the clinical trial.

Collaborators:

The Department of Food Science and Technology on the Bunda Campus of the Lilongwe University of Agriculture and Natural Resources (LUANAR): LUANAR, formerly known as the Bunda College of Agriculture.

Malawi College of Medicine

Approaches and Methods:

Using food development techniques used by the Washington University team and the resources of LUANAR, the research team will develop food recipes using cowpeas and common beans. The recipes will be developed in accordance with the WHO specifications: The candidate recipes will then undergo acceptability testing in by children similar to the study population over a 2-week period to select those to be used in the study, the acceptability studies will receive the support of the Malawi College of Medicine. Prior to initiating the acceptability trial, we will submit ethical approvals for both the Malawian College of Medicine and the Washington University Human Research Protection Office for approval.

Objective 3:

Enrollment, intervention delivery and specimen collection in young children with a dietary legume.

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 LImela in Machinga District will be 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 will be recruited between the ages of 12-24 months, and their participation will last for 12 months. Enrollment will occur in 3 month period and involve 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 are optimistic about community engagement and subject retention.

Eligible children will be screened by the research supervisors and physicians from our team. Specific exclusion criteria will be 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 will not be encouraged to do so, and any participant desiring to leave the study after enrollment will be 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.

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 initiating 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, will be charged with developing the study procedures, guidelines and materials for the study, she will be under the guidance of the PI and his research team. The Agriculture Department at LUANAR, led by Vernon Kambambe, will be engaged developing formulations and recipes using cowpeas and common beans, the PI and his team will train two student LUANAR food scientists on the development processes used in the Washington University food science labs.

Trainees

Chrissie Thakwalakwa – PhD Candidate, Malawi College of Medicine 2 students from LUANAR to develop recipes

2 COM PhD students to conduct the research project

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:

- Recipe development report on lab development of cowpea and common bean interventions
- Enrollment and initial study results

V. Engagement of USAID Field Mission(s)

Continued communication, engagement and collaboration are planned with Cybill Sigler and John Edgar from the FTF team at the USAID mission in Lilongwe, Malawi. They will take on an associate role in this project. The PI and his team will remain in communication with their team and look for the potential of future engagements.

VI. Partnering and Networking Activities:

The PI and his team will work with the Program Manager for the Soil Health Consortium of Malawi about spreading the word about the projects development. The main role of the consortium is to encourage stakeholders to disseminate knowledge on Integrated Soil Fertility Management (ISFM), which includes legume rotation. The consortium holds ISFM symposia, travel workshops, and annual meetings, producing technical and policy briefs after these various consultations. Our research team will communicate with their group about relevant advances and technologies in the legume sector. All project outputs will be shared with these groups and the research team will seek out opportunities for synergy and collaboration.

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.

VIII. Timeline for Achievement of Milestones of Technical Progress:

See attached Milestones

Appendix 1: Workplan for Training and Capacity Strengthening (FY 2016) (use format below).

Degree Training:

1. Nicole Benzoni, USA, Female
   Washington University in St. Louis, MPHS (Master of Population Health Sciences)

   Supervisor: Mark Manary

   Participant Trainee: Yes

   Host Country Institution to Benefit from Training: LUANAR

   Research Area: Development of common bean and cowpea flour recipes

   May 2015 – July 2015

   Training status: Completed

   Type of LIL Support: Indirect

2. Lucy Bollinger, USA, Female
   Washington Unviersity in St. Louis, MA in Biological Sciences

   Supervisors: Mark Manary and Indi Trehan

   Participant Trainee: Yes

   Host Country Institutions to Benefit from Training: LUANAR and University of Malawi College of Medicine

   Research Areas: Production and quality control of common bean and cowpea flour recipes; Clinical trial of flours to improve EED and stunting

   June 2015 – May 2016

   Training status: Active

   Type of LIL Support: Indirect

3. Kevin Stephenson, USA, Male
   Non-degree Training

   Supervisors: Mark Manary, Ken Maleta, Chrissie Thakwalakwa, Indi Trehan

   Participant Trainee: Yes

   Host Country Institutions to Benefit from Training: University of Malawi College of Medicine

   Research Area: Clinical trial of flours to improve EED and stunting

July 2015 – May 2016

Training Status: Active

Type of LIL Support: Direct

4. Sophia Agapova, USA, Female
   Non-degree Training

   Supervisors: Mark Manary, Ken Maleta, Chrissie Thakwalakwa, Indi Trehan

   Participant Trainee: Yes

   Host Country Institutions to Benefit from Training: University of Malawi College of Medicine

   Research Area: Clinical trial of flours to improve EED and stunting

   July 2015 – May 2016

   Training Status: Active

   Type of LIL Support: Indirect

5. 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

6. 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

7. 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

8. 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: Recipe Development

Type of training: Recipe development for dietary interventions

Description of training activity: Develop recipes based on WHO recommendations for dietary interventions using cowpeas and common beans

Location: LUANAR Duration: 2 months

When will it occur? October 2015

Participants/Beneficiaries of Training Activity: Graduate students and researchers at LUANAR anticipated numbers of Beneficiaries (male and female): 2

PI/Collaborator responsible for this training activity: Mark Manary List other funding sources that will be sought (if any): None

Training justification: By engaging students and faculty at LUANAR, the development of appropriate recipes for our chosen legume varieties will also be culturally sensitive and feasible i n the village setting, and the interventions that are successful are more likely to be implemented for the long term. Students will also be trained by the Washington University research team, a group that has successfully developed over 50 recipes in prior studies that have been accepted by the Malawian general population.

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: 1week

When will it occur? November 2015/ongoing

Participants/Beneficiaries of Training Activity: Research team Anticipated numbers of Beneficiaries (male and female): 10

Pl/Collaborator responsible for this training activity: lndi 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.

Equipment (costing >$5,000):

FY 2016 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, Michigan State University

Approaches and Methods:

In FY 2016, we plan to focus on two activities under this objective.

1a. Analysis of baseline study in Guatemala: After consulting with the PIs of other Legume Innovation Lab Projects, several opportunities were identified for baseline assessments, including the "**socio-economic baseline study on the constraints and opportunities for research to contribute to increased productivity of climbing beans in Guatemala."** This is a joint activity with the SO1.A1 project team under their objective '*Genetic improvement of climbing black beans for the highlands of Central America*.' The data collection from more than 500 farm households from five FTF Departments in Guatemala representing the highland bean growing regions has been completed in FY 15, and data cleaning and organization is currently underway. In FY 16, this project plans to complete the data analysis and generating publications 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 and examining the determinants of (or constraints to) the adoption of these legume based 'sustainable intensification' practices. As part of FY 17 workplan,

this project plans to initiate rigorous panel data analyses to provide strategic insights on following questions:

a. What are the factors driving the adoption of legume based intensification technology (or parts of it) and its impacts on productivity, nutrition, and incomes?
b. Do policy interventions such as seed subsidies affect long-term adoption of legume crops and improved technologies by farmers?

Existing panel datasets from LSMS-ISA surveys in Tanzania, Uganda and/or Malawi will be used to address these questions. In addition, the forthcoming Zambia RALS (Rural Agricultural Livelihood Survey) panel data (collected in 2012 and 2015) will be also explored as another potential data source (esp. for research question 1), if a follow-up anthropometrics survey will be supported by USAID/Zambia as part of the 2015 RALS round. 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 and Nicole Mason, Department of Agricultural, Food and Resource Economics (MSU), Byron Reyes and J.C. Rubyogo, CIAT, Susan Nchimbi-Msolla, Paul Kusolwa and Fulgence Mishili, SUA, Tanzania, and researchers from SOI.A2, SOI.A3 and SOI.A4 teams

Approaches and Methods:

In FY 16, 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 in FY 15 under this broad theme and the plan is to continue/extend this work in FY 16 as described here.

i. *Willingness of small holder farmers to pay for quality seed:* This will be a continuation of the study initiated in FY 15 in Tanzania to assess farmers' willingness to pay for quality seed over grain. This research is being done in collaboration with the bean research team at SUA and CIAT (i.e., Dr. J. C. Rubyogo and Byron Reyes). 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 biding experimental auctions (BEA) to test farmers' willingness to pay for different types of seeds (i.e., certified seed, quality declared seed and recycled seed). Due to delays in finding a suitable mechanism to channel the funds to cover the cost of the field work in Tanzania, all the field experiments did not take place in the long rainy season as planned. In one of the districts, the experiments were planted in July and the BEA will be conducted in the end of September-early October. Field experiments in one other district will be planted around that time before the start of the short-rains. The BEA for this second set of experiments will be conducted in December. Data collected from Auction participants, and the results of the field experiments and auctions will be analyzed and report generated in the first half of 2016.

The reason for selecting Tanzania for this study is because it is one of the few countries in the ESA region that produces and recognizes quality declared seed (QDS), and it will be interesting to compare the performance of QDS vs. certified seed and then assess farmers' willingness to pay for these two types of seed, which have different cost of production associated with them. Depending on the results of this study and interest from other legume innovation lab country collaborators, the plan is to extend this to other countries with a focus on conducting field experiments to do cost-benefit comparison under farmer conditions of planting different generations of recycled (farmer saved) seed, QDS and certified seed. Tentative candidates for these experiments are Zambia (for beans) and Burkina faso (for cowpeas).

ii. Case study on community based seed system: In FY 15, in response to a request from the Management Office, this project initiated a case study of a farmer association in Burkina Faso called *Association Song Koaadba* (ASK), which was established more than 20 years ago with the goal of promoting food self-sufficiency and food security in rural farming communities. It currently has 7000 members spread over a large part of the country, including the provinces of Oubritenga, Kourweogo , Kouritenga, Ganzourgou, Sanmatenga, Passore and Sissili. The purpose of this case study is to: a) Document the cowpea seed production and distribution model used by ASK; b) Collect and analyze data / information to: understand the economics of community based smallholder seed production, and identify strengths and weaknesses of the model used by ASK; and, c) Derive principles of sustainability underlying the model used by ASK for broader applicability within Burkina Faso and other countries. Data collection based on qualitative and quantitative surveys/interviews has been completed, and analysis and report writing will be completed by the end of this year. To better understand the strengths and weaknesses of the community based seed system such as ASK (that produces QDS), it is also important to understand the formal seed system and the economics (i.e., costs/benefits) of producing certified seed, which is the only officially recognized 'seed' by the regulatory system in Burkina Faso. Data collection towards this component will be initiated in FY 16.

2b. Impact study in Haiti: There is a strong interest from the SO4.A4 project team to do an impact study in Haiti, which will also serve as an opportunity to collect data/information about the problems farmers are facing, which can be used by the SO4.A4 team to target bean research to address these problems. We plan to collaborate with SO4.A4 project team

to conduct an impact assessment study focused in areas where the Bean Technology Dissemination (BTD) project had disseminated improved bean varieties, for example, the Lower Central Plateau and the Cul-de-Sac Valley of Haiti. The challenge in doing an ex post impact study is to identify a credible counterfactual group to be able to attribute the impacts to bean research. The BTD project records will be used to guide in the sampling strategy, and to find comparison groups that can be used to assess the impact of the adoption of outputs of bean research and the BTD project activities. Funds approved for the 2015 HC capacity building proposal submitted by Haiti collaborators will be used to support the field work for this study. The plan is to do the data collection in March-April 2016. The proposed activities in FY 16 include:

a. Conceptualizing and developing an impact assessment design, data collection instruments, sampling plan, and survey implementation plan.
b. Conducting training in collaboration with the National Agricultural Statistics Service of Haiti to train enumerators and supervisors on the survey methodology, IRB guidelines, data collection instruments, interview techniques, use of GPS.
c. Developing the data entry tool and training the data entry staff
d. Implementing the farm household survey. The plan is to implement the survey in the following 5 Departments in areas where the BTD project and NSS have disseminated improved bean varieties—Artibonite, South, Grand Anse, Central Plateau, and Northeast. The plan is to randomly select about 400 beneficiary farmers and 300 non-beneficiary farmers that share similar characteristics as the beneficiary farmers, and establish a counterfactual using the Propensity Score Matching statistical technique.
e. Data entry and data checking using a statistical program
f. Data analysis and report writing

Proposed activities d and e will be led by the National Agricultural Statistics Service with technical support and guidance from this project team. All other activities will be a joint collaboration between SO4.1 and the host country partners.

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

Collaborators: NARS and CIAT partners

This project will address the objective of institutional capacity building and human resource development through the following activities planned in FY 16:

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:

See the attached excel file

IV. Outputs:

Specific outputs to result from this project by the end of FY 16 include:

a. Completion of two Impact Briefs
b. Completion of two manuscript for publication in academic journals and/or presentations at professional meetings

V. Engagement of USAID Field Mission(s)

No specific plans for engagement of USAID Field Mission(s) are envisioned in FY 16. 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 Department of Agricultural, Food and Resource Economics at MSU has awarded a Graduate student recruitment fellowship to Ms. Christine Sauer for Fall 2015 under the mentorship of M. Maredia. This project will use this fellowship opportunity to fund this student to contribute towards data analysis planned under Objective 1 (activity 1b).

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: Christine
Last Name: Sauer
Citizenship: USA
Gender: Female
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 panel data analysis of existing datasets

Start Date: Fall 2015

Projected Completion Date: Fall 2017

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

Short-term Training:

Name of training program: Survey design and implementation training in Haiti

Type of training: Short-term training (classroom and field testing)
Description of training activity: A 3-4 days training of HC collaborators, enumerators, supervisors and data entry staff will take place in Haiti to provide an understanding of the questionnaire, the methodology and survey design, and the interview techniques for doing impact assessment studies.

Location: Haiti
Duration: up to 4 days
When will it occur? March-April 2016

Participants/Beneficiaries of Training Activity
Anticipated numbers of Beneficiaries (male and female): 10 male 5 female

PI/Collaborator responsible for this training activity: M. Maredia

Approximate budget allocation from USAID funds for training: $17,697

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

Training justification: This training activity will help build the local capacity to track, monitor and evaluate the adoption and impact of agricultural technologies, such as improved bean varieties, agronomic practices, inputs, etc.

Equipment (costing >$5,000)**: None**