

LEGUME INNOVATION LAB FOR COLLABORATIVE RESEARCH ON GRAIN LEGUMES

FY 2013 – 2014 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, Haiti and Tanzania.

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

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 Agrícola (ICTA), Guatemala

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

Paul Kusolwa and Susan Nchimbi-Msolla - Sokoine University of Agriculture (SUA), Tanzania

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 BGYMV permitted increased bean production in El Salvador. Bean production in Guatemala and Nicaragua has expanded into more humid lowland regions whereas a significant portion of the beans in Haiti continues to be produced in the lowlands. Bean production in Africa could be expanded if lines with better lowland adaptation were developed. This Legume Innovation Laboratory project will address several of the biotic and abiotic constraints often encountered by bean producers in the tropical lowlands.

Andean bean breeding lines developed by Dr. Paul Kusolwa at Sokoine University of Agriculture have a unique combination of traits that confer a high level of resistance to bruchids. These breeding lines include the 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 BCMV, BCMNV and BGYM. 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.

BCMNV threatens bean production in warmer bean production regions of Africa. The recent arrival of BCMNV in the Caribbean made the selection for resistance to this virus a priority breeding objective in Haiti, the Dominican Republic and Puerto Rico. An INIFAP bean scientists mentioned at the 2013 Bean Improvement Cooperative that BCMNV is 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 are currently being developed at Zamorano. These BGYMV and BCMNV resistant black and small red bean lines will be available in the event that BCMNV emerges as a threat to bean production in Central America. The availability of small red bean breeding lines with BCMNV resistance will permit the evaluation of the performance of this seed type in Tanzania where red beans are consumed. These field trials will provide an appraisal of the potential benefit of Middle American bean production in the lowlands of Eastern Africa. Compared with Andean beans, small red and black beans tend to have greater yield potential and heat tolerance. Middle American beans may also have greater resistance to pathogens in Africa, since these pathogens have co-evolved with Andean beans.

Increased resistance to common bacterial blight and web blight is needed for beans produced in warm and humid lowland regions such as the Petén in Guatemala. This combination of resistances may also permit increased production of beans in Central America during the first growing season when rainfall is 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. In a previous Pulse CRSP project, Dr. Phil Miklas developed Andean bean breeding lines with resistance to BCMNV and anthracnose that should be useful to both Legume Innovation Lab breeding projects.

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. The project will use a similar approach in Tanzania to collaborate with the Ministry of Agriculture bean research program and CIAT.

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. 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. Yellow, red mottled and white bean breeding lines having BCMNV resistance will also be tested in Tanzania.

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.

There are regions and/or growing seasons in Central America, Haiti and Tanzania 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.

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. Dr. Phil McClean at NDSU will lead the collaborative effort to develop improved molecular markers.

The TMAC and the Management Office of the Legume Innovation Lab pointed out the need for SUA to engage the Agricultural Research Institute (ARI) in Uyole to enhance bean breeding capacity for the highlands of southern Tanzania. The focus of bean breeding will be the improvement of yellow beans, Kablanketi and Calima types which are produced throughout southern Tanzania. Mbeya is a good screening site for many of the diseases that limit bean production and for the evaluation, testing and dissemination of improved varieties in southern Tanzania. SUA has the capacity to help the ARI in Uyole to screen bean breeding lines using marker-assisted selection for resistance to rust, anthracnose and angular leaf spot. Dr. Phil Miklas will serve as the lead U.S. Co-PI for Tanzania, given his previous experience collaborating with SUA bean researchers and his expertise with the utilization of molecular markers for bean improvement. He will also lead the effort to evaluate the performance of Durango race beans in eastern Africa. A meeting at Morogoro and Uyole will be convened in May or June of 2014 to discuss collaborative research and training activities in southern Tanzania for FY15-FY17. Participants will include Co-PIs from Tanzania and the U.S and representatives from the ARI and CIAT. The principal objective of the meeting will be the development of strategies to strengthen collaboration among bean research programs in southern Tanzania. This should enhance the capacity of SUA and ARI breeding programs to develop and deliver of technologies that will address the needs of bean growers in Tanzania.

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

Objective 1: Genetic improvement of common and tepary beans for Central America, Haiti and Tanzania

Objective 1a: Genetic improvement of common beans for Central America, Haiti and southern Tanzania

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
Paul Kusolwa and Susan Nchimbi-Msolla – Sokoine University of Agriculture (SUA), Tanzania
Michael Kilango - Agricultural Research Institute, Tanzania

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 and both lowland and highland regions of southern Tanzania.

Bruchid resistant bean breeding lines developed by Dr. Kusolwa at Sokoine University of Agriculture will be 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 will be used to evaluate the resistance of bean breeding lines. Molecular markers will also be used to identify lines having traits (null phaseolin, arcelin 2 and APA locus) associated with bruchid resistance. An additional breeding objective is to combine bruchid and virus (BCMV, BCMNV and BGYMV) resistance. Bruchid resistant Andean bean lines with BCMV and BCMNV ($1 + bc-1^2$) resistance have already been developed. Considerable progress has also been made toward the development of black beans that combine bruchid and virus resistance. During FY14, a small group of lines selected in Tanzania and/or 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. The project will attempt to identify a FTF collaborator to characterize the amino acid profile of bruchid resistant common beans.

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.

Zamorano 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.

Small red, white and red mottled bean lines from Zamorano and the UPR having BCMNV resistance will be tested in southern Tanzania. Results from these field trials will provide valuable information concerning the potential value of Middle American beans in Eastern Africa.

The Middle American and Andean Diversity panels will be screened in Central America, the Caribbean and Tanzania 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, the Caribbean and southern Tanzania. The Middle American Diversity Panel will be screened in Puerto Rico for resistance to ashy stem blight. Durango race bean lines in the Middle American Diversity Panel will be evaluated for potential production in Tanzania. Durango beans will be bred for increased seed size in desired market classes and for resistance to the most important diseases including BCMNV, anthracnose angular leaf spot and 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. Morogoro, in the eastern part of Tanzania, and Mbozi, in the southern part of Tanzania, are also good sites for screening for low N. These sites will be used to evaluate the performance of bean breeding lines derived from recurrent selection for increased BNF and/or selected for greater nitrogen use efficiency. These sites will be inoculated with efficient *Rhizobium* strains to allow indirect selection for enhanced biological nitrogen fixation.

Specific research activities for objective 1a during FY14:

Central America

- Develop and test black and small red bean breeding lines for the lowlands that combine disease and pest resistance with greater tolerance to abiotic stress.
- 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.
- Test improved tepary bean lines.

- Initiate the development of bean breeding populations in Guatemala with the goal of releasing a locally-developed cultivar by the end of the five-year extension period.

Haiti

- Test black and Andean bean breeding lines that combine disease and pest resistance with greater tolerance to abiotic stress.
- Test improved tepary bean and photoperiod insensitive Lima 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.
- Initiate 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.

Tanzania

- Test the performance of elite small red, white, yellow and red mottled bean breeding lines from Central America and the Caribbean
- Test the performance of improved tepary bean lines.
- Evaluate Durango bean lines in the Middle American Diversity Panel for potential production in Tanzania.
- Screen the Middle American Diversity Panel for performance in low N soils.

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.
- In collaboration with the MSU breeding project, screen 'Zorro x Puebla 152' RIL population for BNF traits.
- Screen the Middle American Diversity Panel for resistance to ashby stem blight and performance in low N soils.
- Screen bean lines and populations derived from recurrent selection for root rot resistance and adaptation to low N.
- Coordinate Andean bean line performance trials for the Caribbean and Tanzania.

Objective 1b: 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

Susan Nchimbi-Msolla - Sokoine University of Agriculture (SUA), Tanzania
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 in FY13 and FY14 and then 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.

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.
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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 UPRM (FY13) using leveraged ARS-FTF funds.

Multi-location testing of improved tepary bean breeding lines

- Collaborators in Central America, Haiti, and Tanzania 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 2: Develop and implement robust molecular markers for disease resistance genes

Collaborators:

Phil McClean, North Dakota State University, Fargo, ND, USA
 Karla Ponciano, ICTA, Guatemala City, Guatemala
 Paul Kusolwa, Sokoine University of Agriculture, Morogoro, Tanzania
 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.

Identify genetic materials for marker evaluation

Potential targets for improved marker development include:

- Bean golden yellow mosaic virus resistance genes and QTL (*bgm*, SW12, *Bgp*)
- Bruchid resistance genes (*Arc2*, *Arl3*, *PHA* and *aAl3*)
- BCMV and BCMNV (*I*, *bc-3*, *bc-1²*)
- Bean rust (*Ur-4*, *Ur-5*, *Ur-11*).

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

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, Tanzania and Uganda have the facilities and technical expertise needed to immediately adopt the use of indels for marker-assisted selection.

Objective 3: Institutional capacity building

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
Paul Kusolwa and Susan Nchimbi-Msolla – Sokoine University of Agriculture (SUA), Tanzania
Michael Kilango, Agricultural Research Institute, Tanzania

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 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 at the first meeting of Legume Innovation Lab researchers to discuss recent advances in the use of molecular techniques for bean and cowpea improvement.
- Workshops will be held in Honduras and Tanzania 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, research with *Rhizobium*, participatory plant breeding and agro-ecological techniques. The workshop in Tanzania will include participants from both SUA and the ARI. U.S. PIs will take advantage of their trip to Tanzania in 2014 to offer presentations to researchers and technical staff on topics related to their research.

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 and Sokoine University will be provided opportunities to participate in bean research activities related to Legume Innovation Lab project objectives.
- M.S. degree training will be completed at the UPR of Ana Vargas (Nicaragua), Angela Miranda (Guatemala) and Diego Rodriguez (Ecuador).
- Ph.D. degree training at NDSU of two bean researchers from Central America, the Caribbean or Africa. 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 and rust.
- Testing and possible release in Haiti and Tanzania 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, the Caribbean and Tanzania 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 Feed the Future funds which complement Legume Innovation Laboratory research and training activities in Tanzania. Dr. Miklas, Dr. Porch, Dr. Rosas, Dr. Beebe and Dr. Beaver will participate in the Penn State University project led by Dr. Jonathan Lynch dealing with abiotic stress. An online group has been established in Google+ to discuss collaborative research and regional nurseries. Legume Innovation Lab project personnel will strive to coordinate activities so that regional field trials and travel plans complement the goals of both projects. It would be useful for both projects to utilize the same database for the collection and management of data from field trials.

VII. Leveraging of Legume Innovation Laboratory Resources:

Project scientists will continue close collaboration with the 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). In Puerto Rico, the project currently collaborates with the Michigan State University in the evaluation of a bean population for biological nitrogen fixation in a low N soil.

Dr. Porch has received FTF 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.

Researchers in Tanzania participate in a Kirkhouse Trust project aimed at developing bean varieties with multiple disease resistance using marker-assisted selection (MAS). Bean lines with multiple disease resistance developed in this project could be used for further genetic improvement by this Legume Innovation Lab project.

Tanzania is part of the Southern Africa Bean Research Network (SABREN) and Eastern Africa Bean Research Network (ECABRN). Participation in these networks allows testing of promising bean breeding lines developed by this Legume Innovation Lab project in the regional nurseries. This should result in wider adoption of varieties developed by the project, thus greater impact. On the other hand promising breeding lines from other countries or CIAT in these regional nurseries can be used as parents by the Legume Innovation Lab project.

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 2013 – 2014

Degree Training:

First and Other Given Names: Ana Gabriela

Last Name: Vargas

Citizenship: Nicaragua

Gender: F

Training Institution: University of Puerto Rico

Supervising CRSP PI: Tim Porch and 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: To be defined

Start Date: Jan. 2013

Projected Completion Date: May 2015

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

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

First and Other Given Names: Angela Nadeshda Nichte

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? - No

Host Country Institution to Benefit from Training: ICTA

Thesis Title/Research Area: To be defined

Start Date: Jan. 2014

Projected Completion Date: May 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: Diego

Last Name: Rodriguez

Citizenship: Ecuador

Gender: M

Training Institution: University of Puerto Rico

Supervising CRSP PI: Jim Beaver and Phil Miklas

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: INIAP

Thesis Title/Research Area: To be defined

Start Date: August 2013
Projected Completion Date: December 2015
Training status (Active, completed, pending, discontinued or delayed): Pending
Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: 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

First and Other Given Names: TBD
Last Name: TBD
Citizenship: TBD
Gender: F
Training Institution: Zamorano
Supervising CRSP PI: J.C. Rosas
Degree Program for training: B.Sc.
Program Areas or Discipline: Plant breeding
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?
Host Country Institution to Benefit from Training: TBD
Thesis Title/Research Area: Improvement of beans for tolerance to low N soils
Start Date: Jan. 2014
Projected Completion Date: Dec. 2014

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

First and Other Given Names

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) for training activity

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? - 2014

Participants/Beneficiaries of Training Activity: 2

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

PI/Collaborator responsible for this training activity: Phil McClean

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

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

Type of training: Workshop

Description of training activity: A workshop will be held at the first global meeting of Legume Innovation Lab researchers to discuss recent advances in the use of molecular techniques for bean and cowpea improvement.

Location: TBD

Duration: TBD

When will it occur? 2014

Participants/Beneficiaries of Training Activity: Legume Innovation Laboratory scientists

Anticipated numbers of Beneficiaries (male and female): TBD

PI/Collaborator responsible for this training activity: Phil McClean

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

Training justification: This training will benefit Legume Innovation Lab scientists to become familiar with recent advances in the development and use of molecular markers for bean and cowpea breeding programs.

Type of training: Workshops

Description of training activity: Workshops will be held in Honduras and Tanzania 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: Tanzania and Honduras

Duration: One week

When will it occur? - 2014

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

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.

Type of training: In- service

Description of training activity: Techniques for screening lines for resistance to BCNMV.

Location: UPR

Duration: 3 months

When will it occur: Jan.-April, 2014

Participants/Beneficiaries of Training Activity: Senior student from Zamorano

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

PI/Collaborator responsible for this training activity: J. Beaver

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

Training justification: Screening advanced breeding lines with strain NL3 and implementation of bc3 marker at Zamorano program.

Equipment (costing >\$5,000):

None during FY-14