LEGUME INNOVATION LAB FOR COLLABORATIVE RESEARCH

ON GRAIN LEGUMES

FY 2015 WORKPLAN

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

Julio C. Villatoro, ICTA-Guatemala

Fernando Aldana, ICTA-Guatemala

Karla Ponciano, ICTA-Guatemala

Julio Martinez, ICTA-Guatemala

Edgardo Carrillo, ICTA-Guatemala

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 and beans are the main staple food in most households with a per capita consumption of 9.4 kg per year. Since few other sources of protein are available, this amount is not enough to ensure an acceptable nutritional quality, especially within poor households. As expected, the lack of protein intake has reduced the nutritional quality in many households, significantly affecting children.

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 study.

II. Planned Project Activities for the Workplan Period (October 1, 2014 – September 30, 2015)

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: Field testing of 10 selected accessions (ICTA) and other early-generation genetic material: The bean breeding program at ICTA has planted a selected a group of 10 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 April and May 2014 at 10 locations representing five departments. Most locations will be tested under the intercropping system and few under monoculture. The accessions were planted using a Randomized Complete Block Design (RCBD) with 2 or 3 replications depending on space and resources at each location.

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.

In addition to these 10 selected accessions, a group of 23 bolonillo advanced lines and 28 early-generation (F_3) bolonillo lines were planted at the ICTA station in Quetzaltenango in FY2014 and will be harvested at the beginning of FY2015. Also, 23 lines of different classes of climbing beans (bolonillo, piloy, etc.), were planted at the ICTA station in Chimaltenango in FY2014. Agronomic evaluation of this material during the last phenological stages (early FY2015) will include several of the traits mentioned previously.

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 FY2015 again across 10 locations. 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 1.2).

1.2: Genetic purification of selected material (ICTA): As explained Technical Project Description, phenotypic variation has been detected within accessions. Some individual plant selections were made last year and will be tested again this year for homogeneity at the Chimaltenango station. 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, 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.

1.3: Field evaluation of Bolonillo-TEXEL (ICTA): One of the improved lines selected by Dr. Fernando Aldana at advanced breeding stages (known as Bolonillo-Texel) was planted in 20 grower's fields during FY2014. Each field consist of 400 m^2 planted with Bolonillo-Texel and surrounded by the variety or varieties the grower normally uses. 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).

In order to obtain additional data about the agronomic performance of Bolonillo-Texel in the target regions, a similar approach will be implemented in FY2015. 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. 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.

1.4: First crossing block: With the results obtained from the field testing and the evaluation of the germplasm collection, a first set of potential parents will be 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) will be tested to see if it would be possible to advance 2 generations per year. The first generation of single crosses will be designed and will serve as the first batch of genetic material towards the creation of breeding pipeline 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: Karla Ponciano, Julio Cesar Villatoro, Fernando Aldana, Edgardo Carrillo.

Approaches and Methods:

2.1: Evaluation of core collection with the 6k SNP chip (NDSU): The core collection of approximately 300 accessions will be re-evaluated with a larger number of markers at NDSU. A new set of 6000 Single Nucleotide Polymorphism (SNP) markers is available as product 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. The big issue to accomplish this objective has been the processing of a phytosanitary certificate by the Guatemalan Ministry of Agriculture in order to send the seed to NDSU for DNA extraction and molecular analysis. Therefore, we are behind our proposed timeline in this regard. Once a phytosanitary certificate is obtained from the Guatemalan Ministry of Agriculture (expected in the next two months), seed from each accession of the climbing bean collection will be sent to NDSU for DNA extraction and SNP genotyping.

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 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 FY2015.

2.2: Assessment of the intra-accession variability (NDSU): As mentioned before, once a phytosanitary certificate is obtained from the Guatemalan Ministry of Agriculture, seed from each accession of the climbing bean collection will be sent to NDSU for DNA extraction and SNP genotyping. Genetic assessment of variation within the 10 selected lines used in objective 1A 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 each accession 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): The entire collection of climbing beans from ICTA has been planted in FY2014 at the ICTA station in Chimaltenango to allow a re-evaluation of the material and also the production of a newer batch of seed. Each accession has been planted in short rows (~2 m) mostly for phenotypic observation. The project director will spend time taking notes and evaluating this collection in order to make sure accessions with potential interest are not missed. Some of these evaluations will overlap with FY2015.

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 first 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: Julio Martinez, Julio Cesar Villatoro, Fernando Aldana, Edgardo Carrillo.

Approaches and Methods (Julio Martinez-ICTA):

A grower survey will be deployed in the main regions where climbing beans are produced. We will focus on the following departments: Quiche, Huehuetenango, San Marcos, Totonicapán, and Quetzaltenango which represent most of the climbing bean production areas. A proper sample size for accurate statistical analyses and estimates will be decided based on the previous information collected. The survey will include questions about cultivation methods, preferred seed types, household consumption, and marketing of harvested beans, among other things.

The survey is currently under development (FY2014) in collaboration with Legume Innovation Lab. project SO5.A1 (Dr. Mywish Maredia). In addition, IRB approval of the survey protocol by NDSU will be needed before the survey can be actually executed. Julio Martinez is the social economist at ICTA and will be leading the execution of these surveys in the field once approved. Once information is collected, data will be tabulated and analyzed by Julio in collaboration with project SO5.A1. 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.

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

Recruiting efforts during FY2014 at ICTA have allowed the identification of one potential candidate for M.S. at NDSU. Gabriela Tobar Piñon is an ICTA employee initially identified through the CAPA project, which is an early career program at ICTA to identify outstanding individuals for future employment and ICTA. Gabriela has expressed interest and hopes to start graduate studies at NDSU in the fall semester of 2014. She is currently in the application process, with TOEFL and GRE requirements already met. The project director interviewed four more candidates during FY2014 and will keep interviewing potential

candidates during his visits to Guatemala during FY2015 in order to identify a second candidate. The main issue with the candidates is the low level of English skills found among most of them. If suitable candidates cannot be found in Guatemala, good candidates from neighboring countries could be considered. We expect to have a second individual to come and do graduate studies at NDSU (Plant Sciences) starting in 2015 with the goal that they will be incorporated into agricultural research back into the region in the future.

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.

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. Field testing of 10 selected accessions and other early-generation genetic material (ICTA).
1.2. Genetic purification of selected material (ICTA).
1.3. Field evaluation of Bolonillo-TEXEL (ICTA).
1.4. First crossing block (ICTA)

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. Field evaluation of the ICTA collection of climbing beans

3. Objective 3:

3.1. Grower surveys at 5 departments (ICTA).
3.2. Data tabulation and analysis (ICTA).

4. Objective 4:

4.1. Identification/recruitment of potential graduate students (ICTA-NDSU).

4.2. First 2 graduate students at NDSU (ICTA-NDSU).

V. Engagement of USAID Field Mission(s)

Host country scientists will be 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. Local USAID Missions will be contacted when U.S. scientists visit 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. In addition, P. McClean will be 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-2150 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. Advance 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 2013 – 2014 (use format below)

Degree Training:

1 graduate student are expected to start M.S. at NDSU in the fall 2014. Recruitment efforts are currently underway to identify a second candidate.

Degree Training:

First and Other Given Names
Last Name
Citizenship
Gender
Training Institution

Supervising CRSP PI

Degree Program for training
Program Areas or Discipline

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?
Host Country Institution to Benefit from Training
Thesis Title/Research Area

Start Date

Projected Completion Date

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

Short-term Training:

None for this year. Informal training will be given to the ICTA personnel when the NDSU scientists visit the country.

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

None.

FY 2015 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 Workplan Period (October 1, 2014 – September 30, 2015)

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.

There are three major Objectives, all of which should enhance the research institutional capacity.

Objective 1: Develop and evaluate innovative new technologies (DEPI and PhotosynQ) for improvement of grain legumes both under controlled yet dynamic and field conditions.

Collaborators:

Greg Austic (MSU)

Dan TerAvest (MSU)

Robert Zegarac (MSU)

Kelvin Kamfwa (MSU/U. Zambia)

Wayne Loescher (MSU)

James Kelly (MSU)

Phil McClean (NDSU)

Stanley Nkalubo (NaCRRI, Uganda).

Approaches and Methods:

In the Oct. 2014- Sept 2015 work year, we will focus on establishing the basic technologies, training students and performing the first proofs of concept experiments.

1) Construction and testing of first 15 PhotosynQ MultispeQ units.We are currently building "locked beta" units of the PhotosynQ multspec device. We will construct and test 15 of these devices configured for the current project.

2) Preparation of instruction modules for use of PhotosynQ platform.

3) Preparation of prototype field measurement protocols

Objective 2) Test Identification of QTLs.

We will employ these technologies in proof-of-concept projects to identify QTLs in cowpea and common beans that modulate the efficiency of photosynthesis and its responses to changing environmental conditions in collaboration with Professor Tim Close (U.C. Riverside, Identification of photosynthesis- and heat-stress related QTLs in cowpea using the multiple advanced generation InterCross (MAGIC) approach), Professor Phil McClean (NDSU, photosynthesis-related genes in a genome wide association (GWAS) panel of common beans) and Professor Maren Friesen (MSU, Plant Biology, Assessing the ability of DEPI and PhotosynQ to probe differences in biological nitrogen fixation and plant-microbe interactions)

Collaborators:

Phil McClean (NDSU)

Tim Close (U.C. Riverside) and
Phil Roberts (U.C. Riverside)
Phil McClean (NDSU)
Maren Friesen (MSU, Plant Biology)

Approaches and Methods:

In the 2014-2015 work year, we will focus on determining which lines and conditions give promising results using the DEPI platform.

1) Test selected cowpea MAGIC parent lines under environmental conditions expected to occur in Zambia and in two sites in the U.S.

2) Test a selected population of common bean GWAS genotypes

3) Test the ability of DEPI to probe interactions of beans and cowpeas with soil microbes.

4) Use established statistical methods to assess which conditions and genetic populations are likely to yield strong results for the next years work.

Objective 3) Increase the capacity, effectiveness and sustainability of agriculture research institutions which serve the bean and cowpea sectors in the target FTF countries by establishing an African-USA community of networked scientists, extension agents, students and growers to address field-level research and production questions.

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:

1) Training on the PhotosynQ Platform. In 2015, two graduate students—Isaac Dramadri (from Uganda, currently in the the Kelly lab at MSU), and Kelvin Kamfwa (from Zambia, Uganda currently in the the Kelly lab at MSU), will learn the operation, theory and use of the PhotosynQ platform for local field application.

2) Establish the reliability, calibration and appropriate methodologies for the field experiments in greenhouses and fields at MSU. The student team will be immediately supervised by Greg Austic, Dan TerAvest and Jeffrey Cruz (USA, Kramer lab).

3) Train collaborators at UC Riverside and NDSU. Students Dramadri and Kamfwa will travel to UC Riverside or NDSU to train researchers in the use of the PhotosynQ device.

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 following FTF guidelines.

IV. Outputs:

(*Identify specific technical outputs that will result from this project during the 12 month period of the Workplan. Please be reminded that outputs from research activities are frequently not "finished" technologies but research achievements (I.e., evidence for a new resistance gene, discovery of a molecular marker, etc.) that give evidence of technical progress toward the project's objectives. Success in achieving projected outputs will be a basis for assessing project productivity and performance by the Management Office and the Technical Management Advisory Committee at the end of each fiscal year. It is therefore critical that thought be given to clearly defining these outputs.)*

1) Construction and testing of first 15 PhotosynQ MultispeQ units.
2) Two instruction modules for use of PhotosynQ platform.
3) Development of a prototype field measurement protocols
4) Assessment of cowpea and common bean genotypes in DEPI chambers
5) Training of two graduate students
6) Short-term training via the PhotosynQ platform of 5-10 undergraduates and masters students.

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 2015 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 to include 'milestones" from the FY 2013-14 performance period that PIs don't anticipate will be completed. The expectation is that these activities will be completed during FY 2015 or that the Workplan will present a case for a change. 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. It is therefore important that the milestones be clearly identified (in terms of its size/scale/scope and target location), quantitative (to the extent possible), logistically feasible, and with the responsible institution(s) identified for completing the Milestones.)

Appendix 1: Workplan for Training and Capacity Strengthening (FY 2015)

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: September 2014

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: Samuel

Last Name: Lotz

Citizenship: USA

Gender: M

Training Institution: MSU

Supervising Legume Innovation Lab PI: David M. Kramer

Degree Program for training: Doctorate

Program Areas or Discipline: Plant Molecular Biology and Bioinformatics

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: Physiological studies on drought tolerance in Andean beans.

Start Date: Jan., 2015 on Legume Innovation Funding

Projected Completion Date: September 2018

Training Status: First year graduate student

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

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 in the XXX program 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, 2015

Participants/Beneficiaries of Training Activity:

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

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 WORKPLAN

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

Lead U.S. Principal Investigator

James D. Kelly, MSU, East Lansing, MI

Collaborating Scientists

Wayne Loescher, Dept. Horticulture, MSU

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

Stanley Nkalubo – NaCCRI, 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 2014-15

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 and FY14 have been completed for each objective listed in the workplan.*

Training/Capacity Building Workplan for FY 2014 – 2015

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: September 2014
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: September 2017
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: September 2017
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 2014 – March 2015
   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 2014- March 2015
   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.

FY 2015 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 include the arcelin 2 seed protein from common beans, the null phaseolin trait from *P. coccineus* and the APA locus derived from *P. acutifolius*. The bruchid resistant breeding lines have been used as progenitors at the University of Puerto Rico to introgress this resistance into black, small red 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 Bean/Cowpea and Pulse CRSP resulted in 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 will be 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.

The previous Dry Grain Pulse CRSP project (UPR-1) developed Middle American and Andean bean breeding lines having adaptation to the lowland tropics and different combinations of resistance to diseases (common bacterial blight, rust, angular leaf spot, web blight and root rot) and tolerance to edaphic constraints (low N soils, high temperature). During the next five years, the Legume Innovation Lab project will use these elite breeding lines as the base for the continued improvement of beans for our target countries.

Several improved black and small red bean germplasm lines and cultivars are expected to be released in Central America and the Caribbean during the next five years. This Legume Innovation Laboratory will continue, in collaboration with CIAT, to support bean research network activities in Central America and the Caribbean. Collaborative activities such as the regional performance nurseries will help to extend the impact of this project through the release of improved cultivars throughout the region.

During the next five years, the project plans to release in Haiti red mottled, yellow and white bean cultivars with enhanced levels of disease resistance including BGYMV and BCMNV. These seed types are produced in regions in Haiti where the CRSP projects had less impact. This effort is consistent with the FTF 2011-2015 multi-year strategy in Haiti to increase the production of staples such as beans to increase food security.

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 should contribute 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 was well accepted by farmers in Central America and Haiti. After two cycles of recurrent selection elite 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 interespecific 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, 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 FY15, 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.

Dr. Juan Carlos Rosas will coordinate the regional testing of small red 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 Andean Diversity Panel will be screened in Haiti for reaction to powdery mildew and in Honduras for angular leaf spot. Performance of the Middle American Diversity Panel will be evaluated in low N environments in Central America and the Caribbean. The Middle American Diversity Panel will be screened in Puerto Rico for resistance to ashy stem blight.

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 FY15:

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.
- Multiply and maintain breeder and foundation seed stocks of recently-released small red and black bean cultivars.
- Coordinate the regional testing of small red and black bean breeding lines in the lowlands of Central America and Haiti.
- Utilize recurrent selection to develop bean populations for better adaptation to low N soils and greater resistance to web blight.
- Characterize pathogen variability of *Phaeoisariosis griseola* isolates from Guatemala and Honduras.
- Evaluate the ADP for resistance to angular leaf spot in Honduras.
- Test the performance of improved tepary bean lines.
- Test the performance of bruchid resistant lines when exposed to natural infestation.
- 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.
- Develop 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.

Haiti

- Test on research stations and farms black and Andean bean breeding lines that combine disease and pest resistance with greater tolerance to abiotic stress.
- Test the performance of improved tepary bean lines.
- 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.
- Strengthen collaboration between the NSS and NGOs in Haiti for on-farm testing of improved bean breeding lines (black, white, yellow and red mottled)

- Screen the Andean Diversity Panel (ADP) in Haiti for resistance to powdery mildew to identify new sources of resistance and to use association mapping to identify molecular markers for resistance.
- Conduct field trials to test the performance of elite lines selected from the second cycle of recurrent selection for enhanced biological nitrogen fixation.
- Conduct field trials to test the performance of elite lines selected from the second cycle of recurrent selection for web blight resistance.
- 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.
- Screen the Middle American Diversity Panel for resistance to ashy stem blight and performance in low N soils.
- Screen bean lines from recurrent selection for enhanced biological nitrogen fixation for root rot resistance and adaptation to low N soil.
- Coordinate the Andean bean line performance trials for the Caribbean.
- Test the performance of bruchid resistant lines when exposed to natural infestation.

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) will be selected for hybridization during FY13-14.
- F_1 Pv x Pa hybrids will be completed during FY14 from crosses between selected parents above at ARS-TARS.
- Embryo rescue will be initiated from the BC_1F_1 generation material in FY15 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) will be evaluated for CBB (FY13), adaptation (FY14) at USDA-ARS-TARS using leveraged ARS-FTF funds.
- The CIAT tepary bean germplasm collection (~250 lines) will be evaluated for response to NL3 at the UPR (FY15) using leveraged ARS-FTF funds.
- The CIAT tepary bean germplasm collection will be evaluated for BGYMV in Honduras
- Multi-location testing of improved tepary bean breeding lines
- 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

Karla Ponciano and Julio Cesar Villatoro, ICTA, Guatemala City, Guatemala

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

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 codominant 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 od 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-4, Ur-5, Ur-11*).
- 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.
- The ADP will be evaluated in Haiti for reaction to powdery mildew.
- 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 December 2014 to train technical personnel concerning bean research techniques with the goal of improving the quality of field research. Topics will include the development and management of field trials, breeding and selection methods, field evaluation techniques, the use of molecular markers, research with *Rhizobium*, participatory plant breeding and agro-ecological techniques.

- 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 or the Caribbean. Both students will be trained in the use of conventional and molecular techniques.

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 of lowland black 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, the Caribbean and Eastern Africa.

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-2150 which is a multi-disciplinary network of U.S. bean researchers.

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 and travel plans complement the goals of both projects.

VII. Leveraging of Legume Innovation Laboratory Resources:

Project scientists will 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. For example, we recently provided collaborators in Ecuador with a source of bruchid resistance. 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 which 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 should 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 Bean Technology Dissemination associate award led by Michigan State University allowed the Pulse CRSP and Legume Innovation Lab projects to produce and distribute seed of improved black and small red bean cultivars and *Rhizobium* inoculants to thousands of farmers in Central America and the Caribbean.

VIII. Timeline for Achievement of Milestones of Technical Progress:

Please refer to the document describing milestones

Training/Capacity Building Workplan for FY 2015

Long-term training:

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

Citizenship: U.S.
Gender: M
Training Institution: University of Puerto Rico

Supervising CRSP PI: James Beaver

Degree Program for training: M.S.
Program Areas or Discipline: Plant breeding

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?- No
Host Country Institution to Benefit from Training: None
Thesis Title/Research Area: TBD

Start Date: Aug. 2014

Projected Completion Date: 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: Angela Nadeshda Nicte

Last Name: Miranda Mijangos
Citizenship: Guatemala
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. 2014

Projected Completion Date: Aug. 2016

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: M.J.
Last Name: Cunguan Cundar
Citizenship: Ecuador
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: Molecular analysis of the genetic diversity of common bean landraces from Honduras and El Salvador.

Start Date: Jan. 2014

Projected Completion Date: Dec. 2014..

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: C.
Last Name: Lopez Ramos
Citizenship: Ecuador
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: Molecular analysis of the genetic diversity of common bean landraces from Honduras and El Salvador.

Start Date: Jan. 2014

Projected Completion Date: Dec. 2014

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: L.A.
Last Name: Avilés López
Citizenship: El Salvador

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: Applications of the bc3 gen marker in selection for resistance to BCNMV.

Start Date: Jan. 2014

Projected Completion Date: Dec. 2014..

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: S.D.
Last Name: Escobar Flores
Citizenship: El Salvador

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: Applications of the bc3 gen marker in selection for resistance to BCNMV.

Start Date: Jan. 2014

Projected Completion Date: Dec. 2014..

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: M.D.
Last Name: Goyzueta Altamirano
Citizenship: Bolivia

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: Selection of small red bean lines with multiple resistance to BCMV, BCNMV and BGYMV

Start Date: Jan. 2014

Projected Completion Date: Dec. 2014..

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: S.D.
Last Name: Chicas Marquez

Citizenship: El Salvador

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: Selection of small red bean lines with multiple resistance to BCMV, BCNMV and BGYMV.

Start Date: Jan. 2014

Projected Completion Date: Dec. 2014..

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: E.D.
Last Name: Gutierrez Benitez

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: Selection of disease resistant bean lines with better adaptation to climate change and greater mineral content.

Start Date: Jan. 2014

Projected Completion Date: Dec. 2014.

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: M.G.
Last Name: Cruz Cerrato

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: Characterization of bean differentials lines inoculated with Rhizobium species.

Start Date: Jan. 2014

Projected Completion Date: Dec. 2014.

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? - 2015

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: Workshops

Description of training activity: A workshop will be held in Honduras to train technical personnel concerning bean research techniques with the goal of improving the quality of field research. Topics will include the conduct of field trials, breeding and selection methods, field evaluation techniques, research with *Rhizobium*, participatory plant breeding and agro-ecological techniques.

Location: Honduras

Duration: One week

When will it occur? - December 2014

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

Anticipated numbers of Beneficiaries (male and female): 30

PI/Collaborator responsible for this training activity: Juan Carlos Rosas and Consuelo Estevez

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

Training justification: Trainees will improve their skills in conducting field and laboratory research. This should improve the quality and reliability of research conducted in host countries.

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

None during FY-14

FY 2015 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 & Jean-Baptiste Tignegre, 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 identity 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 have also been working closely with the CGIAR-GCP Integrated Breeding Platform program development using our cowpea data as a test user case, and bring these technological advances 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, 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, 2014 – September 30, 2015)

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

Mr. Joseph Batieno, INERA, Burkina Faso

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 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*) 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 continue to apply the KASP SNP platform that we developed with the GCP IBP and LGC KBioscience for SNP genotyping both in the QTL discovery phase and for breeding. The 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. We will genotype all parent and control genotypes with the full set of SNPs. Then we will select the polymorphic SNPs for a desired pair of parents

and genotype the progenies (individuals or bulked families) with the polymorphic subset of SNPs. This approach can be used for genotyping RIL populations or F2:3 families for QTL mapping purposes, or 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, 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. The data will be returned within a 4-week turnaround, 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. Because of the high density of markers and our ability to choose the cM distance and specifically QTL flanking markers for the population-specific SNP marker subsets (using our in-house 'SNP selector' program available at Breedit.org), efficient genetic gain by pyramiding the target traits can be made. In FY15 for the first time the new 60,000 Illumina iSelect SNP platform will be available. We will begin applying this high density marker resource to parents and derived mapping populations during FY15.

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 GCP Integrated Breeding Platform (IBP) 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 and Optimas 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.

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. Uniform screens in field locations across all project NARS (Burkina, Ghana, Senegal) and California are being conducted in 2014 in field plots or in screenhouses, with 4-fold replication, using standard resistance assessment scales across all test sites. The uniform test design and coordination planning for the aphid resistance assessment was developed by the project team in FY13 – FY14. Additional germplasm lines are included in the screening sites to search for more sources of resistance. This multi-site phenotype screening for resistance response will be repeated in FY15, following additional seed increases, to provide a minimum of 2 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 extraction, with a view to developing a DNA sequence based fingerprint 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 are finishing a QTL discovery effort for aphid resistance in IT97K-556-6. In Ghana we have an F2 population between a susceptible elite line and resistance donor KvX295-2-124-99. This population will be genotyped and phenotyped in FY15 for QTL mapping. From the wild donor IITA line TVNu1158 a RIL population has been developed for mapping QTL but will require phenotyping and genotyping. This work is being planned in collaboration with Dr. Fatokun at IITA, Nigeria under the TL1 project, but the results will directly impact the LIL breeding decisions. 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, Njouro and Tamale during the FY15 workplan period. This will provide a second year of phenotyping following phenotyping trials being conducted in FY14. Additional germplasm lines will be included in the screening sites to search for more sources of resistance in both FY14 and FY15. 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 and these populations will be advanced to F3 in FY15. In Ghana, three Sanzi-derived F3 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 F3 population. The SARI team will phenotype the three F3 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.

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 FY14 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 FY15 to provide validated QTL mapping data. Additional potential tolerance donor lines are included in the initial phenotyping screens in FY14, including those in the pedigree of resistance donor IT86D-716, to broaden the knowledge base and potentially identify additional sources of tolerance. Two existing F2 populations generated from resistance donor IT86D-716 with parents Kvx771-10 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 FY14 and FY15 for pod bug resistance in Burkina Faso, in collaboration with Dr. Dabire. The F2 were advanced to F3 in FY14 to provide screening resources for FY15. Using leaf samples collected from phenotyped plants in Burkina Faso, single F2 plants and F3 family bulks consisting of a minimum of 12 individual plants will be genotyped. The phenotype and genotype data from the F2 and F3 generations will be used for QTL discovery with the ICI Mapping program, which will be conducted at UCR.

For the three insect groups (aphids, thrips, pod bugs), we 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 collection, in which insects are placed in plastic bags with silica gel packs; this dries the insect samples and preserves the DNA. Tests on aphid DNA with primers for the COX1 gene demonstrated excellent DNA integrity.

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 Muruca resistance with our SNP marker panel. Genotyping was initiated in FY14 primarily focused on background selection with genome-wide markers in segregating progeny of backcross breeding populations in Burkina Faso and Ghana. The goal is to expedite the selection of lines with the highest percentage of elite recurrent parent content in each country (e.g., improvement of elite variety IT97K-499-35 in Ghana and several elite local varieties in Burkina Faso, including Moussa Local, Gourgou 3, 7 and 11, IT98K-205-8 and KVX 745-11P). We are genotyping Burkina Faso BC3 and Ghana BC2 progenies in FY14 and our plan for FY15 is to continue with additional rounds of SNP genotyping on the next generation of breeding lines. In FY15 the new 60,000-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, Director of

AATF, Abuja, Nigeria, received extensive hands-on training at UCR in March 2014 and will be further trained in March 2015 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.

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 three large white grain type cowpeas (at least 25 g /100 grains) developed by Dr. Cisse were approved for release by the national variety release committee in May 2014. 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). Breeder Seed is being used in 2014 for Foundation Seed development. Dr. Cisse will continue with Foundation Seed production in the FY15 off-season (October – April) using sites at Bambey and Thilmakha. The Foundation Seed will be used by Certified Seed producers in the main season 2015, with training inputs from Dr. Cisse.

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 will be re-evaluated in the off-season in FY15 (October- April), 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 mid-FY15. 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). This will be used to initiate Foundation Seed production in the FY16 off-season.

In California, we will field test advanced breeding lines for release potential, based on performance data collected in 2014. 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 2014, we will conduct on-farm yield 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 will convene a training workshop in March – April 2015 at UCR, using training modules developed by the UC-R team and by the CGIAR GCP Integrated Breeding Platform program (IBP). The IBP is using our tropical legumes project cowpea breeding population data for the training modules development. We conducted our first breeding workshop in FY14 (March 2014) at UCR which was a great success, and will use the same format for the workshop in FY15. 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 cowpea genomics and breeding.

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 and 2016.

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.

Discovery of QTL for aphid resistance in KvX295-2-124-99

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 F3 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 Seed of 3 large white-seeded CRSP varieties in Senegal.

9 pre-release CRSP lines evaluated in on-farm trials and Breeder Seed produced (BF).

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 2015, the UC-R PI and Co-PI will make field visits to the three HCs to review and coordinate field based phenotyping activities. During these HC trips, we will arrange to visit the Senegal and the Ghana country missions and also the West Africa regional mission in Accra. The mission visits 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 each country and in the region. In Burkina Faso, we will connect with the mission representation from Niger to inform them of our activities, and as we have done in the past, with US Consulate leaders in Ougadougou. The UC-R team will also 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 $80M commitment to 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 I. Atokple 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.

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 $10,000 - 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 December 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) and Senegal (PI N. Cisse), and IITA (PI, O. Boukar). This project funded at $2.729M plus $140,000 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. This project provides an excellent leveraging for CRSP activities described here to be used for cowpea modern breeding. The project also links 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 60,000-SNP Infinium iSelect genotyping platform, which will be developed by late 2014. We will leverage this advancement by applying it to our LIL project genotyping needs, thereby enhancing the quality and efficiency of the genotyping component.

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.

The Kirkhouse Trust is supporting a project under Dr. Cisse at ISRA on molecular breeding for Striga resistance for 3 years (July 2012 – June 2015) for $90,000.

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 2015

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: MS
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: 06/2016

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 of these workshops was held in March 2014, and we will continue the same successful format in March - April 2015.
Location: TBD, linked to LIL Global meeting
Duration 5 days
When will it occur? March - April 2015

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 CGIAR-GCP Tropical Legumes I project and 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 2015 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)
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. Thus, as we move forward over the next four years we will determine the population genetic structure of the other pests of cowpea. We have developed molecular tools to accomplish such a task (Agunbiade et al., 2013). We will also 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 will research and develop scalable solutions, with the potential and actualization of larger-scale impact through donor community buy-in.

II. Planned Project Activities for the Workplan Period (October 1, 2014-September 30, 2015)

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 need 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 is statistically no different than extension agents – in other words they were basically as effective as an extension agent to encourage adoption of a pest control strategy - suggesting that animations have the potential to be a highly effective tool for adoption of pest control strategies.

The next issue is we need to determine 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? This is something that we are well positioned to test experimentally. 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 be explored and implemented through co-operatives and other business models that empower women and unemployed youth. Finally, we will refine our online interfaces and create Apps 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 – a final version is in progress and pending release upon completion of data accumulation software and all legal disclaimers/approvals by UIUC. This has been paid for through funding from the UIUC Chancellors Office. The App will be made available for free use and downloadable from a variety of websites and offline file sharing systems. 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®.

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). 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, Professor Wale Adekunle, Director of Partnerships and Strategic Alliances, Forum for Agricultural Research in Africa (FARA) has received internal funding from FARA to visit the SAWBO team at UIUC (fall of 2014) to integrate SAWBO content, including all of our animations on cowpea pest management, into at least a subset of FARA educational programs. 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. We will continue to explore 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 notification on 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. We will also test the impact of IPM approaches on farmer incomes, through studies with Dr. Mywish Maredia at MSU. 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 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 FY15 (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. A website on this is currently in development and will be operational in FY15. 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.

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 site 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.

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 FY15, 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 FY15 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 investigate host range, biology and ecology of novel parasitoids of *Maruca vitrata* while at the same time carrying out confined experimental releases (IITA). (2) Scaling out rearing of most promising new parasitoids in the IITA biocontrol agent pipeline (IITA). (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 sex and aggregation pheromones in pod sucking bugs for developing rearing-cum-release devices for their egg parasitoids (IITA). Olfactometric studies at IITA will be continued to detect responses of the egg parasitoid *Gryon fulviventre* to pheromones of the brown pod bug *Clavigralla tomentosicollis*. (5) We will continue to develop and test molecular techniques for detecting endophytic strains of the entomopathogenic fungus *Beauveria bassiana* applied to cowpea at planting, while developing inside the vascular tissues of the cowpea plant during its growth (IITA). (6) We will continue to assess the technical feasibility of storing MaviMNPV virus both as liquid and solid substrate for facilitating the cottage industry production of this bio-pesticide by self-help women groups. Production of the virus will continue at IITA and staff from the above grouping will undergo technical training sessions on how to produce good quality viral inoculums. Specifically, we will 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 FY15. (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 FY15, we will continue to conduct inoculative releases of biocontrol agents against thrips (*Ceranisus femoratus*) and pod borers (*Apanteles taragamae* and/or *Nemorilla maculosa*) 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 look at 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 – 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). These has 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 SusDeViKI system and the animations 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. 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. One of these NGOs has already started their own ICT training sessions, of which the SAWBO team has participated in through Skype. The SAWBO team will host a Forum for Agricultural Research in Africa (FARA) representative (trip funded by FARA) at UIUC in order to "pass off" our educational materials to FARA, so that they can use these materials in their extension and educational programs in West Africa. 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 encouraging the adoption of pest control technologies – suggesting real potential for the animated approach in dissemination of the technologies we have and will continue to develop. Additionally, we tested out a new "App" for easy access and download for our educational materials. We are now dealing with development of software to understand the use and impact of such an App when it is released (in collaboration with Dr. Tarek Abdelzaher in Computer Science at UIUC). We expect release of the App, for Android and iPhones, in the fall of 2014; pending UIUC approval. The Android App would allow 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. The iPhone version will allow for users to download the animations and store them on their phones – Apple does not allow for Bluetooth® transfer from "i devices" to "non-i devices".

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.

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 also 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 start training staff of the self-help group, with particular attention to women, in the production of pod borer larvae using the technology developed during the previous phase of the project, i.e. using cowpea sprouts. The larvae will be inoculated with the virus supplied by IITA (at least until they get their own stock cultures) and passed through 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 will have 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 4.1 will occur (see cell 19I of the Impact pathway template as weel): 1) Ongoing graduate education across all four HC and a student at UIUC (funded by HHMI) will be fully completed her degree by the beginning of FY15 and all of her papers will be published, 2) we will release an App that will allow for easy access to our educational content, 3) technician training initiated for biocontrol agents that will be released (this will involve sending technicians across to different programs with the training primarily occurring at IITA, however the NARS programs will also exchange between Burkina Faso, Niger, and Ghana where necessary). 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 will have completed here UIUC PhD, supported by a Howard Hughes Fellowship, and will have published all of her thesis papers. 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 identify and 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 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 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 $53,057.00 will be used at UIUC to support activities to develop and implement training materials and sessions.

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 FY15. IITA will use $11,300 of their budget for these activities.

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

Please see our "Performance Indicators – Targets" form for the project for 2015.

IV. Outputs:

Defining the pest problems - We expect to collect 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 perform initial molecular work on these populations and we expect to continue 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, with Dr. Larry Beach, has already met with the Ghana mission during our program planning meeting and Dr. Pittendrigh will be presenting (this will likely be past tense by time the review of this document occurs) 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 has already begun to contact 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. Thus, we have already begun this important process of engaging missions in West Africa in regards to our program. Our Ghanaian PI's were involved in the July 8 and 9 (2013) meeting involving USAID Mission staff. In FY15 we will follow-up on the leads (including potential visits) and opportunities that emerge from these two major interactions with the USAID Mission staff. We also plan to visit with the USAID Mission staff in Niger in FY15.

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 one – Ghana) 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 FY15. We will continue to expand our networks with other NGO and international organizations like FARA – 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 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 will require 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: Tolulope Adebimpe
Last Name: Agunbiade,
Citizenship: Nigeria (but formerly living in Ghana and previously worked for IITA)
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 – This student will be funded from a Howard Hughes Medical Institution grant
Host Country Institution to Benefit from Training: Benin
Thesis Title/Research Area: IPM-omics – Use of molecular tools to make better pest management decisions in cowpea cropping systems in West Africa

Start Date: Continuation (Started Fall 2009)

Projected Completion Date (2014)

Training status (Active, completed, pending, discontinued or delayed): Completed degree in spring of 2014 – final papers in revision at journals
Type of Innovations Lab Support (full, partial or indirect) for training activity: Indirect

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: Djibril Aboubakar
Last Name: Souna
Citizenship: Benin
Gender: Male
Training Institution: IITA (also interacting with INRAB)

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 Innovations Lab 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: 2015

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: Hilaire
Last Name: Kpongbe
Citizenship: Benin
Gender: Male
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: Effect of aggregation pheromones of *Clavigralla tomentosicollis* on its egg parasitoid *Gryon fulviventre*

Start Date: 2013

Projected Completion Date: 2014

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: Cossi Roland Maximilien
Last Name: Belogoun
Citizenship: Benin
Gender: Male
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: Biology and competitiveness of *Phanerotoma syleptae*, a novel parasitoid of the pod borer *Maruca vitrata*

Start Date: 2013

Projected Completion Date: 2014

Training status (Active, completed, pending, discontinued or delayed): Completed
Type of Innovations Lab 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: 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: Effect of aggregation pheromones of *Clavigralla tomentosicollis* on its egg parasitoid *Gryon fulviventre*

Start Date: 2013

Projected Completion Date: 2014

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: Cossi Roland Maximilien
Last Name: Belogoun
Citizenship: Benin
Gender: Male
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: Biology and competitiveness of *Phanerotoma syleptae*, a novel parasitoid of the pod borer *Maruca vitrata*

Start Date: 2013

Projected Completion Date: 2014

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

First and Other Given Names: Maryse
Last Name: Tossou
Citizenship: Benin
Gender: Female
Training Institution: IITA

Supervising CRSP PI: Tamò

Degree Program for training: BSc
Program Areas or Discipline: Entomopathology

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: Comparing spent grain and milled rice as substrate for mass production of *Beauveria bassiana*

Start Date: 2014

Projected Completion Date: 2014

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

First and Other Given Names: Maimouna
Last Name: Abdourahamane
Citizenship: Niger
Gender: Female
Training Institution: INRAN

Supervising CRSP PI: Ibrahim Baoua

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: Niger
Thesis Title/Research Area: Study of the incidence of *Clavigralla tomentosicolis* on cowpea yield, promoting a biopesticide (neem extract and Mavi viral suspension) for the effective control against the pest in the regions of Maradi and Zinder

Start Date: 2014

Projected Completion Date: 2017

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: Ousseina
Last Name: Abdoulaye
Citizenship: Niger
Gender: Female
Training Institution: INRAN

Supervising CRSP PI: Ibrahim Baoua

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: Niger
Thesis Title/Research Area: Study of the incidence of pod borer (*Maruca vitrata*) on cowpea yield, promoting a biopesticide (neem extract and Mavi viral suspension) for the effective control against the pest in the regions of Maradi and Zinder

Start Date: 2014

Projected Completion Date: 2017

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: Abdou
Last Name: Harouna
Citizenship: Niger
Gender: Male
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)*

Start Date: 2011

Projected Completion Date: 2014

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: July 2015

Training Status During Fiscal – Year 2014: 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

First Name: Dorcas

Last Name: Dushie

Citizenship: Ghanaian

Gender: Female

Training Institution: KNUST and CRI

Degree Programme: BSc. (Hons) Agric. Degree (Seasonal distribution of cowpea pests in the forest region of Ghana)

Start Date: Oct. 2014

Completion Date: July, 2015

Type Innovations Lab. Support: Partial/indirect

First Name: Joseph

Last Name: Anyem Darkwah

Gender: Male

Citizenship: Ghanaian

Training Institution: KNUST and CRI

Degree Programme: BSc. (Hons) Agric. Degree (Assessment of botanical extracts/biopesticides for management of cowpea pests)

Start Date: Oct. 2014

Completion Date: July, 2015

Type Innovations Lab. Support: Partial/indirect

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 2013

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 Benin (or Burkina Faso) and several online when and where opportunity permits with collaborating organizations
Location: One in Benin and others virtually or during other training opportunities/trips
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)

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 2015 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:

Eric Abbott - Iowa State University
Andrew Lenssen - 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
Haroon Sseguya - Makerere University, Uganda
Onesimus Semalulu - Soils & Agro-meteorology, National Agricultural Research Laboratories, Uganda
Ricardo Maria - Institute of Agriculture Research of Mozambique
Cassamo Sumila - 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 or very uneven extension systems and rural social and economic institutions, limiting widespread access to improved crop technologies, quality inputs and credit. This research project is based on two premises: (1) sustainable intensification of agriculture production requires improved soil fertility management in which legumes are an integral part of cropping systems; and (2) effectively addressing soil-related constraints will be based on enhancing smallholder farmers' capabilities in diagnosing and finding solutions to important yield constraints, as well as helping to remove barriers to increased access to various types of soil amendments.

Project research activities are taking place in key common bean production regions in these countries – in Masaka and Rakai districts in south-central Uganda and in Gurué district (Zambézia province) in northern Mozambique. To understand potentially limiting soil nutrients, the team has analyzed the 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. The results of these analyses guided greenhouse 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. Complementing the NOS is the lime requirement study (addressing low pH, Ca and Mg availability, and Al toxicity) which is expected to demonstrate a consistent requirement for pH amelioration for adequate bean root growth on specific soils. Consequently, researcher-managed field trials in the study communities initiated in the second season in 2014 in Uganda and the main (rainy) 2014-2015 season (Oct. – Apr.) and second (dry) season (May – Sept.) in Mozambique are expected to demonstrate the soil-specific nutrient and crop management practices that are necessary to increase bean crop productivity in farmer fields.

The research team has established a base understanding of smallholder farmers' practices of field selection and preparation, crop and variety selection, planting methods and spacing, use of various types of inputs, intercropping and rotation patterns, gender-based division of labor, problem identification and management practices, market sales and storage practices in several communities in Uganda (Mukungwe and Kabonera sub-counties in Masaka District) and (Lwankoni sub-county in Rakai District), and Mozambique (Tetete, Mepuaguía, Ruace and Lioma administrative posts in Gurué District).

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 management practices and technologies (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 MPT.

This project is developing aids (methods and procedures) that will enable smallholder farmers with varying levels of education to better diagnose soil-related production constraints, and make improved site-specific crop system management decisions that contribute to higher productivity (including grain legumes) in the short term as well as improvements in soil fertility in the long term. It will assess the effectiveness of innovative communication approaches and technologies to engage farmers with diverse characteristics and other key stakeholders in widespread dissemination and adoption of diagnostic and decision support aids.

II. Project Activities for the Workplan Period (October 1, 2014 – September 30, 2015)

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

Approaches and Methods

Our initial discussions and interviews with productive and innovative farmers and soil surveys revealed that smallholder farmers recognize the role of a variety of soil-related characteristics that impact bean yield in their production systems: soil color (black soils are generally more suitable for beans than red soils), particle size, soil texture, topsoil depth, rocks, slope, water holding capacity, plant vigor, previous yield results, weeds, etc. In community focus group discussions, they identified factors and ranked the relative importance of each. Farmers identified fields with the predominant soils characteristics for extraction of samples for analysis, and for participation in development and testing of diagnostic aids, presented under Objective 3. In south-central Uganda, these are referred to as Liddugavu (black), Luyinjayinja (black, stony), Limyufumyufu (red); in northern Mozambique, they are called Intethe (black), Cotxoca/Ikochokwa (red), Makande/Etchirokwe (paddy), Ehava (sandy). A significant range of soil types often exists within a given community, and indeed often on specific farms – providing both challenges and opportunities.

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, planting methods and spacing, use of various types of inputs, intercropping and rotation patterns, problem identification and management practices utilized by farmers to date. It guides the research team in its observations and learning how farmers use existing knowledge to help determine crop system needs and to improve conditions. 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. Current MPT that farmers highlighted include:

- Purchase of good quality seeds, where and when available
- Changing the location for planting specific bean varieties, sometimes from season to season
- Minimum tillage – with and without use of herbicides to manage weeds
- Timing of planting - ranging from early to late, depending on rains, pests, market opportunities
- Planting patterns and spacing - some in rows, others broadcast
- Intercropping, with an array of different partner crops and precise timing of bean planting
- High plant density (makes weeding difficult and high risk of rapid pest or disease propagation)
- Crop Rotation – various patterns
- Chemical Fertilizers (relatively uncommon, limited by availability but also price)
- Foliar sprays (purported to be fertilizers, often lacking nutrient value)
- Pesticides (commonly used in Masaka, rarely available and used in Gurué)
- Weeding, from one to three times per season
- Incorporating (burying) crop residues in soil, rather than burning
- Mounding ridges where beans and other crops are planted
- Farmyard manure (very rare, given low density of livestock)
- Mulching – various materials and methods
- Fallowing (very rare, given perceived 'shortage' of land)

Based on information obtained and analyzed to date, women and men often differ in terms of the priority for growing beans, constraints identified, trust in information sources, resource accessibility, decision making roles regarding various aspects of bean production, and solution strategies adopted.

We met with key staff of a non-governmental development organization that focuses on production of certified bean seed. In Uganda's Rakai district, adjacent to Masaka district, Community Enterprises Development Organization (CEDO) works with 80 farmers groups in five adjacent districts, including Masaka. CEDO has been active in Lwankoni sub-county in Rakai since 2005, and almost all farmers interviewed reported getting their bean seed through CEDO. CEDO may be an important source of high quality bean seed for project farmers as our research, demonstrations and dissemination progress.

Obj. 1a. Continue collection of primary data in research communities (lead researchers: M. Tenywa, O. Semalulu, R. Maria)

1a.1. Monitor field experiments with selected farmers in Masaka/Rakai (two rainy seasons) and Gurué (rainy and dry seasons) (also: R. Yost, A. Lenssen)

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

Milestones

Oct. 2014 – Mar. 2015

1.1 - Reports on farmers' participation in field experiments

Apr. 2015 – Sept. 2015

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

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

Collaborators:

Jalia Namakula, GIS specialist, NARL, Uganda

Venâncio Salegua - Institute of Agriculture Research of Mozambique

Approaches and Methods

Participatory Rural Appraisal (PRA) activities (semi-structured key informant interviews, focus group discussions, and situation analysis) initiated the community level research process for understanding smallholder farmers' current knowledge, practices, motivations, experiences and conditions in Uganda and Mozambique. Building on the information obtained through the PRAs, the baseline household survey of practices and conditions is providing a detailed community-wide profile of farmers' sources and uses of information about bean crop and soil fertility management, problem diagnoses and solutions adopted, flows of key resources (information, production materials, labor, food, money, etc.), consumption, market sales, decision making practices and risk management strategies. Contextual factors analyzed include availability, accessibility and affordability of key resources (natural, physical, financial); and value chain development (input and output markets). Baseline data serve as the reference point for monitoring changes in knowledge, attitudes, practices and conditions over time.

Key social, cultural, economic, institutional and contextual factors which shape farmers' decision making – individually and collectively - that are being analyzed include: gender and other roles (who makes or negotiates which types of decisions, alone or with others); goals and priorities; criteria (factors considered and the relative importance of each); information base (nature, sources and credibility); resources required (and the social relationships and economic costs of accessing each); resource constraints (material, labor, financial, etc.); risk assessment/tolerance; decision processes (timing, stages, sequencing); evaluation of experiences; and adjustments over time (responding to changes in both internal and external factors); group and network size and strength; collective action for enhancing access to vital resources; and progress toward livelihood goals. Institutional factors include culturally defined roles, community-based organizations, governance, and socioeconomic status (wealth, gender, ethnicity). These factors may influence current knowledge, attitudes, practices, and subsequently processes of information dissemination, training, utilization, and support to stimulate and sustain widespread implementation. Important outcomes from characterizing farmer decision-making processes in part comes from gaining insight into which households are more prone or able to make fundamental changes and why.

Acreages for all crops combined average 2-8 acres in Uganda and some communities in Mozambique, but also with significant variation (some farmers use 10-25 acres). Beans fields range from 0.25 acres to 5 acres or more. Many farmers in both countries cite 'shortage of land' as a constraint. Ugandan farmers have several months between two rainy seasons, while in Mozambique cultivation of beans and other crops in the dry season almost immediately follows harvest of crops grown during the rainy season.

The support system for cash crops differs significantly between Uganda and Mozambique, as well as among communities. Support involves training, provision of seed and other inputs, and marketing; overall, such support is more directly available in Mozambique, provided by private sector foreign investors, NGOs and international research organizations. In Mozambique, an array of cash crops have been introduced or efforts intensified in the past decade - soybean, pigeon pea, sunflower, pineapple, cotton, tobacco; in contrast, common bean production and sales appear to be almost exclusively driven by domestic market actors. If/when the support is reduced or eliminated, or the market prices declines significantly, common bean production is more lucrative. In Uganda, the two major cash crops are currently affected by disease - banana bacterial wilt and coffee rust; pineapple production is also widespread. Storage after harvest is

rare in both countries, because of income needs at (or before) harvest time and farmers' inability to store bean grain and seed safely; in Uganda, farmers try to avoid bruchid damage by using strong chemicals (unsafe for human consumption), while most farmers in Mozambique use nothing.

To date, we have learned that 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. In Mozambique, farmers groups (associations) are relatively common, being the principal mechanism to access training and other support. A forum is comprised of several associations, and several forums constitute the apex organization, a federation; 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.

Obj. 2a. Characterize access to resources required for bean production (lead researchers: H. Sseguya, C. Sumila)

2a.1. Continue analysis of household survey data to describe resource base variation, characterize how access to key resources is obtained and negotiated, and describe the economic costs involved (also: E. Luvaga, R. Mazur)

2a.2. Continue analysis of household survey data to explain resource constraints (also: E. Luvaga, R. Mazur)

Milestones

Oct. 2014 - Mar. 2015

2.1 – Reports on: resource base, access, costs, resource constraints

Apr. 2015 – Sept. 2015

2.2 - Reports on implications for modeling decision making behavior

Obj. 2b. Characterize farmers' livelihood goals, resources, strategies and success through analysis of household survey data (lead researchers: R. Mazur, E. Luvaga, H. Sseguya, C. Sumila)

2b.1. Continue analysis of farmers' livelihood values, goals, and priorities

2b.2. Continue analysis of social networks, benefits derived, and risk management arrangements

2b.3. Continue analysis of sources, levels, and consistency of household income

2b.4. Continue analysis of variations in household food security

Milestones

Oct. 2014 - Mar. 2015

2.3 - Reports on farmers' livelihood goals, resources, strategies and success

Apr. 2015 – Sept. 2015

2.4 - Reports on implications for modeling decision making behavior

Obj. 2c. Assess influence of institutional factors (lead researchers: M. Tenywa, O. Semalulu, R. Maria)

2c.1. Identify farmer- and other community-based organizations (also: H. Sseguya, C. Sumila)

2c.2. Identify nature of extension services (public and private)

Milestones

Oct. 2014 - Mar. 2015

2.5 - Analysis of local organizations and extension services

Apr. 2015 – Sept. 2015

2.6 - Recommendations for training and support of 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 tools will be developed with and for farmers who have varying levels of education, based upon field-observable soil classification characteristics in diverse agroecologies in two target bean production regions in Uganda and Mozambique. Utilizing farmer experience and input from soil scientists and crop systems agronomists, we will draw from the global knowledge base of appropriate practices and technologies, soil and cropping systems management strategies and options appropriate for various smallholder farm systems.

Shortened fallow periods, lack of fertilizer inputs, reduced soil organic matter concentration, and erosion from water have been purported to result 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 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. Additionally, Al^{+3} levels were significant, further constraining potential root growth for water and nutrient extraction. Results for the Luyinjayinja (black, stony) soil samples were more similar to those of Limyufumyufu than for Liddugavu soils, with low pH and concentrations of available nutrients. Additionally, these soils typically had a zone of higher clay concentration that likely limits hydraulic conductivity and root growth into subsoil. Results from our January 2014 soil survey in Uganda documented that numerous specific soil sites had good soil quality yet farmers still experienced low and unsatisfactory bean yields. Analysis of soil samples recently obtained from farmers in Gurué will yield similarly useful results and provide insights regarding nutrient limitations in bean productivity.

The subsequent monitoring of bean growth, development, and pests in Uganda provided strong evidence that other factors in addition to soil fertility strongly impact bean yield. These factors included low plant density, seeding of older cultivars with low levels of host plant resistance to important pathogens, and early and sustained onset of foliar diseases. Exactly which soil nutrients are inadequate for bean production has not been systematically addressed across a range of important soils; however, nutrient omission studies are currently ongoing in Uganda. Lime requirements for pH management are not yet known. Available aluminum (Al^{+3}) has not been determined for extensive areas. Where data are available, available P concentration usually is low in older, weathered soils typical of Uganda and Mozambique and other areas within SSA. The high concentrations of available Fe and Al in low pH soils rapidly complex available P, making it unavailable for uptake by plants, perhaps explaining in part why phosphorus fertilization does not always improve yield or N fixation by bean and other pulses.

The nutrient omission studies will provide new information on the relative importance of nine nutrients for bean growth and development on Liddugavu, Limyufumyufu, and Luyinjayinja soils from Uganda. Results will be used in designing several potential treatment strategies that are practical for smallholder farmers. Additionally, previously untested solution strategies can be tested on researcher-managed sites to determine validity of identified management practices and technologies (MPT). Diagnostic aid

development is in part based on results from the nutrient omission studies. A key element in diagnostic aid development is the inclusion of farmers' input during all developmental phases, not just during testing.

Diagnostic criteria provide implicit comparisons of 'what if' scenarios. Highly observable characteristics are 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 anticipate that our criteria will rely in part on comparisons of plant growth and development, dry matter accumulation, and color of bean plants grown in the representative soils under different nutrient or management levels. Photographs taken during the course of the nutrient omission studies will comprise an important component that allow farmers to quickly note important differences between or among important management practices. Initially, images will be available from the nutrient omission and lime requirement studies, but in subsequent years, images will be available from productive and innovative farmer fields where the criteria were used, providing direct comparison of bean growth, development, and yield between management systems used. Additionally, comparisons can be done between productive and 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 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 document nutrient limitations on farmers' fields and attempt to address the most critical limiting soil nutrients. Given inherent precipitation, soils, and other differences between Masaka district (beans are planted in both rainy seasons) and Gurué district (beans are planted in the 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, and final key soil chemical and physical properties. Initial properties determined typically will be those documented in the nutrient omission study in impact bean growth and development. Bean stand density, yield, yield components (pods/m^2, seed/pod, seed weight), seed protein and germination percentage are determined in fields under both management systems and for the non-selected farmer control group. Additionally, timing and intensity of foliar disease development are assessed, providing relevant results for deployment of newer, more disease resistant varieties as a potentially viable 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 soil fertility and other bean production constraints (lead researchers: M. Tenywa, O. Semalulu, R. Maria, M. Amane, R. Yost, A. Lenssen)

3a.1. Conduct field studies comparing bean management systems and soil fertility

3a.2. Compare bean varietal responses to crop management systems and soil fertility

Milestones

Oct. 2014 – Mar. 2015 and Apr. 2015 – Sept. 2015

3.1 - Conduct field studies on crop management, soil fertility and bean varieties

3.2 - Analyze soil samples after cropping season

Obj. 3b. Develop Diagnostic Methods and Aids (lead researchers: M. Tenywa, O. Semalulu, R. Maria, M. Amane, R. Yost, A. Lenssen)

3b.1. Identify relevant diagnostic criteria and methods by and for farmers

3b.2. Initiate application of diagnostic criteria and methods by project farmers

Milestones

Oct. 2014 - Mar. 2015

3.3 - Identify relevant diagnostic criteria and methods by and for farmers

Apr. 2015 – Sept. 2015

3.4 - Initiate application of diagnostic criteria and methods by project farmers

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, Gurué District Agricultural Extension Officer, Mozambique
Venâncio Salegua - Institute of Agriculture Research of Mozambique

Approaches and Methods

To realize our goals, we will work with existing institutions and organizations to identify and develop messages that can provide farmers with 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' perspectives revealed some strengths and weaknesses of current information providers and existing agricultural information dissemination systems in Uganda and Mozambique. Current and valued sources include extension services, training workshops, exchange visits, field days, media (community and national radio, TV, newspapers), phones, traders, and input dealers. The perceived accuracy and value of each type of sources varies among study communities. Some information received through training sessions seems to conflict with information previously disseminated; in addition, some information broadcast on the radio by private sector businesses is viewed as misleading or inaccurate. We

have developed an initial list of available and potential information channels and associated organizations. Discussions with providers will enable us to assess their capacity and willingness to develop and deliver messages concerning beans and soil fertility.

The project will engage the core groups of farmers, women and men, in developing and testing innovative communications approaches and technologies for learning and sharing information about new options for sustainable improvement in increased yields and soil fertility. Given limited extension system resources in Uganda and Mozambique, local peer-to-peer dissemination and learning (field days, exchange visits, local community based organizations, farmer associations) will be important methods. To benefit those with low literacy skills – especially women, communication approaches and technologies that may be used include: a variety of visual aids (print materials and animated videos - Scientific Animations Without Borders), and radio campaigns in local languages will be used. Working through project staff and extension, we will provide training to Community Knowledge Workers who can function as intermediaries between extension/NGO communication systems and farmer groups or associations for effectively disseminating agricultural information using participatory methods.

In order to initiate the process of working with local information providers and dissemination systems, we will utilize existing training materials regarding anaerobic bean grain and seed storage using jerry cans and the triple bag system that were developed during the previous Pulses CRSP project in Uganda's Kamuli District. This will enable us to test the information system and providers so that subsequent messages regarding crop and soil management practices and technologies can be launched effectively and efficiently. We will identify the specific type of weevils present in stored grain. The Masaka District Agricultural Officer is currently using those materials to learn about and evaluate the effectiveness of these anaerobic storage methods during a three month period. If successful, a second trial will take place following the second season harvest in late 2014. This will involve participating farmers and local agricultural officials. Training materials will be refined, pre-tested and distributed for this trial on a controlled basis to a sample of farmers. Results will be evaluated by the end of March 2015. In addition, pricing fluctuation data for beans in the local market will be monitored. It is expected that prices are very low at the time of harvest, when most farmers sell, and much higher later. We did note that in Gurué beans produced during the dry season are generally of higher quality and obtain higher prices.

If successful, a full-scale trial would be scheduled following the first season of 2015 (June and July 2015) including participating farmers plus all target farmers in the area. Target farmers are those who produce enough beans and could save them for at least three months before marketing. Extensive publicity would be given to this trial, including radio, extension, and local NGOs plus farmer groups. The messages would be targeted at those who can store beans for at least three months to benefit from increases in market prices later. Data would be collected on: (1) knowledge of the jerry can and triple bagging techniques prior to the experiment (carried out as part of the baseline survey); it is expected that knowledge levels and use would both be very low at this time; (2) knowledge of the jerry can and triple bagging techniques following the publicity campaign, and stated intent to use the techniques after the next two growing seasons; (3) economic analysis of bean price trends over the period to test whether or not bean prices increase as expected in months after the harvest; (4) effectiveness of the jerry can and triple bagging techniques, as measured by the extent of weevil damage to treated jerry cans or a control sample that is stored in the traditional way; and (5) the final project survey would also assess adoption and use of the technique. The assessments would track channel and message effectiveness, and would be used as input for other dissemination activities developed later after soil tests and on-farm trials have been completed.

Following soil nutrient and crop analysis and community communication assessment, we will work with project staff and extension to develop an initial message that can test the communication system with a small number of farmer groups/associations. We will then evaluate the effectiveness of the dissemination

system and provide additional training and/or revise methods to prepare for subsequent participatory dissemination activities.

Dissemination, training and support will target priority decision-making points for individuals and groups. Horizontal farmer-to-farmer learning has been found to be preferred by many communities. 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. Test Existing Information Dissemination Systems (lead researchers: E. Abbott, J. Bello-Bravo, B. Pittendrigh, H. Sseguya, C. Sumila)

4a.1. Develop prototype message/media

4a.2. Field test prototype message/media

Milestones

Oct. 2014 - Mar. 2015

4.1 - Develop prototype message/media

Apr. 2015 – Sept. 2015

4.2 - Test prototype message/media

Obj. 4b. Identify and Develop Messages for Decision Making about Bean Production and Soil Fertility, Based on Farmer Identified Management Practices and Technologies (lead researchers: E. Abbott, J. Bello-Bravo, B. Pittendrigh, H. Sseguya, C. Sumila)

4b.1. Identify priority issues

4b.2. Develop messages/media

Milestones

Apr. 2015 – Sept. 2015

4.3 - Identify priority issues

4.4 - Develop first message/media

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 will be training three 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 will study Communication at Iowa State University and conduct research on innovative socio-technical approaches for dissemination of information and decision support aids
- one Ph.D. student from Mozambique will study soils/crops at the University of Hawaii and conduct research on alternative management practices for improving bean production

One M.S. student studying Agronomy at Iowa State University will conduct 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 will test the management strategies developed from Objectives 1, 2, and 3 in replicated, researcher-managed studies, complementing the farmer assisted research.

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

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

Each country has one research technician who is gaining experience in multidisciplinary research activities and specific skills in preparing and analyzing soil and crop samples. Additionally, short-term training needs are identified as research activities continue. Training of agricultural technicians in methods of acquiring, verifying, and recording information is especially important in Mozambique.

Milestones

Oct. 2014 - Mar. 2015 and *Apr. 2015 – Sept. 2015*

5.1 - Students continue 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 and 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 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

In Mozambique, project PIs from U.S. and Ugandan universities and from IIAM met with the USAID Mission Director and Feed the Future staff on May 29, 2013 in Maputo. This provided a tremendous opportunity for sharing information about USAID programs in Mozambique and the Legume Innovation Lab program. In-depth discussion of our project and the expertise of research team members revealed several key points of significant interest for Mission staff. These included soil test kits, animated videos about management practices, and use of agricultural technologies. 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. Project researchers met with key staff in the Mission in Kampala on June 6, 2014. The PI and Co-PIs will establish ties with Mission development partners, as recommended. 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 continues to learn about relevant existing and emerging conservation agriculture approaches and technologies (e.g., how upland farming practices in Gurué can be improved for reducing erosion and quality of low land where rice and bean are grown), and explore opportunities to collaborate and coordinate research efforts with CIAT scientists (Steve Beebe, Cali; Clare Mukankusi, Kampala; and others currently being contacted in the PABRA network), 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 (with which Haroon Sseguya and Robert Mazur are in discussions), Africa RISING which focuses on maize-legume based systems in the Eastern Highland of Africa, the Bill and Melinda Gates Foundation, and IFDC. Project researchers will continue to build collaborative relationships with two African based networks under PABRA (the Pan-African Bean Research Alliance): the Eastern and Central Africa Bean Research Network (ECABREN) and the Southern Africa Bean Research Network (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 2015

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: August 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: Haroon Sseguya
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: **Evaluation of Soil Fertility Management Options for Beans in Masaka**
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
Description of training activity
Location
Duration
When will it occur?
Participants/Beneficiaries of Training Activity
Anticipated numbers of Beneficiaries (male and female)
PI/Collaborator responsible for this training activity
List other funding sources that will be sought (if any)
Training justification

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:

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. II. Project Activities for the Work plan Period (October 1, 2014 - September 30, 2015)

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

The research partners agreed to stage this objective in a way that minimized risks and increased the potential value of the outputs and their impacts. To this end, the table below describes the specific activities, timelines and partner responsibilities related to Objective 1 for the FY 2015.[1]

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

[1] A number of administrative challenges have contributed to the restructuring of our initial timelines. Sub-award contracts for host country institutions were not completed by Kansas State University until April 2014. While we have received signed contracts back from Lilongwe and Sokoine, we are still awaiting University of Zambia's signed contract. Funds to conduct fieldwork cannot be transferred by Kansas State University until the contracts are completed. We had expected such delays and built them into our original project plan. Therefore, our delivery timelines do not change despite the changes in our activity timelines.

Approaches and Methods

Objective 1 employs 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. The method is explained extensively in the technical proposal for this project. We will used CAPI in collecting the data from the experiments, eliminating the need to input data, reduce errors and the need data cleaning. This time savings gives us confidence that the lost time due to our administrative challenges will not adversely affect our deliverables. The data will be analyzed using STATA® and standard econometric modeling. The results will show the extent to which specific consumer demographic and socio-economic characteristics influence choice of legumes as well as the position of their choice in their food hierarchy.

Period	Activity	Specific Responsibility
Jan – Feb 2015	Conduct discrete choice experiments in Zambia, Malawi and Tanzania sequentially using a CAPI tool. This will eliminate the need to input field data and minimize data cleaning, allowing rapid progress to analyses and report writing.	Research Team with US PIs and HC PIs leading
March - Spetember2015	Complete analyses and report on legume consumption in the focus countries.	Research Team with each HC PI leading their country initiative
Aug/Sept 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
Sept 2015	Report distributed to Legume Innovation Lab partners, regional CG partners, country USAID missions and country policy makers.	US PIs and HC PIs leading
Sept 2015	Begin planning for report rollout in each country in the fall. HC PIs will coordinate with local agencies to maximize rollout impact.	Research team

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 uses 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. We are using econometric models and analyses to determine the production situation.

This effort is also 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 is currently under way with the help of our MS students in the respective HC institutions. We are using the World Bank's nationally representative Living Standards Measurement Study-Integrated Survey on Agriculture (LSMS-ISA) data for Malawi and Tanzania and the Food Security Research Project (FSRP) dataset for Zambia to conduct the situation analyses of primary production in the three countries. We expect this component to be completed in FY2015. 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, we will have MS theses on the subject coming from each host country. HC PIs will be responsible for overseeing students' research activities, ensuring quality production and delivering the report on time. We are anticipating draft of the situation analyses of primary production to be completed by December 2014.

Situation analyses of downstream activities will be conducted with secondary quantitative data from SABREN and primary qualitative data from focus group interviews conducted with industry stakeholders after the rollout of the consumer report. This is because we believe the opportunities discovered from the consumer study would inform the assessment of downstream capabilities and gaps in forward thinking way. Therefore, the second component of Objective 2 will be implemented in FY16, in proximity to the development of outreach programs to address the gaps that are identified by the industry.

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 one student already enrolled in the Master of Agribusiness (MAB) program at Kansas State University. The recruitment information for Academic Year 2015 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. The specifics of the activities will be elaborated in the Work Plan for FY16 because that is when these industry training take off.

Under FY15, we propose to provide a number workshops to the general agri-food sector stakeholders whenever the U.S. PIs are in any of the host countries. We used this approach in the previous project we undertook in Zambia and it was well-received. Host country PIs have the responsibility to work with the industry, faculty and/or students to identify a topic in the research and teaching area of the U.S. PIs and publicize it with date, time and location.

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 report detailing the relative position of legumes in consumers' food ranking in Zambia, Malawi and Tanzania.
- A report describing the factors defining legume consumption in the three focus countries and their elasticities.
- 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 end of FY15. (The final policy brief is scheduled to be completed in the first quarter of 2016).

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. We will visit the Missions in Tanzania and Malawi when we get there in January 2015 and provide them with an update of our activities. We will 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, we will continue working with breeders and breeding researchers like Kennedy Muimui in Zambia and fully engage Susan Nchimbi-Msola, in Tanzania and Rowland Chirwa in Malawi. We will also continue working with IAPRI and CCARDESA on policy development and dissemination. We will expand our relationship with HC agricultural and food public policy making bodies – government ministries and relevant institutions – to facilitate the impact we expect from our work on policy.

VII. Leveraging of CRSP Resources

The Gates Foundation is currently funding a capacity building initiative in the agri-food and agribusiness sector in Africa. The US Lead PI is an advisor to this initiative and will explore opportunities to leverage resources from this initiative to complement the development and capacity building efforts in later stages of this project. We will continue to explore other initiatives in other agencies of the US Government, private foundations, development partners and donor agencies working in the region whose vision are congruent with ours.

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 2015)

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.

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

First and Other Names	Nyumbani	Marynia
Last Name	Moyo	Mazunda
Citizenship	Malawian	Malawian
Gender	Male	Female
Training Institution	LUANAR ,Bunda College, Malawi	LUANAR ,Bunda College, Malawi
Supervising CRSP PI	Dr L. Mapemba	Dr L. Mapemba
Degree Program for training	Master of Science	Master of Science
Program Areas or Discipline	Agribusiness Management	Agribusiness Management
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 production of common bean in Malawi	Situation analysis of post-production segments of Malawian legume industry
Start Date	May 2014	May 2014
Projected Completion Date	December 2014	May 2015
Training status	Active	Active
Type of CRSP Support for training activity	Partial	Partial
First and Other Names	Adelina	Ocran
Last Name	Mfikwa	Chengula
Citizenship	Tanzania	Tanzania
Gender	Female	Male
Training Institution	Sokoine University of Agriculture	Sokoine University of Agriculture
Supervising CRSP PI	Fredy T. M. Kilima	Fredy T. M. Kilima
Degree Program for training	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	
HC Institution to Benefit from Training	Ministry of Agriculture Food Security and Cooperatives	Ministry of Agriculture Food Security and Cooperatives
Thesis Title/Research Area	Bean Production and Marketing in Tanzania	Market Participation Among Smallholder Bean Farmers In Tanzania
Start Date	Sept. 2013	Sept. 2013
Projected Completion Date	Sept. 2015	Aug. 2015
Training status	Active	Active
Type of CRSP Support for training activity	Partial	Partial

First and Other Given Names	Winnie	
Last Name	Pele	
Citizenship	Zambian	
Gender	Female	
Training Institution	Kansas State University	
Supervising CRSP PI	Vincent Amanor-Boadu	
Degree Program for training	MAB	
Program Areas or Discipline	Agribusiness	
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?	No	
HC Institution to Benefit from Training		
Thesis Title/Research Area	Consumer Preferences for Beans in Zambia	
Start Date	Jan. 2013	
Projected Completion Date	May 2015	
Training status	Active	
Type of CRSP Support for training activity	Full	

Short-Term Training

Training Type	Workshop	Workshop
Description	Building Successful Value Chains in Agri-Food	Discrete Choice Analysis and Simulations
Location	Zambia; Malawi; Tanzania	Zambia; Malawi; Tanzania
Duration	1 day	2 days
Dates	TBD	TBD
Participants/Beneficiaries	Agri-food sector stakeholders, faculty, students	Faculty and students at HC institutions
Anticipated Attendance	25 per country (72% male)	30 per country (50% male)
Responsible PI	U.S. PI	U.S. PI and HC PIs
Other Funding Sources	None yet.	None 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.	Although choice is central in economics, choice models are only recently becoming widely used in research. This workshop seeks to help researchers in host institutions hone their skills in using this method in their work.

FY 2015 WORK PLAN

(April 1, 2014 – September 30, 2015)

Project Code and Title: Legumes and growth

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 MS, Lecturer in Community Health, University of Malawi College of Medicine
- Indi Trehan MD, Assistant Professor of Pediatrics, Washington University School of Medicine in St. Louis

I. Project Problem Statement and Justification:

Each year millions of children in Africa die from malnutrition and even more are stunted due to nutritional and absorption deficiencies, interventions to help children affected and at risk are urgently needed to improve the lives of these children. Environmental 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. Planned Project Activities for the Work plan Period (April 1, 2014 – Sept. 30, 2015)

We will prepare to conduct a randomized, controlled clinical trial to investigate the effect of cowpea or common bean consumption on infant growth and gut health.

Objective 1:

Develop a working Manual of Operations to conduct the research projects in the field.

Collaborators:

Malawi College of Medicine

Approaches and Methods:

Chrissie Thakwalakwa and the research team will develop a method of operations and standard operating procedures that will be followed through out the duration of the project. The study procedure guide will describe the mode of operations for all study related participant and community interactions, including clinic operations, patient and participant screening, participant consent, enrollment, and food distribution. The methodology will also provide guidelines for data collection, giving instructions on surveys, home visits, and anthropometric measurement guidelines including taking mid-upper arm circumference and collecting biological samples. We will also develop an events reporting procedure for any unexpected and adverse events that could occur during the duration of the project. The manual will provide the field work directives for the Malawian graduate students and the local research team. Ms. Thakwalakwa will lead the development of the operations manual.

Objective 2:

Develop and test the acceptability of two sets of 3-4 recipes that include either cow peas or common beans for use infants in the clinical trial.

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: 200 kcal/d for children 6-9 months old and 300 kcal/d for children 9-11 months old. The candidate recipes will then undergo acceptability testing in 6-11-month-old Malawian infants 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. About 3-4 recipes will be selected for each of the target legumes (cowpea and common bean) to offer diversity and choice to the caretakers, as they will be asked to feed the food to their child daily for 6 months.

Objective 3:

Complete preparations to initiate study aim 1, including staff recruitment, training and community engagement and organization.

Approaches and Methods:

Working with our staff in Malawi and at the College of Medicine, the research team will be hired to initiate specific aim 1. A graduate student will be recruited by the College of Medicine in Malawi to take on the responsibilities of this project. Study staff including drivers, nurses and research assistants will undergo extensive training by the PI and his team in Clinical Good Practice techniques and in data collection methods to properly conduct all enrollment and data collection. The research team will visit Mitondo district clinics to mobilize and engage them in the upcoming research project. The team will also conduct meetings with local community leaders and health centers. Concurrently, all ethical approvals will be initiated to conduct the study; approvals will be sought from the Malawi College of Medicine and Washington University Board of Ethics.

Objective 4:

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

Approaches and Methods:

While initiating Study Aim 1, 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 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

1 COM PhD student 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:

- Manual of Operations for Field Work
- Recipe development report on lab development of cowpea and common bean interventions

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. Leveraging **of CRSP Resources:**

VIII. Timeline for Achievement of Milestones of Technical Progress:

See attached

Training/Capacity Building Work plan for FY 2014 - 2015

Degree Training:

First and Other Given Names: Chrissie
Last Name: Thakwalakwa
Citizenship: Malawi
Gender: Female
Training Institution: Malawi College of Medicine

Supervising CRSP PI: Ken Maleta and Mark Manary

Degree Program for training: Public Health Nutrition
Program Areas or Discipline: Public Health

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? No
Host Country Institution to Benefit from Training: Malawi College of Medicine
Thesis Title/Research Area: Public Health Nutrition

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

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? Spetember 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 in 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: 1 week
When will it occur? Aug 2015

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

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

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

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

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

-80C freezer

FY 2015 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) and Byron Reyes (Collaborator), 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.

Building on the momentum and experience gained over the last three years, the proposed research will contribute towards evidence-based rigorous ex ante and ex post assessments of outputs, outcomes and impacts with the goal of assisting the Legume Innovation Lab program and its Management Office (MO) to achieve two important goals--accountability and learning. Greater 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 will ultimately help increase the overall impact of such investments.

II. Planned Project Activities for the Workplan Period (April 1, 2013 – September 30, 2014)

Objective 1:
Provide technical leadership in the design, collection and analysis of data for strategic input and impact evaluation

Collaborators:

Juan Osorno (NDSU) and Julio Martinez (ICTA)

Biaou Agué Eustache and Hinnou C. Léonard (INRAB), Manuele Tamo (IITA) and Barry Pittendrigh (UIUC)

Approaches and Methods:

In FY14, after consulting with the PIs of other Legume Innovation Lab Projects, several opportunities were identified for baseline assessments. Discussions and preliminary planning for two of these studies was initiated in FY 14. But most of the field work will be implemented in FY 15. These activities include:

1a. Socio-economic baseline study on the constraints and opportunities for research to contribute to increased productivity of climbing beans in Guatemala: This will be a joint activity with the SO1.A1 project team under their objective '*Genetic improvement of climbing black beans for the highlands of Central America*.' This study will be designed to establish a baseline about production of climbing beans in the highlands of Guatemala, and to better understand the current status of the climbing bean/maize intercropping production system. Information and data concerning cultivated area, number of different species grown, number of farmers utilizing this cropping system, production problems, seed quality and culinary preferences will be collected to help establish priorities for the climbing bean breeding program.

1b. Study on the market potential for biopesticides in Benin: This will be a collaborative activity with the SO1-B1 project team, specifically with Biaou Agué Eustache and Hinnou C. Léonard from INRAB-Benin, under their objective 3 '*Scaling of solutions.*' This study will be designed to assess the potential groups that can develop, market and sell biopesticides, and serve as the logical "pass-off" groups in host countries for scaling up these technologies. This study will serve as a baseline to assess the market potential for biopesticides (e.g., what farmers are willing to pay, what will be the costs to enter the market place for small industries, what are skill-sets that need to be developed for womens' groups to potentially

make and profit from selling such materials, etc.) and will determine the networks of NGOs and other organizations where the project can "pass-off" educational approaches (e.g., animations) for scaling. The field work will consist of the following three phases:

1. Documentation phase: collection of secondary information
2. Exploratory survey in main cowpea production areas mainly through group interviews of major stakeholders in the value chain, but also to collect preliminary data for designing the individual survey questionnaire
3. Detailed survey with individual questionnaires administered to key players in the cowpea value chain particularly targeting producers and consumers, and their willingness to pay for biopesticides and biopesticide-treated cowpea, respectively

For these two studies, the Impact Assessment team will provide technical support in the form of human resources and professional expertise in data collection (i.e., sample design, evaluation design, designing data collection instruments, training enumerators, data entry templates, etc.) and analysis. This will be a joint activity with the relevant research team and rely on the logistical support from the host country partners. A majority of resources for data collection have been budgeted under the relevant research projects. However, for the study in Guatemala, resources to meet the budget shortfall to ensure that a rigorous study is conducted, will be met from this project's FY 14 budget allocation.

Objective 2: Conduct ex ante and ex post impact assessments

Collaborators:

Robert Shupp, Department of Agricultural, Food and Resource Economics (MSU)

Susan Nchimbi-Msolla, Paul Kusolwa and Fulgence Mishili, SUA, Tanzania

Jim Beaver (UPR) and Emmanuel Prophete (Haiti)

Approaches and Methods:

Under this objective, this project plans to: 1) assess the realized (ex post) impact of the Legume Innovation Lab (and the predecessor CRSP program's) investment in technologies/outputs where there is evidence of adoption, and 2) enhance future impacts by engaging in innovative and evidence-based research that will serve as an input in making strategic research priority decisions by the Legume Innovation Lab program, and in developing strategies for technology dissemination for maximum impact. In FY 15, following research studies and activities will be undertaken under this objective.

2a. Assessment of the willingness of small holder farmers to pay for quality seed?

In FY 15, we plan to implement a research study in Tanzania to assess farmers' willingness to pay for quality seed over grain. This research will be done in collaboration with the bean research team at SUA and the CIAT/PABRA seed research theme leader (i.e., Dr. J. C. Rubyogo). Opportunities to engage a MS student at SUA in the implementation of the field research component will be explored with the SUA team.

The methodology/ approach to address this research question will consist of first conducting field experiments in farmers' fields to demonstrate the value of planting different types of seeds of the same variety (to keep the genetic component of the planting material constant) vs. grain saved from previous harvest (representing different years of recycled seed) or purchased from the market, and then conducting choice experiments (CE) and/or biding experimental auctions (BEA) to test farmers' willingness to pay for seed vs. grain. These experiments will include various treatments related to the type of materials used for planting: grain (saved from previous harvest representing different years of recycled seed), grain purchased from the market, quality-declared seed, and certified seed. The experiments could be designed to understand the following elements of seed demand – quantity of seed, frequency of seed purchase, and willingness to pay for seed for a given quantity and frequency. The major field costs of doing this study will include conducting the field experiments in different sites (to represent different agro-ecological and socio-economic conditions) and going to the field (after harvest) to conduct the CE/BEA experiments and data collection. The reason for selecting Tanzania for this study is because it is one of the only countries in the ESA region that officially recognizes quality declared seed (QDS), and it will be interesting to compare the performance of QDS vs. certified seed and then assess farmers' willingness to pay for these two types of seed, which have different cost of production associated with them. Potential sites where this study will be conducted include Manyara, Arusha or Kilimanjaro in northern Tanzania, and Mbeya in Southern Highlands.

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 has recently 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.

No resources are available to cover the data collection cost in the SO1.A4 project budget. However, in-kind support and technical guidance from the SO1.A4 project (and esp. from HC PI) will be available. We are currently in the process of getting estimates on the cost of conducting this study. Tentatively, the plan is to use some of the resources available through this impact assessment project to partially cover the cost of data collection. However, the study will be implemented in FY 15 only if funding is secured to meet the estimated budget.

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 15:

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.
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).
c. Short courses on impact assessment. Three short-term training workshops to build capacity of local partners is being planned in collaboration with CIAT, MSU's Food Security Group faculty members and other NARS partners as described in the Training section. These training workshops will focus on teaching theoretical concepts and demonstrating practical applications of these concepts to rigorously assess the impact of agricultural projects and programs. The topics will include current theory and methods on impact evaluation, sampling methods, data collection instrument design, data collection using computer assisted personal interviewing software and paper questionnaires, and the use of statistical software for data cleaning and analysis.

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 15 include:

a. Completion of one Impact Brief
b. Completion of one 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 15. 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. Leveraging of Legume Innovation Lab Resources:

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. Some examples of anticipated leverage activities include exploring funding opportunities in response to RFAs in the area of impact assessment research. For example, the International Initiative for Impact

Evaluation (3ie) routinely issues RFPs to promote research in the area of impact evaluation of development interventions in developing countries. In the next round, opportunities will be sought to leverage funding from this organization to conduct 'impact evaluation' of a legume based project in partnership with host country PIs and collaborators to promote objective 2 of this project.

VIII. Timeline for Achievement of Milestones of Technical Progress:

See the attached excel file

Training/Capacity Building Workplan for FY 2015

Degree Training:

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

Supervising CRSP PI: Mywish Maredia

Degree Program for training: Ph.D.
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: Potential and realized impact of bean research in Guatemala and Haiti

Start Date: Fall 2014

Projected Completion Date: Fall 2016

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

Short-term Training:

***Description of training activity*:** Three short-term training workshops are tentatively planned in FY 15. These will focus on teaching theoretical concepts and demonstrating practical

applications of these concepts to rigorously assess the impact of agricultural projects and programs. The topics will include current theory and methods on impact evaluation, sampling methods, data collection instrument design, data collection using computer assisted personal interviewing software and paper questionnaires, and the use of statistical software for data cleaning and analysis.

***Location*:** of these three workshops is:

1) East/South Africa (country to be determined-TBD): this workshop will be given in collaboration with CIAT and NARS partners and the country will be selected based on the existence of current Legume Lab projects and country location (i.e., easy to travel from other countries in the region).

2) Mozambique (not confirmed at the time of finishing this document): this workshop will be organized by an AFRE/MSU colleague and SO4.1 collaborators and might be given in collaboration with CIAT (to be determined).

3) Uruguay: this workshop will be organized by Uruguay's NARS, in collaboration with PROCISUR and will be given by SO4.1 and CIAT collaborators. One of the participants to the training workshop that CIAT organized in collaboration with project SO4.1 in April 2014 was extremely satisfied with the topics taught and what he learned and indicated his interest in us giving a similar workshop in Uruguay. This person has been able to secure funding for this course, which will most likely be given in March or April 2015 and is in charge of organizing it.

***Duration*:** Each workshop will last 4.0-4.5 days

***When will it occur*:** Between March-August, 2015. Exact dates are not available yet.

***Participants/Beneficiaries of Training Activity*:** Researchers and economists from national and international research centers and universities from the countries where the workshops will be held and, in most cases, neighboring countries.

***Anticipated numbers of Beneficiaries (male and female)*:** Participants will include 20-25 economists from several countries in the first workshop (country TBD), 10-15 economists from Mozambique in the second workshop, and around 15 economists from South America (it is expected that two NARS economists from each of the following countries will participate: Argentina, Brazil, Chile and Paraguay plus several economists from Uruguay; all these members of PROCISUR, organization that will fund their participation) in the third workshop. The male:female ratio is not available at this time, but female participants are expected.

***PI/Collaborator responsible for this training activity*:** Byron Reyes (collaborator), Mywish Maredia (PI)

***List other funding sources that will be sought (if any)*:**

1) For the first workshop in Africa (country TBD), current funding from SO4.1 is only available to cover travel expenses and salary for the SO4.1 collaborator; thus, obtaining funding for all other expenses will be needed (CIAT collaborators will cover their participation costs). The realization of this workshop will depend on obtaining the funding needed for it.

2) For the second workshop in Mozambique, a final decision about whether to implement it will be made before October 2014 by the MSU colleague in charge of organizing and funding it. If a final decision is made to implement the course, it will be fully funded. Thus, the SO4.1 project might only need to cover salary of the SO4.1 collaborator (it is likely that travel expenses will be covered by the organizer of the course).

3) For the third workshop in Uruguay, it will be fully funded by Uruguay's NARS and PROCISUR. Thus, is likely that project SO4.1 will only need to cover salary of the collaborator since Uruguay's NARS will cover the travel cost of the speakers (i.e., SO4.1 collaborator, CIAT).

***Training justification*:** Based on the experiences from implementing similar workshops during 2014, it is clear that building the capacity of local partners is still necessary. Since the previous two workshops (implemented in 2014) were implemented in Latin America, we consider that it is necessary to also replicate these workshops in Africa. Further, given that the workshops implemented in 2014 generated high interest from participants, one of the participants in one of the workshops took the initiative of obtaining funding to replicate a similar workshop in Uruguay, as previously indicated. In the case of Mozambique, our colleague at AFRE/MSU has expressed interest in providing this type of training to his project partners in this country and economists from NARS collaborating with the Legume Lab could also participate. The third workshop will be mostly directed to Legume Innovation Lab and CIAT partners from African countries.

These workshops will be led by Legume Innovation Lab collaborators and other MSU faculty, and will include economists from CIAT. This will be a joint activity in collaboration with NARS partners, who will assist during the organization and in some cases, cover most of the local cost of organizing the short course and supporting the participants.

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