LEGUME INNOVATION LAB FOR COLLABORATIVE RESEARCH ON GRAIN LEGUMES

FY 2016 WORKPLAN

Project Code and Title: S01.A4

Development and implementation of robust molecular markers and genetic improvement of common and tepary beans to increase grain legume production in Central America and Haiti.

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

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Phil Miklas - USDA/ARS, Prosser, WA, USA
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Juan Carlos Rosas - Escuela Agrícola Panamericana (Zamorano), Honduras
Julio Cesar Villatoro - Instituto de Ciencia y Tecnología Agrícola (ICTA), Guatemala
Emmanuel Prophete - National Seed Service, Ministry of Agriculture, Haiti

I. Project Problem Statement and Justification:

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

Andean bean breeding lines developed by Dr. Paul Kusolwa at Sokoine University of Agriculture have a unique combination of traits that confer a high level of resistance to bruchids (*Acanthoscelides obtectus*). These breeding lines may include the arcelin 2 seed protein from common beans, the null phaseolin trait from *P. coccineus* and the APA locus derived from *P. acutifolius*. These bruchid resistant breeding lines have been used as progenitors by the University of Puerto Rico bean breeding program to introgress this resistance into black, small red, red mottled, cranberry, yellow and white beans that have resistance to *Bean Common Mosaic* Virus (BCMV), *Bean Common Mosaic Necrosis Virus* (BCMNV) and BGYMV. Regional performance trials will be conducted in Central America and the Caribbean to measure the durability of the resistance when exposed to different genera and ecotypes of bruchids.

The recent arrival of BCMNV in the Caribbean made the selection for resistance to this virus a priority breeding objective in Haiti, the Dominican Republic and Puerto Rico. BCMNV is also a

serious disease in lowland bean production regions of southeastern Mexico. Collaborative research supported by the Legume Innovation Lab contributed to the development and release of black bean lines such as DPC-40, XRAV-40-4 and MEN-2201-64ML that combine resistance to BCMNV and BGYMV. Small red bean breeding lines with the same combination of resistances have been developed at Zamorano. These BGYMV and BCMNV resistant black and small red bean lines are available in the event that BCMNV emerges as a threat to bean production in Central America.

Increased resistance to common bacterial blight and web blight is needed for beans produced in warm and humid lowland regions such as the Petén and southern Guatemala. This combination of resistances may also permit increased production of beans in Central America during the first growing season when rainfall is more abundant and reliable. Angular leaf spot resistance was identified by participants in the Bean Research Workshop held at Zamorano in April 2015 as an important disease limiting bean production throughout Central America.

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

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

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

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

There are regions and/or growing seasons in Central America and Haiti that are too hot and/or dry to produce common beans. The tepary bean (*P. acutifolius*) is a potential alternative grain legume for these stressful environments. In fact, farmers on the Pacific coast of Central

America and some countries of Africa already produce tepary beans on a limited scale. In addition to heat and drought tolerance, tepary bean lines with high levels of resistance to common bacterial blight, bruchids and other important traits have been identified. Resistance to BCMV, BGYMV, larger seed size and improved agronomic traits, would increase the potential adoption of tepary beans. Interspecific crosses with common beans could be used to introgress these traits into tepary beans. This effort represents the first systematic attempt to genetically improve tepary beans. The S01.A4 project will collaborate with the USDA/ARS FTF project to select *Bradyrhizobium* efficient strains and to study the inheritance of interspecific tepary bean x common bean populations for specificity to establish symbiosis with *Rhizobium* and/or *Bradyrhizobium* using *nod*C, *rec*A y *atp*D genes.

Bean breeders were early adopters of marker-assisted selection to identify lines with desired combinations of traits. This has resulted in increased efficiency in the development of improved breeding lines. There are, however, molecular markers available for a limited number of traits. Others, such as the SAP-6 SCAR marker, are only effective in a specific gene pool. Therefore, there is a need to develop new or more robust markers, particularly for traits of economic importance to bean breeding programs in the tropics. Recent advances by the BeanCAP project, led by North Dakota State University, in sequencing the bean genome and the development of a SNP array will facilitate the mapping and development of molecular markers for traits of economic importance, while breeder-friendly indel markers are a broadly applicable technology. The availability of phenotypic data in appropriate populations is a major factor limiting the development of these markers. This Legume Innovation Lab will assist this effort through the development of the populations and information needed to identify improved markers for traits such as the *Ur-11* gene for rust resistance.

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

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

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

Collaborators:

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Timothy Porch – USDA/ARS/TARS, Mayaguez, PR, USA
Phil Miklas – USDA/ARS, Prosser, WA, USA
Juan Osorno and Phil McClean – North Dakota State University (NDSU)
Juan Carlos Rosas – Escuela Agrícola Panamericana (Zamorano), Honduras
Julio Cesar Villatoro - Instituto de Ciencia y Tecnología Agrícola (ICTA), Guatemala
Emmanuel Prophete– National Seed Service, Ministry of Agriculture, Haiti

Approaches and Methods:

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

Bruchid resistant bean breeding lines developed by Dr. Kusolwa at Sokoine University of Agriculture have been used to introgress resistance to this pest into commercial seed types (black, small red, red mottled, white, light red kidney and yellow) produced in the target countries. A laboratory screening technique developed at the University of Puerto Rico has been used to evaluate the resistance of bean breeding lines. Molecular markers (arcelin 2 and APA locus) developed by Dr. Kusolwa will be evaluated to determine their effectiveness in identifying lines with high levels of resistance to bruchids. An additional breeding objective is to combine bruchid and virus (BCMV, BCMNV and BGYMV) resistance. Bruchid resistant Andean bean lines with BCMV and BCMNV (*I* + *bc-1*^{2}) resistance have already been developed. Considerable progress has also been made toward the development of black beans that combine bruchid and virus resistance. During FY16, a small group of lines selected in Puerto Rico for bruchid resistance will be tested in Central America and Haiti to evaluate the durability of resistance when exposed to different ecotypes of *Acanthoscelides obtectus* and other genera (*Zabrotes subfasciatus*) of bruchids.

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

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

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

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

Specific research activities for objective 1 during FY16:

Central America

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

Haiti

- Test on research stations and farms, in collaboration with AKOSSA and Zamni Agrikol, elite black and Andean bean breeding lines that combine disease and pest resistance with greater tolerance to abiotic stress.
- Conduct regional field trials and evaluate promising bean breeding lines from Honduras, Puerto Rico and CIAT
- Multiply breeder and basic seed stocks of recently-released bean cultivars.
- Study the potential benefit of thicker pod walls in common bean to prevent seed germination during periods of wet weather during the harvest.

- Support the development of bean breeding populations in Haiti with the goal of releasing a locally-produced cultivar by the end of the five-year extension period. During the upcoming year crosses will be made to combine multiple virus resistance with resistance to powdery mildew and germination of seed in the pod under humid conditions.
- Support the production of *Rhizoboium* Inoculants to be used for advanced breeding lines
- Strengthen collaboration between the NSS and NGOs in Haiti for on-farm testing of improved bean breeding lines (black, white, pinto, yellow and red mottled)
- Conduct field trials to test the performance of elite lines selected from the second cycle of recurrent selection for enhanced biological nitrogen fixation.
- Test the performance of bruchid resistant lines when exposed to natural infestation.

<u>Puerto Rico (UPR and USDA/ARS/TARS)</u>

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

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

Collaborators:

Timothy Porch - USDA/ARS/TARS, Mayaguez, PR, USA
James Beaver and Consuelo Estevez de Jensen - University of Puerto Rico, Mayaguez, PR, USA
Phil McClean- North Dakota State University, Fargo, ND USA
Juan Carlos Rosas - Escuela Agrícola Panamericana (Zamorano), Honduras
Julio Cesar Villatoro - Instituto de Ciencia y Tecnología Agrícolas (ICTA), Guatemala
Emmanuel Prophete - National Seed Service, Ministry of Agriculture, Haiti
Kirstin Bett- U. of Saskatchewan, Saskatoon, Canada
Mark Brick- Colorado State University, Ft. Collins, Colorado, USA

Approaches and Methods:

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

A tepary breeding program was initiated at USDA-ARS-TARS in 2008. Advanced breeding lines developed from these previous breeding efforts will be increased and shared with the collaborators for testing in Tepary Adaptation Trials (TAT). New tepary F_4 lines will be generated from crosses between promising large and round seeded genotypes from the CIAT collection and breeding lines selected for disease and abiotic stress tolerance. Using leveraged funds, these materials will be initially tested through a shuttle breeding program with M. Brick at Colorado State University. This effort will focus on seed size/shape, drought and heat tolerance, and CBB and bruchid resistance in PR; and on photoperiod insensitivity, broad adaptation, rust resistance, and yield in Colorado. Superior lines will then be tested in the host countries for potential future release.

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

Efficient strains will be selected for BNF in crosses between lines from the CIAT tepary collection and promising breeding lines. In addition, the inheritance of interespecific (tepary bean x common bean) populations to establish symbiosis with *Rhizobium* and/or *Bradyrhizobium* using *nod*C, *rec*A y *atp*D genes will be studied.

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

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

- Based on previous Pa x Pv crossing efforts, effective Pv and Pa parents (e.g. Pv 'Beniquez' with all 4 virus genes) were selected for hybridization during FY13-14.
- F_1 Pv x Pa hybrids were completed during FY14 from crosses between selected parents above at ARS-TARS.
- Embryo rescue was initiated from the BC_1F_1 generation material through collaboration with the U. of Saskatchewan.

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

- A small subset representing tepary genetic diversity will be assembled at USDA-ARS-TARS in FY13 and sent to NDSU.
- NDSU will evaluate a subset of the 3,000 Pv indels on the Pa germplasm to evaluate potential use.

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

- The CIAT tepary bean germplasm collection (~250 lines) were evaluated for CBB (FY13), adaptation (FY14) at USDA-ARS-TARS using leveraged ARS-FTF funds.
- The CIAT tepary bean germplasm collection (~250 lines) were evaluated for response to NL3 at the UPR (FY15) using leveraged ARS-FTF funds. Evaluate RILs to identify genes and markers for resistance.
- The CIAT tepary bean germplasm collection was evaluated for BGYMV in Honduras - Multi-location testing of improved tepary bean breeding lines. BGYMV Resistant lines crosses with tepary beans with resistance to CBB,BCMNV and rust
- Collaborators in Central America and Haiti will initiate testing of breeding lines in Tepary Adaptation Trials (TAT) to test wide adaptation as well as specific adaptation of lines to specific potential growing areas.

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

Collaborators:

Phil McClean and Juan Osorno, North Dakota State University, Fargo, ND, USA
Phil Miklas, USDA/ARS, Prosser, WA, USA
Julio Cesar Villatoro, ICTA, Guatemala City, Guatemala

Approaches and Methods:

This project will leverage the results from the USDA Common Bean Agricultural Project and the USDA/DOE/JGI common bean sequencing project. The BeanCAP project developed a suite of ~3000 indel markers distributed across all common bean chromosomes. These markers are co-dominant and designed to be functional with a single experimental condition (PCR protocol). The power of these markers is that they are simple to implement and thus completely portable in all laboratories and are amenable to multiplexing with suites of markers. Multiplexing reduces the cost of genotyping an individual line. The release of the common bean whole genome assembled sequence allows for precise localization of each of these markers. The final key element that facilitates this project is the development, over the last fifteen years, of markers that are linked, from 0-5 cM, to important target disease genes. While useful, there has been some difficulty in the portability of these markers from one laboratory to another. They all have unique experimental conditions that preclude multiplexing, and 5% recombination reduces effectiveness due to recombination between marker and target gene.

Dr. Phil McClean and Dr. Miklas will coordinate phenotyping, marker development, and the use of markers to facilitate the breeding of disease resistance beans. Molecular markers for critical gene or gene clusters will be improved and employed in breeding multiple disease resistant bean lines. Major genes for resistance to ALS, anthracnose, BCMV, BGMV, common blight, halo blight, rust and other diseases of economic importance to breeders will be targeted for marker-assisted selection in small and large-seeded market classes, and for specific production regions. Dr. Miklas' research will integrate McClean's genomic work with the needs of Legume Innovation Lab bean breeders. The critical *I* gene for BCMV, the *Ur-11*

gene for rust, *Phg-1* gene for angular leaf spot, the *Co-4*^{2} for anthracnose, and the new Xa11.4 QTL for CBB resistance will be targeted for more reliable and efficient marker-assisted selection.

Identify genetic materials for marker evaluation

Potential targets for improved marker development include:

- Improved markers for bean rust resistance genes (*Ur-3, Ur-4, Ur6 Ur-5, Ur-11*).
- Improved marker for I gene developed
- Populations will be developed for subsequent development of improved markers for BGYMV resistance genes and QTL (*Bgp*, SW12, and *bgm*).
- Investigate efficacy of currently available markers for bruchid resistance genes.
- Establish background information for marker development for ashy stem blight resistance by conducting association mapping analysis.
- Evaluate the genetics of web blight resistance through association mapping analysis.
- Resistance genes will be surveyed in the *P. vulgaris* genome.

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

Development of Indel markers

- DNA will be isolated from genetic populations or collections of lines with known phenotypes.
- The physical locations of target genes or markers will be identified using sequence information and the common bean genome sequence. If the sequence information is poor or unavailable, the specific marker will be cloned and sequenced.
- Indel marker selection: Once the location of the marker is determined, it will then be compared to the indel database to discover 30 indel markers that straddle the physical location of the marker. Those indel markers will be used in PCR amplification to determine which one acts as a definitive marker that is unambiguous in its predictive power. If several markers have equal predictive power, then the one that will best work as a multiplexing marker will be selected. Legume Innovation Lab bean breeding programs in Guatemala, Honduras, Ecuador and Uganda have the facilities and technical expertise needed to immediately adopt the use of indels for marker-assisted selection.

Objective 4: Institutional capacity building

Collaborators:

James Beaver and Consuelo Estevez de Jensen - University of Puerto Rico, Mayaguez, PR, USA
Timothy Porch - USDA/ARS/TARS, Mayaguez, PR, USA
Phil Miklas - USDA/ARS, Prosser, WA, USA

Juan Osorno and Phil McClean – North Dakota State University (NDSU), Fargo, ND, USA
Juan Carlos Rosas – Escuela Agrícola Panamericana (Zamorano), Honduras
Julio Cesar Villatoro - Instituto de Ciencia y Tecnología Agrícolas (ICTA), Guatemala
Emmanuel Prophete– National Seed Service, Ministry of Agriculture, Haiti

Approaches and Methods:

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

Informal training

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

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

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

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

Formal training

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

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

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

IV. Outputs:

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

V. Engagement of USAID Field Mission(s)

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

VI. Partnering and Networking Activities:

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

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

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

Researchers in Central America and the Caribbean often make scientific presentations at the annual meeting of the PCCMCA. The meeting provides an opportunity for the Central American/Caribbean research network which includes national programs, CIAT and the Legume Innovation Laboratory scientists to meet to exchange results from research and plan activities for the upcoming year

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

VII. Leveraging of Legume Innovation Laboratory Resources:

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

Dr. Porch has received funds from the USDA that are being used to support a graduate student from Nicaragua (Ana Vargas). He is coordinating collaboration between the USDA/ARS and Legume Innovation Lab in the evaluation of the Andean Bean Diversity Panel for powdery mildew and root rot resistance, low fertility response, and biological nitrogen fixation efficiency.

The McKnight Foundation supports work in Tanzania on the development of bruchid resistance in farmer-preferred varieties and the integration of botanical and physical methods to control bruchids. Bean lines developed from this project will be useful to the Legume Innovation Lab project for bean improvement in collaborating countries. Marker-assisted selection will be used to develop bean lines with bruchid resistant genes.

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

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

The USDA Participating Agency Service Agreement program requested a proposal to increase the availability of seed of improved bean cultivars in Haiti. We proposed a scheme that would involve the production of basic seed stocks in the Western U.S. during the summer months when bean production in Haiti is threatened by high temperature and tropical storms. This high-quality basic seed would be sold to NGOs and farmer associations who produce seed under irrigation during the winter months. The seed produced by the NGO's and farmer associations would be sold to small-scale farmers who plant on the hillsides beginning in April. Funds generated from the sale of basic seed stocks would be deposited in a rotating account to enable the basic seed production to become a self-sustaining activity. We also proposed to strengthen the capacity to produce *Rhizobium* inoculant that should increase bean yield in low N soils.

VIII. Timeline for Achievement of Milestones of Technical Progress:

Please refer to the document describing milestones

Training/Capacity Building Workplan for FY 2016

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

First and Other Given Names: Giovanni Lorenzo
Last Name: Vazquez
Citizenship: U.S.
Gender: M
Training Institution: University of Puerto Rico
Supervising CRSP PI: James Beaver
Degree Program for training: M.S.
Program Areas or Discipline: Plant breeding
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?- No
Host Country Institution to Benefit from Training: None
Thesis Title/Research Area: TBD
Start Date: Aug. 2014
Projected Completion Date: Aug. 2016
Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Julian
Last Name: Colley Pabón
Citizenship: US Puerto Rico
Gender: M
Training Institution: University of Puerto Rico
Supervising CRSP PI: Consuelo Estevez de Jensen Degree Program for training: M.S.

Degree Program for training: M.S.
Program Areas or Discipline: Plant Pathology
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? - Yes
Host Country Institution to Benefit from Training: ICTA
Thesis Title/Research Area: Resistance to Macrophomina phaseolina
Start Date: January. 2015
Projected Completion Date: December. 2016
Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Héctor
Last Name: Martínez
Citizenship: Guatemala
Gender: M
Training Institution: University of Puerto Rico Supervising
CRSP PI: James Beaver and Tim Porch
Degree Program for training: M.S.
Program Areas or Discipline: Plant breeding
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? - Yes
Host Country Institution to Benefit from Training: ICTA
Thesis Title/Research Area: To be defined
Start Date: Aug. 2015
Projected Completion Date: Aug. 2017
Training status (Active, completed, pending, discontinued or delayed): Pending
Type of CRSP Support (full, partial or indirect) for training activity: Full

First and Other Given Names: Iveth
Last Name: Rodriguez
Citizenship: Honduras
Gender: F
Training Institution: University of Puerto Rico
Supervising CRSP PI: James Beaver and Tim Porch
Degree Program for training: M.S.
Program Areas or Discipline: Plant breeding
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? - Yes
Host Country Institution to Benefit from Training: ICTA
Thesis Title/Research Area: To be defined
Start Date: Aug. 2015
Projected Completion Date: Aug. 2017
Training status (Active, completed, pending, discontinued or delayed): Pending Type of CRSP Support (full, partial or indirect) for training activity: Full

First and Other Given Names: Pablo
Last Name: Pizarro
Citizenship: Ecuador

Gender: M
Training Institution: Zamorano
Supervising CRSP PI: Juan Carlos Rosas
Degree Program for training: B.S.
Program Areas or Discipline: Agronomy
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? - No
Host Country Institution to Benefit from Training: None
Thesis Title/Research Area: Evaluación de la resistencia a gorgojos de grano *Acanthoscelides obtectus* y *Zabrotes subfasciatus* en frijol común.
Start Date: Jan. 2015
Projected Completion Date: Dec. 2015
Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Tatiana
Last Name: Escobar Vados
Citizenship: Honduras
Gender: F
Training Institution: Zamorano
Supervising CRSP PI: Juan Carlos Rosas
Degree Program for training: B.S.
Program Areas or Discipline: Agronomy
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? - No
Host Country Institution to Benefit from Training: None
Thesis Title/Research Area: Evaluación de la resistencia a gorgojos de grano *Acanthoscelides obtectus* y *Zabrotes subfasciatus* en frijol común.
Start Date: Jan. 2015
Projected Completion Date: Dec. 2015.
Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Jason
Last Name: Rizo
Citizenship: Nicaraguan
Gender: M
Thesis Title/Research Area: Evaluación de líneas de frijol tolerantes a baja fertilidad.
Start Date: Jan. 2015
Projected Completion Date: Dec. 2015.
Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Johan
Last Name: Gabor
Citizenship: Ecuador
Gender: M
Training Institution: Zamorano
Supervising CRSP PI: Juan Carlos Rosas

Degree Program for training: B.S.
Program Areas or Discipline: Agronomy
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? - No
Host Country Institution to Benefit from Training: None
Thesis Title/Research Area: Evaluación de líneas de frijol tolerantes a baja fertilidad.
Start Date: Jan. 2015
Projected Completion Date: Dec. 2015.
Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: José Manuel
Last Name: Martínez
Citizenship: El Salvador
Gender: M
Training Institution: Zamorano
Supervising CRSP PI: Juan Carlos Rosas
Degree Program for training: B.S.
Program Areas or Discipline: Agronomy
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? - No
Host Country Institution to Benefit from Training: None
Thesis Title/Research Area: Caracterización de razas de *Pseudocercospora griseola* y la resistencia a la mancha angular del frijol.
Start Date: Jan. 2015
Projected Completion Date: Dec. 2015.
Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Luís Alonso
Last Name: Peñate
Citizenship: El Salvador
Gender: M
Thesis Title/Research Area: Caracterización de razas de *Pseudocercospora griseola* y la resistencia a la mancha angular del frijol.
Start Date: Jan. 2015
Projected Completion Date: Dec. 2015.
Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Luis
Last Name: Monserrate
Citizenship: Ecuador
Gender: M
Training Institution: Zamorano
Supervising CRSP PI: Juan Carlos Rosas
Degree Program for training: B.S.
Program Areas or Discipline: Agronomy
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? - No

Host Country Institution to Benefit from Training: None
Thesis Title/Research Area:Evaluación de germoplasma de frijol por la resistencia a la mancha angular.
Start Date: Jan. 2015
Projected Completion Date: Dec. 2015.
Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Henry
Last Name: Espinoza
Citizenship: Ecuador
Gender: M
Training Institution: Zamorano
Supervising CRSP PI: Juan Carlos Rosas
Degree Program for training: B.S.
Program Areas or Discipline: Agronomy
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? - No
Host Country Institution to Benefit from Training: None
Thesis Title/Research Area: Evaluación de germoplasma de frijol por la resistencia a la mancha angular.
Start Date: Jan. 2015
Projected Completion Date: Dec. 2015.
Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: Juan
Last Name: Nuñez
Citizenship: Honduras
Gender: M
Training Institution: Zamorano
Supervising CRSP PI: Juan Carlos Rosas
Degree Program for training: B.S.
Program Areas or Discipline: Agronomy
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? - No
Host Country Institution to Benefit from Training: None
Thesis Title/Research Area: Evaluación de germoplasma de frijol para la tolerancia a altas temperaturas.
Start Date: Jan. 2015
Projected Completion Date: Dec. 2015.
Training status (Active, completed, pending, discontinued or delayed): Active Type of CRSP Support (full, partial or indirect) for training activity: Partial

First and Other Given Names: To be determined (TBD)
Last Name: TBD
Citizenship: TBD
Gender: TBD

Training Institution: North Dakota State University Supervising
CRSP PI: Phil McClean and Juan Osorno Degree Program
for training: Ph.D.
Program Areas or Discipline: Plant breeding and genetics
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? - Yes
Host Country Institution to Benefit from Training: TBD
Thesis Title/Research Area: TBD
Start Date: TBD
Projected Completion Date: TBD
Training status (Active, completed, pending, discontinued or delayed): Pending Type
of CRSP Support (full, partial or indirect) for training activity: Full

First and Other Given Names: To be determined (TBD)
Last Name: TBD
Citizenship: TBD
Gender: TBD
Training Institution: North Dakota State University Supervising
CRSP PI: Juan Osorno and Phil McClean Degree Program
for training: Ph.D.
Program Areas or Discipline: Plant breeding and genetics
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? - Yes
Host Country Institution to Benefit from Training: TBD
Thesis Title/Research Area: TBD
Start Date: TBD
Projected Completion Date: TBD
Training status (Active, completed, pending, discontinued or delayed): Pending Type
of CRSP Support (full, partial or indirect) for training activity: Full

Short-term Training:

Type of training: In-service training
Description of training activity: In-service training will be provided at NDSU for Legume Innovation Lab scientists to review recent advances in sequencing the bean genome and the utilization of a SNP arrays to develop indel markers for traits of economic importance.
Location: NDSU
Duration: Two weeks
When will it occur? - 2016
Participants/Beneficiaries of Training Activity: 2
Anticipated numbers of Beneficiaries (male and female): 1M, 1F
PI/Collaborator responsible for this training activity: Phil McClean
List other funding sources that will be sought (if any): None
Training justification: This training is needed to permit host country scientists to take advantage of the recent advances in the development and use of molecular markers for bean breeding programs.

Type of training: Workshop

Description of training activity: A workshop will be held in Honduras to train technical personnel concerning topics related to research for improving the tolerance of common bean to abiotic stresses (drought, heat and low fertility).
Location: Honduras
Duration: One week
When will it occur? - December 2015
Participants/Beneficiaries of Training Activity: Technicians working for bean research programs in Central America and Haiti.
Anticipated numbers of Beneficiaries (male and female): 20
PI/Collaborator responsible for this training activity: Juan Carlos Rosas and James Beaver
List other funding sources that will be sought (if any): None
Training justification: Trainees will improve their skills in conducting field and laboratory research to screen germplasm and breeding lines for tolerance to abiotic stress factors. This should improve the quality and reliability of research conducted in host countries

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