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 (S01.A4)

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I. Abstract of Research and Capacity Strengthening Achievements

Conventional plant breeding techniques and marker-assisted selection were used to develop dry bean cultivars with enhanced levels of disease resistance and greater tolerance to abiotic stresses. During the past few years, the Bean Technology Dissemination project multiplied and distributed seed of improved bean cultivars developed by S01.A4 plant breeders to thousands of farmers in Central America and Haiti. The multiple disease resistant black bean cultivar *XRAV-40-4* and red mottled bean breeding lines PR0737-1 and PR0633-10 were formally released. White and pinto bean lines that combine resistance to BGYMV, BCMNV and rust resistance and yellow beans that have resistance to BGYMV, BCMV and leafhoppers were developed. The BGYMV and BCMNV resistant black bean line MEN-2201-64ML from Zamorano had superior performance under drought conditions in Nicaragua and El Salvador. Black bean breeding lines that combine resistance to BGYMV, BCMNV and bruchids are ready for field testing. Angular leaf spot isolates from Honduras and Puerto Rico were found to have high levels of virulence. Populations are being developed to identify a molecular marker for the *Bgp-1* gene that confers resistance to pod deformation in the presence of BGYMV. The tepary bean Tep-22 that combines resistance to common bacterial blight, rust and bruchids was formally released. A potential source of resistance to BCMNV in tepary bean was identified. Populations to increase seed size and improve agronomic traits of tepary beans were developed. Informal training in plant pathology and BNF research techniques was provided at Zamorano and the University of Puerto Rico. Candidates for M.S. degree training of students from Honduras, Guatemala and Honduras have been identified. Several B.S. degree students have opportunities to work with the bean research program at Zamorano.

II. Project Problem Statement and Justification

Increased bean production during the past 30 years in Central America and Haiti has been due, in large part, to expansion of production in the lowlands (less than 1000 m). Greater heat tolerance combined with resistance to BGYMV increased bean seed yield and 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.

BCMNV threatens bean production in warmer bean production regions of Central America, the Caribbean and 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. BCMNV is also a serious disease in lowland bean production regions of southeastern Mexico. Collaborative research supported by the Bean/Cowpea and Pulse CRSP resulted in the development and release of black bean cultivars and breeding 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 field testing of this seed type in Eastern Africa.

Small red and black beans tend to have greater yield potential and heat tolerance than Andean beans. Middle American beans also tend to have greater resistance to diseases in Africa, since pathogens in this region 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 generally more abundant and reliable. The previous Dry Grain Pulse CRSP project (UPR-1) developed Middle American and Andean bean breeding lines having adaptation to the lowland tropics and different combinations of resistance to diseases (common bacterial blight, rust, angular leaf spot, web blight and root rot) and tolerance to edaphic constraints (low N soils, high temperature). During the next five years, the Legume Innovation Lab project will use these elite breeding lines as the base for the continued improvement of beans for our target countries.

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

During the next five years, the project plans to release in Haiti red mottled, yellow and white bean cultivars with enhanced levels of disease resistance. These seed types are produced in regions in Haiti where the CRSP project had less impact. This effort is consistent with the FTF 2011-2015 multiyear strategy in Haiti to increase the production of staples such as beans to increase food security. 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 Legume Innovation Lab breeding projects in Africa and the Caribbean. Yellow, red mottled and white bean breeding lines having BCMNV resistance will be available for Legume Innovation Lab or Feed the Future projects to test in Eastern Africa.

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 seed protein from common beans including 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 and white beans that also 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.

The project will continue to screen germplasm to identify additional sources of resistance to diseases that limit bean production in Central America and the Caribbean. For example, more resistance to ashy stem blight, caused by *Macrophomina phaseolina*, is needed to improve adaptation to hot and dry environments such as the dry corridor in Guatemala and southwestern Haiti. Greater resistance to web blight, caused by *Rhizoctonia solani*, is required to increase yield and seed quality of beans produced in more humid environments such as the Petén Department in Guatemala and eastern Nicaragua. 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 Africa 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 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.

Differences and linkages between S01.A4 and other Feed the Future (FtF) Projects

- The focus of the S01.A4 project is on biotic constraints and abiotic constraints in the tropical lowlands. Successful bean cultivars need resistance/tolerance to both types of constraints. Other FtF projects are focused on beans in the highlands of Africa and Guatemala.
- The focus of the S01.A4 project is on Latin America/Caribbean vs. Africa. However, exchange of breeding lines among FtF projects is mutually beneficial.
- Genomic research, development of molecular markers and breeding strategies are common links among projects.

III. Technical Research Progress

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

Development, testing and release of improved bean cultivars

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 (less than 1000 m) bean production regions in Central America and Haiti. The bean research program at Zamorano will coordinate the regional testing of small red and black bean breeding lines. The University of Puerto Rico will coordinate the development and testing of Andean beans in the Caribbean. 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, powdery mildew and web blight. Testing sites are chosen to produce reliable results for screening for specific traits.

Greater tolerance to abiotic stress

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. Puerto Rico has good locations for screening beans for performance in a low N soil, root rot resistance and high temperature. 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.

Table 1. Bean and other grain legume trials distributed to Central American and Caribbean Bean Research Network collaborators during 2014–2015.

Trial name	Small red	Small black	Countries
VIDAC	43 entries + 2 checks	30 entries + 2 checks	GU, ES, HO, NI, CR, PR, HA
ECAR	14 entries + 2 checks	14 entries + 2 checks	ES, HO, NI, CR, GU, HA
VIROS	52 entries + 2 checks		ES,HO, NI, CR
ERMAN	24 entries + 2 checks		ES, HO, NI, CR, GU, HA
ERMUS	14 entries + 2 checks		ES, HO, NI, CR, GU
AGROSALUD	9 entries + 1 check		ES, HO, NI, GU, CR
ERCAUPI (cowpeas)	9 entries		ES, HO, NI, GU
ERTEPARI (tepary bean)	21 entries + 1 check		ES, HO, NI,
ERLIMA (Lima bean)	12 entries		ES, HO, NI, CR

Bruchid resistance

Bruchid resistant bean breeding lines developed by Dr. Kusolwa at Sokoine University of Agriculture have been used to introgress resistance to this pest into commercial seed types (black, small red, red mottled, light red kidney and yellow) produced in the target countries. A laboratory screening technique developed at the University of Puerto Rico has been used to evaluate the resistance of bean breeding lines. The effectiveness of using molecular markers for traits (null phaseolin, arcelin 2 and APA locus) associated with bruchid resistance is under evaluation. An

additional breeding objective is to combine bruchid and virus (BCMV, BCMNV and BGYMV) resistance. Bruchid resistant *Rojo* backcross lines developed in collaboration with Jim Myers (Oregon State University) and Paul Kusolwa (Sokoine University of Agriculture) were identified to also have BCMV and BCMNV (*I* + *bc-1*^{2}) resistance. Considerable progress has also been made toward the development of black beans that combine bruchid and virus resistance.

Evaluation of bean diversity panels and identification of new sources of disease resistance

The Middle American (MDP) and Andean Diversity (ADP) panels will be screened in Central America and the Caribbean for specific traits. For example, the Andean Diversity Panel will be screened in Haiti for reaction to powdery mildew and in Honduras for angular leaf spot. Performance of the Middle American Diversity Panel will be evaluated in low N environments in Central America and the Caribbean. The Middle American Diversity Panel has been screened in Puerto Rico for resistance to ashy stem blight.

Genetic Improvement of Tepary Beans

Although tepary bean has high levels of abiotic stress tolerance, it is susceptible to viruses such as BGYMV, BCMV, and BCMNV. 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.

<u>Objective 2.</u> Develop and implement robust molecular markers for disease resistance genes

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 in labs with a simple set of equipment and reagents (Thermal Cycler, gel chambers, and UV lamp). 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 (mostly SCARS) 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 five percent recombination reduces effectiveness due to recombination between marker and target gene. In addition, these SCAR markers don't work across different market classes or genetic backgrounds. Contrastingly, most InDel markers developed at NDSU are market class specific, which will facilitate their use and increase their reliability.

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 *αAI3*)
- BCMV and BCMNV (*I, bc-3, bc-1*^{2})
- 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. Project personnel have already participated in the evaluation of the Middle American and Andean Diversity Panels for reaction to several different diseases.

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. 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 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

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

1. In-service training will be provided during FY15 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.
2. A workshop will be held in Honduras in December 2014 to train technical personnel from Central America and the Caribbean 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 agroecological techniques.
3. The project received Institutional Building Funds to conduct a workshop at Zamorano during FY15 to discuss with technical personnel from Central America and the Caribbean techniques needed to produce, process and store high quality seed stocks. The training will improve the capacity of the bean research programs in Central America and Haiti to produce basic and foundation seed stocks of recently-released bean cultivars.
4. Significant information concerning bean research techniques is available on the Bean Improvement Cooperative (BIC) website, 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.

IV. Major Achievements

Development, testing and release of improved bean cultivars

- XRAV-40-4, a multiple disease resistant black bean adapted to the humid tropics, was developed and released cooperatively by the Puerto Rico (UPR) and Nebraska (UNL) Agricultural Experiment Stations, the USDA–ARS, the Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF), the Escuela Agrícola Panamericana, Zamorano, Honduras, and the National Seed Service of the Ministry of Agriculture of the Republic of Haiti. *XRAV-40-4* combines resistance to BGYMV, BCMV, and BCMNV. When planted at higher altitudes, XRAV-40-4 has earlier maturity than the black bean cultivar *DPC-40*. A description of the release of XRAV-40 was published in the J. of Agric. of the Univ. of Puerto Rico (Beaver *et al*., 2014). XRAV-40-4 is expected to be released in Central America as *Azabache 40* and in Haiti as *Sankara*. XRAV-40-4 performed well in on-farm trials conducted by the NSS with support from FAO.

- Red mottled bean lines PR0737-1 and PR0633-10, which combine the *bgm-1* gene for resistance to BGYMV and the *I* and *bc-3* genes for resistance to BCMV and BCMNV, were released as improved germplasm (Prophete *et al*. 2014. *J. Plant Reg.* 8:49–52). Seed of PR0737-1 is currently being multiplied in Haiti and is in the process of being formally released as a cultivar.

- White bean lines were developed that combine the *bgm-1* gene and the SW13 *QTL* for resistance to BGYMV, the *I* and *bc-3* genes for resistance to BCMV and BCMNV, and resistance to a wide range of rust races. Results from inoculations with specific races of rust conducted by Dr. Pastor Corrales, USDA–ARS–Beltsville suggest that the white bean lines have a unique combination of the *Ur-4, Ur-5* and *Ur-11* rust resistance genes. Posters describing the development of these lines were presented at the 2014 meetings of PCCMCA in Nicaragua and the American Phytopathological Society in Minneapolis, Minnesota. A manuscript has been submitted to the *J. Plant Registrations* for the release of two of the lines as improved germplasm. This will be the first release of improved bean germplasm that combines multiple virus (BGYMV, BCMNV and BCMV) and rust resistance.

- The rust resistant white bean breeding lines were used as parents to introgress high levels of rust resistance into black beans. DPC-40 and XRAV-40-4 were used as the other parents so progeny from these crosses have multiple virus resistance. F_5 black bean lines with good agronomic type were selected from these populations. These lines will be screened during FY15 at Zamorano for resistance to rust. Previous research has found rust races in Honduras to have high levels of virulence. Dr. Pastor Corrales (USDA FtF project collaborator) will conduct greenhouse evaluations of lines that are rust resistant in field trials in Honduras. This effort should lead to the development of black bean lines that combine multiple virus resistance and the *Ur-4, Ur-5* and *Ur-11* rust resistance genes.

- Yellow bean lines that combine the *bgm-1* gene for resistance to BGYMV and the *I* gene for resistance to BCMV were developed and tested in Puerto Rico, Angola and Haiti. One of the lines had tolerance to leafhoppers in a trial planted in Damien, Haiti (Annex Fig. 1) and produced a mean seed yield of 1,884 kg/ha in seven environments. Seed of this line has been multiplied for on-farm trials that will be conducted in Haiti during FY15. $F_{5:6}$ yellow bean plants with superior agronomic traits and commercial seed types were selected in a nursery planted in Puerto Rico. They will be screened using molecular markers and greenhouse evaluation to identify lines that combine resistance to BGYMV, BCMV and BCMNV.

- Pinto beans have gained popularity in Haiti after this market class was imported as food aid. Consumers note that pinto beans have a shorter cooking time than other seed types used in Puerto Rico. During the past year, we selected $F_{5:6}$ plants that have multiple virus resistance. The *bgm-1* gene and the SW12 QTL for BGYMV resistance and the *I* gene for BCMV resistance were identified using marker-assisted selection. The *bc-3* gene was identified in greenhouse inoculations using the NL-3 strain of BCMNV. All of the selections have commercial pinto seed type and many have an erect growth habit. During the upcoming year, these lines will be evaluated in trials in Haiti and Puerto Rico. These pinto

lines should segregate for the *Ur-11* gene so special attention will be given to lines that do not develop rust symptoms. Two generations will be planted in Puerto Rico during FY15 to multiply seed of the most promising lines.

- Advanced generation black bean lines (F_7) from Puerto Rico that were identified to possess the *bgm-1* gene for resistance to BGYMV and the *I* and *bc-3* genes for resistance to BCMV and BCMNV were tested in Haiti and Puerto Rico. Many of these lines have progenitors with heat tolerance and resistance to common bacterial blight and web blight. These lines expressed little damage from leafhoppers in Damien, Haiti although many bean lines in neighboring trials were severely damaged.

- During the winter of 2013–1014, the National Seed Service in Haiti planted a seed increase of the Lima bean landrace *Beseba*. *Beseba* is a Haitian Lima bean landrace in Caribbean Lima bean landrace collection made by the Dry Grain Pulse CRSP and sent to CIAT to be included in the germplasm collection. Dr. Rao, CIAT Physiologist, reported at the 2014 PCCMCA meeting in Nicaragua that Beseba (G25529) produced the greatest seed yield in a high temperature trial conducted in Colombia. Emmalea Ernest reported at the 2014 BIC meeting that G 27529 had among the greatest amount of pollen shed in a high temperature trial conducted in Delaware (BIC 57:41–42).

- IICA personnel reported that the black bean variety ICTAZAM, which possesses a shiny seed coat, is acceptable to consumers in Guatemala. ICTAZAM has resistance to BGYMV, BCMV and web blight and was identified by ICTA researchers to have superior performance in more humid regions such as the Petén.

Greater tolerance to abiotic stress

- INTA and CENTA researchers reported that the black bean line MEN-2201-64ML from Zamorano had superior performance under drought conditions in Nicaragua and El Salvador. This line was also selected for further evaluation in Haiti based on its performance during the dry season. In addition to drought tolerance, MEN-2201 was selected for resistance to BCMV, BCMNV and BGYMV. During the upcoming year, this Legume Innovation Lab project will support the on-farm testing of MEN-2201-64ML in Haiti, Honduras, Guatemala and other Central American countries where drought is a frequent constraint to bean production.

- Small red and black breeding lines were selected at Zamorano from the second cycle of recurrent selection having greater nodulation, plant growth, seed yield, and resistance to BCMV and BGYMV. The most promising lines were distributed to collaborators in Central America for field evaluation in diverse conditions. Greater nodulation in the field (0.08 % N), soil: sand benches (0.06% N) and plastic pouches (nodulation speed) was obtained with *Rhizobium tropici* (CIAT 899) and *R. etli* (CIAT 632).

- During the past two years, Jim Kelly, Jim Beaver and Consuelo Estevez collaborated in the evaluation of *Zorro x Puebla* 152 RILs in a low N soil at Isabela, Puerto Rico. Black bean lines with good yield potential, healthy roots and greater nodulation were selected. These lines were included as entries in a low N trial that also included the lines from Zamorano selected

for greater BNF using recurrent selection and bean lines from the UPR and the USDA–ARS–TARS that have root rot resistance and/or superior performance in low N trials.

- In collaboration with USDA–ARS FtF, 134 lines from the Andean Diversity Panel were evaluated for nodulation characteristics in pasteurized sand inoculated with *Rhizobium tropici* strain CIAT 899 and *Rhizobium etli* CIAT 632 separately. Twelve days after inoculation lines ADP-186, ADP-225, ADP-302, 368, 390, 444, 456, 477 and 514 were selected for their characteristics of early nodulation and best nodulation.

Bruchid resistance

- Rojo's backcross lines were developed in collaboration with Paul Kulsolwa at Sokoine University and Jim Myers at Oregon State University that combine resistance to bruchids [*Acanthoscelides obtectus* (Say)] and the *I* and *bc-1*^{2} genes that confer resistance to BCMV and BCMNV. The performance of these lines is currently being tested in field trials in Puerto Rico and Tanzania. The most promising lines will be considered for release as improved germplasm.

- The *Rojo* backcross lines were used as parents to develop bruchid resistant red mottled, light red kidney and cranberry bean breeding lines. During the upcoming year, these lines will be screened for disease resistance genes using molecular markers.

- Black and white bean lines were developed that combine resistance to bruchids, the *bgm-1* gene for resistance to BGYMV and the *I* and *bc-3* genes for resistance to BCMV and BCMNV. Seed of these bruchid resistant black bean lines were sent to Honduras, Guatemala and Haiti where they will be evaluated for adaptation and for resistance to local eco-types of bruchids.

- Lines selected for bruchid resistance were found to possess the molecular markers developed by Dr. Paul Kusolwa for alpha amylase and phyto-haemagglutinin. These markers, however, did not account for all of the phenotypic variability associated with the bruchid resistance. One of the parents of the *Rojo* backcross lines has the recessive null phaseolin allele. We are exploring, in collaboration with the USDA–ARS FtF project, the possibility that the null phaseolin trait may contribute to bruchid resistance.

Evaluation of bean diversity panels and identification of new sources of disease resistance

- The virulence patterns of *Phaeoisariopsis griseola* isolates from Honduras and Puerto Rico were studied. One isolate from Honduras was virulent to all of the ALS differential lines (race 63-63). The most virulent isolate from Juana Díaz Puerto Rico was race 63:39. This high level of virulence points to the need to pyramid genes for ALS resistance. Molecular markers SH-13 (*Phg-1*), SN02 (*Phg-2*) and E-ACA/M-CTT330 (G10474 dominant gene) were used at Zamorano for marker-assisted selection. Resistance in the field was confirmed using highly virulent races of the ALS pathogen. During the upcoming year, a small red bean line (ALS 0532-6) and a black bean line (ALS 0546-60) that combine resistance to multiple viruses (BGYMV and BCMV), high yield potential and commercially acceptable seed type will be evaluated in validation trials in Central America.

- Populations are being developed at Zamorano that should segregate for the dominant gene *Bgp-1* that confers resistance to pod deformation in the presence of BGYMV. RILs will be phenotyped at Zamorano for pod deformation and the data will be used to attempt to identify a molecular marker for this important gene for resistance to BGYMV.
- The National Seed Service in Haiti plans to screen in the field the Andean Diversity Panel for reaction to powdery mildew. Results will be used to conduct an associated mapping analysis for reaction to *Erysiphe polygoni* in the Andean gene pool.
- In collaboration with the USDA–ARS FTF project, association mapping of the response to *Macrophomina phaseolina* in the Andean Diversity Panel was conducted. Results from field screening identified a small group of lines in the ADP with resistance to ashy stem blight. Regions on Pv03, Pv09, and Pv11 were significant for charcoal rot resistance in the association mapping analysis.

Genetic Improvement of Tepary Beans

- Release of tepary bean selection Tep-22 that combines resistance to common bacterial blight, rust and seed weevil and tolerance to heat and drought (Porch et al. 2013. J. Plant Reg. 7:358–364).
- In collaboration with the USDA–ARS FtF project, tepary bean accessions from the CIAT germplasm collection were inoculated in the greenhouse with the NL3 strain of BCMNV. A few lines appeared to have a resistance reaction. Susceptibility to BCMV is a major limiting factor for tepary bean production in North and Central America.
- In collaboration with USDA–ARS FtF project, 12 Interspecific hybrid *Phaseolus acutifolius/Phaseolus vulgaris* INB lines were evaluated in a replicated field trial with inoculation of *Bradyrhizobium* USDA 3254. A noninoculated control and Nitrogen treatments were included. In addition to that a local check "Verano," TARSLFR-1 and a nonnodulator line "G51496A" were inoculated with *Rhizobium tropici* CIAT 899 strain. An average of 25 nodules were recorded for line INB 835, six nodules for line INB 826. The average for line Tepary 1 was 1.5 nodule and for TARSLFR-1 26 nodules.

V. Research Capacity Strengthening

Legume Innovation Lab plant breeders assisted 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. For example, the ICTA bean research team is using field evaluations and marker-assisted selection to introgress the *Co-4*^{2} gene for anthracnose resistance into black bean breeding lines adapted to Central America. Dr. Porch will provide bulk populations of black beans to Haiti to provide National Seed Service researchers with experience making field selections and managing breeding lines.

The project received Institutional Strengthening funds to continue to support the bean research network in Central America and the Caribbean. These funds will permit bean researchers in the region to attend the annual meeting of the PCCMCA where research results can be shared. The PCCMCA meeting also provides an opportunity for Legume Innovation Lab and CIAT scientists to meet with bean researchers to plan collaboration for the upcoming year.

A planning meeting and field day for the release of improved small red and black bean cultivars was held at Zamorano in April 2014 with NARs and NGOs technical personnel and farmers from Honduras, El Salvador and Nicaragua.

This Legume Innovation Lab project continues to collaborate with many CRSP alumni institutions. This collaboration extends the potential impact of Legume Innovation Lab research and generates information that is valuable to the global bean research community. A few of the collaborative research activities are listed below:

- Bruchid resistance research with Paul Kusolwa at Sokoine Agricultural Univ. in Tanzania.
- Evaluation of red mottled and black bean breeding lines by IDIAF in the Dominican Republic.
- Regional performance trials (SISTEVER) in Nicaragua, El Salvador and Costa Rica.
- Evaluation of Andean and pinto bean lines in Angola.
- Rhizobium Inoculant production in Haiti

VI. Human Resource and Institution Capacity Development

Short-Term Training

Table 2. Summary of short-term training of Legume Innovation Lab project S01.A4 during FY14.

Purpose of Training	Plant pathology and BNF research techniques	Angular leaf spot
Type of training	Workshop	In-service
Countries benefiting	Honduras and Tanzania	Guatemala
Location and dates of training	University of Puerto Rico—September and October 2014	Zamorano - September 2014
Number receiving training (by gender)	2F, 1M	1F
Home institution(s)	Zamorano, Univ. of Puerto Rico and Sokoine Univ.	ICTA, Guatemala
Institution providing training	University of Puerto Rico	Zamorano

Degree Training

Table 3. Summary of degree training of Legume Innovation Lab project S01.A4 during FY14 and FY15.

Name of trainee	**Angela Miranda**	**M. J. Cunguan**	**C. Lopez**	**L.A. Aviles**	**R.J. Escobar**	**S.D. Chicas**	**M.D. Goyzueta**	**E.D. Gutierrez**	**M.G. Cruz**
Country of citizenship	Guatemala	Ecuador	Ecuador	El Salvador	El Salvador	El Salvador	Bolivia	Honduras	Honduras
Gender	F	F	F	F	M	F	F	M	M
H.C. institution	ICTA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Training institution	UPR	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano	Zamorano
Supervising CRSP PI	J.S. Beaver	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas	J.C. Rosas
Degree program	M.S.	B.S	B.S	B.S	B.S	B.S	B.S	B.S	B.S
Field or discipline	Plant Breeding	Plant Science	Plant Science	Plant Science	Plant Science	Plant Science	Plant Science	Plant Science	Plant Science
Research project title	Angular leaf spot resistance	Molecular germplasm characterization	Molecular germplasm characterization	Mutliple virus resistance	Multiple virus resistance	MAS for virus resistance	MAS for virus resistance	High iron and zinc content beans	Differential nursery for Rhizobium-Bean interactions

Name of trainee	**Angela Miranda**	**M. J. Cunguan**	**C. Lopez**	**L.A. Aviles**	**R.J. Escobar**	**S.D. Chicas**	**M.D. Goyzueta**	**E.D. Gutierrez**	**M.G. Cruz**
Start date	Pending	Jan 2014	Jan 2014	Jan 2014	Jan 2014	Jan 2014	Jan 2014	Jan 2014	Jan 2014
Completion date	Yes	Dec 2014	Dec 2014	Dec 2014	Dec 2014	Dec 2014	Dec 2014	Dec 2014	Dec 2014
Participant trainee and registered on TraiNet?	Pending	No	No	No	No	No	No	No	No

VII. Achievement of Gender Equity Goals

The development and dissemination of improved bean cultivars using conventional techniques and marker-assisted selection should produce greater or more reliable bean yields. This should contribute to economic growth and improve the lives of the families of bean producers in Central America and Haiti. The project also supports the participation of women in formal and informal training activities.

VIII. Explanation for Changes

The formal training of Angela Miranda was postponed until January 2014. This was due to delays in obtaining a J-1 Visa.

A severe drought during the first growing season in Central America and the Caribbean significantly reduced bean yield and caused a severe shortage of seed for the second growing season. During the upcoming year, Zamorano and other bean research programs in Central America will need increase the production of basic seed to replenish stocks for the 2015 growing seasons.

IX. Self-Evaluation and Lessons Learned

- The USAID TraiNet system and the requirement for Legume Innovation Lab trainees to have J-1 Visas are time consuming and too complex. In addition, it limits opportunities to match Legume Innovation lab funding with other sources of funding for training.
- The drought in Central America and the resulting shortage of bean seed during the second growing season highlights the vulnerability of the seed production system in the region. There may be opportunities for bean seed producers in the U.S. to serve as an alternative source of seed during years when there are shortages in Central America and the Caribbean. Dr. Phil Miklas demonstrated that small red cultivars such as *Amadeus 77*, *CENTA Pipil* and *DEHORO* and black bean cultivars such as *Aifi Wuriti* and *DPC-40* produce good seed yields in Prosser, Washington.

X. Scholarly Accomplishments

Beaver, J.S., E.H. Prophete, J.C. Rosas, G. Godoy Lutz, J.R. Steadman and T.G. Porch. 2014. Release of “XRAV-40-4” black bean (*Phaseolus vulgaris* L.) cultivar. *J. Agric. of the Univ. of Puerto Rico* 98:83–87.

Beaver, J.S., J.C. Rosas, T.G. Porch, M. Pastor-Corrales, G. Godoy-Lutz and E. Prophete. 2014. Desarrollo de líneas de frijol blanco con resistencia a los virus BGYMV, BCMV, BCMNV y a la roya. Poster presented at the 2014 meeting of the PCCMCA held in Nicaragua from 28 April to 3 May 2014.

Estévez de Jensen, C., T.G. Porch and J.S. Beaver. 2014. Evaluation of *Phaeoisariopsis griseola* on common bean (*Phaseolus vulgaris)* in Puerto Rico. Presentation made at the 2014 meeting of the Caribbean Division of the American Phytopathological Society held in the U.S.V.I. from 6 to 10 July 2014.

Estévez de Jensen, C., Joseph, D., J.S. Beaver and Prophete, E. 2014. Dissemination of *Rhizobium* Inoculants in Haiti. Presentation made at the 2014 Caribbean Food Crops Society Annual Meeting held in the U.S.V.I. from 6 to 10 July 2014.

González, A. y J.S. Beaver. 2014. Desarrollo de líneas de frijol que combinan resistencia a los gorgojos y los virus BGYMV y BCMNV. Presentation made at the 2014 meeting of the PCCMCA held in Nicaragua from 28 April to 3 May 2014.

Porch Clay, T.G., Beaver, J.S., Abawi, G.A., Estevez de Jensen, C.E., Smith, J.R. 2014. Registration of a small red dry bean germplasm, TARS-LFR1, with multiple disease resistance and superior performance in low nitrogen soils. *J. Plant Reg.* 8:177–182.

Porch, T.G., K. Cichy, M. Alameda and J.S. Beaver. 2014. Association mapping analysis of the response to *Macrophomina phaseolina* in the Andean Diversity Panel. Poster presented at the 2014 joint conference of the 6th International Food Legumes Research Conference (IFLRC VI) and 7th International Conference on Legume Genetics and Genomics (ICLGG VII) held in Saskatoon, SK from 7–11 July 2014.

Porch, T.G., J.S. Beaver, S. Colom, A. Vargas, Y. Trukhina, and C. Estevez de Jensen. 2014. Development of tools for *Macrophomina phaseolina* evaluation and for genetic improvement of common bean. *Ann. Rep. Bean Improv.Coop.* 57:189–190.

Prophete, E., G. Demosthenes, G. Godoy-Lutz, T.G. Porch, and J.S. Beaver. 2014. Registration of PR0633-10 and PR0737-1 red mottled dry bean germplasm lines with resistance to BGYMV, BCMV, BCMNV, and common bacterial blight. *J. Plant Reg*. 8:49–52.

Racancoj, A.J., A.G. Vargas, J.C. Rosas, C. Estevez de Jensen, J.S. Beaver and T.G. Porch. 2014. Response of Andean and Mesoamerican common bean genotypes to inoculation with Rhizobium strains. *Ann. Rep. Bean Improv. Coop.* 57: 245–246.

Rodriguez, I.J., A.G. Vargas, J.C. Rosas, J.S. Beaver and T.G. Porch. 2014. Resistance of common bean breeding lines to Phaeoisariopsis griseola isolates from Honduras. *Ann. Rep. Bean Improv. Coop.* 57:215–216.

Rosas J.C., J. S. Beaver, S. Beebe, A. Llano, A. Clará y J. C. Hernández. 2014. Results from the SISTEVER small red bean Trials of 2013. Presentation made at the 2014 meeting of the PCCMCA held in Nicaragua from 28 April to 3 May 2014.

Rosas J.C., J. S. Beaver, S. Beebe, A. Llano, A. Clará, J. C. Hernández and J. C. Villatoro. 2014. Results from the SISTEVER small black bean Trials of 2013. Presentation made at the 2014 meeting of the PCCMCA held in Nicaragua from 28 April to 3 May 2014.

Rosas J.C., I. Rodriguez, C. Esteves de Jensen and J. S. Beaver. 2014. Progress on the genetic improvement of nodulation in common beans. Presentation made at the 2014 meeting of the PCCMCA held in Nicaragua from 28 April to 3 May 2014.

Rosas J.C., I. Rodriguez, and J. S. Beaver. 2014. Progress on genetic improvement of the resistance to angular leaf spot in common beans. Presentation made at the 2014 meeting of the PCCMCA held in Nicaragua from 28 April to 3 May 2014.

van Etten J., J C. Rosas and I. Rodriguez. 2014 First experiences with participatory massive evaluation of common beans in Honduras. Presentation made at the 2014 meeting of the PCCMCA held in Nicaragua from 28 April to 3 May 2014.

Vargas, A. T.G. Porch and J.S. Beaver. 2014. Evaluation of the tepary bean (*Phaseous acutifolius*) CIAT germplasm collection for response to common bacterial blight and bean common mosaic necrosis virus. *Ann. Rep. Bean Improv. Coop.* 57:181–182.

XI. Professional Recognition

1. Dr. Juan Carlos Rosas received the 2014 Gamma Sigma Delta Distinguished Achievement in Agriculture Award.
2. Consuelo Estévez de Jensen. The College of Agriculture of the University of Puerto Rico–Mayaguez presented a **Certificate of Recognition for Excellence in Research, Creativity and therefore, enrichment of the campus research**. Presented on the 9th day of May of 2014 in Mayaguez, Puerto Rico.
3. Consuelo Estévez de Jensen. The Puerto Rican Scientific Society Annual Meeting (SOPCA) awarded the 1st Place **Professional Oral Presentation Award Winner**. Presented at the 38th Annual Meeting SOPCA on the 2nd day of November of 2013. Guayanilla, Puerto Rico. Title of the Presentation “Inoculant Production in Haiti.”

XII. Progress in Implementing Impact Pathway Action Plan

Central America

Since the majority of bean improved cultivars used in Central America were de developed under the Bean/Cowpea and Dry Grain Pulses CRSP projects, Zamorano continue to be the main source of genetic and foundation seed for the national research institutions, national seed systems, NGOs and farmer organizations.

Under the Bean Dissemination Project (2010–13) nearly 27,000 farmers received high quality seed of improved bean cultivars in Honduras, and Zamorano provide foundation seed and Rhizobium inoculant to INTA/Nicaragua, ICTA/Guatemala and NSS/Haiti. In Honduras, several Local Agricultural Research Committees (CIALs), which were involved in this project, continue producing seed using registered seed provided by Zamorano.

Under a similar approach, Zamorano continue providing foundation seed of improved bean cultivars and Rhizobium inoculant to the bean technology dissemination project coordinated by Michigan State University in collaboration with Technoserve and DICTA in Honduras.

Haiti

During the summer of 2014, the National Seed Service produced three MT of seed of the multiple disease resistant black bean variety "XRAV-40-4," two MT of "DPC-40" and one MT of the red mottled bean PR0737-1. The stationary thresher, purchased with funds from the Pulse CRSP, facilitated the harvest at Savane Zombi and generated interest among bean growers. Dry weather during the summer reduced seed yields.

The Bean Technology Dissemination project produced a significant amount of seed in Haiti during 2014. The NGO Zanmi Agrikol produced 18 MT of "DPC-40" during 2014. This seed was sold to 1,000 farmers near Mirebalais. The NGO, Hands Together produced eight MT of DPC-40, the seeds were stored for the December 2014 planting of the growers of an Agricultural Cooperative.

XIII. Annexes

Annex 1. Tables, Figures, and Photos Cited in the Report

Figure 1. Leafhopper tolerant line PR1146-138 (left) vs. a leafhopper

Annex 2. Literature Cited

None

XIV. Milestones

Feed the Future Innovation Lab for Collaborative Researchon Grain Legumes

Report on the Achievement of "Milestones of Progress"
(For the Period: April 1, 2013 -- September 30, 2013)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2013

Project Title: Development and implementation of robust molecular markers and genetic improvement of common and tepary beans to increase grain

	Abbreviated name of institutions																			
	UPR			USDA-ARS-TARS			Zamorano			NSS-Haiti			ICTA			NDSU			USDA-ARS-Prosser		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Milestones by Objectives	**10/1/14**	**Y**	**N ***	**10/1/14**	**Y**	**N ***	**10/1/14**	**Y**	**N ***	**10/1/14**	**Y**	**N ***	**10/1/14**	**Y**	**N ***	**10/1/14**	**Y**	**N ***	**10/1/14**	**Y**	**N ***
	(Tick mark the Yes or No column for identified milestones by institution)																				
Objective 1																					
1.1 Develop and test on research stations and farms bean breeding lines that combine disease and pest	x	x		x	x		x	x		x	x		x	x					x	x	
1.2 Multiply and maintain breeder and foundation seed stocks of recently-released bean cultivars	x	x					x	x		x	x		x	x					x	x	
1.3 Regional testing of small red and black bean breeding lines in the lowlands of Central America and Haiti.	x	x					x	x		x	x		x	x					x	x	
1.4 Utilize recurrent selection to develop bean populations for better adaptation to low N soils and greater resistance to web blight.	x	x					x	x													
1.5 Evaluate pathogen variability and resistance to angular leaf spot, powdery mildew and web blight.	x	x		x		x	x	x		x		x	x	x							
1.6 Support the development of bean breeding populations in Guatemala and Haiti with the goal of releasing a locally-produced cultivar by the end of the five-year extension period.										x	x		x	x							
1.7 Test the performance of bruchid resistant lines when exposed to natural infestation	x	x																			

Milestones, continued

Objective 2: Genetic improvement of tepary beans for Central America and Haiti.																				
2.1 Pv x Pa hybrids will be completed and embryo rescue will be initiated from the BC1F1 generation material in FY15 through collaboration with the U. of Saskatchewan.				x	x															
2.2 The CIAT tepary bean germplasm collection will be evaluated for BGYMV in Honduras.							x	x												
2.3 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.							x	x		x	x		x	x						
2.4																				
2.5																				
Objective 3: Develop and implement robust molecular markers for disease resistance genes																				
3.1 Populations will be developed for subsequent identification of improved markers for BGYMV, BCMNV, BCMV and rust.	x	x					x	x										x	x	
3.2 Investigate efficacy of available markers for bruchid resistance genes (Arc2, Arl3, PHA and aAI3).	x	x		x	x															
3.3 Establish background information for marker development disease resistance through conducting association mapping analysis.				x	x											x	x	x	x	
3.4 Evaluate the genetics of web blight resistance through conducting association mapping analysis	x	x		x	x											x	x			
3.5																				

Milestones, continued

Objective 4: Institutional capacity building																				
4.1 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.																x		x		
4.2 A workshop will be held in Honduras in December 2014 to train technical personnel concerning bean research techniques with the goal of improving the quality of field research.																				
4.3 Undergraduate students at Zamorano will be provided opportunities to participate in bean research activities related to Legume Innovation Lab project objectives.							x	x												
4.4 M.S. degree training will be completed at the UPR of Ana Vargas (Nicaragua) and Angela Miranda (Guatemala).	x		x																	
4.5 Ph.D. degree training at NDSU of two bean researchers from Central America or the Caribbean																x		x		

Name of the PI reporting on milestones by institution	James S. Beaver	Timothy G. Porch	Juan Carlos Rosas	Emmanuel Prophete	Julio Cesar Villatoro	Phil McClean	Phil Miklas
Name of the U.S. Lead PI submitting this Report to the MO	James S. Beaver						
	Signature					**Date**	

** Please provide an explanation for not achieving the milestones on a separate sheet.*

XV. Performance Indicators

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes
PERFORMANCE INDICATORS / TARGETS SPREADSHEET for FY 13 (Second Semester only), FY 14, and FY 15

Project Name: 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.

Summary of all institutions

Indic. numbe	Output Indicators	FY 13 Target (only April 1, 2013 - September 30, 2013)	FY 13 Revised	FY 13 Actual	FY 14 Target (October 1, 2013 - September 30, 2014)	FY 14 Revised	FY 14 Actual	FY 15 Target (October 1, 2014 - September 30, 2015)	FY 15 Revised	FY 15 Actual
1	4.5.2(6) Degree Training: Number of individuals who have received degree tr	0	0	0	4	4	4	8	8	0
	Number of women	0	0	0	2	2	2	5	5	0
	Number of men	0	0	0	2	2	2	3	3	0
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training									
	Total number	0	0	0	0	2	5	67	67	0
	Number of women	0	0	0	0	1	2	23	23	0
	Number of men	0	0	0	0	1	3	44	44	0
	Numbers by Type of individual									
	Producers	0	0	0	0	0	35	20	20	0
	People in government	0	0	0	0	0	25	40	40	0
	People in private sector firms	0	0	0	0	0	0	7	7	0
	People in civil society	0	0	0	0	0	10	0	0	0
3	4.5.2(13) Beneficiaries: (numbers of households)									
	New/Continuing (total)	0	0	0	9000	9000	9000	24000	24000	0
	New	0	0	0	1000	1000	1000	4000	4000	0
	Continuing	0	0	0	8000	8000	8000	13000	13000	0
	Gendered Household Type									
	Adult Female no Adult Male (FNM)	0	0	0	500	500	500	750	750	0
	Adult Male no Adult Female (MNF)	0	0	0	500	500	500	750	750	0
	Male and Female Adults (M&F)	0	0	0	8000	8000	8000	14000	14000	0
	Child No Adults (CNA)	0	0	0	0	0	0	0	0	0
4	4.5.2(11) Number of food security private enterprises (for profit), producers organizations, water users associations, women's groups, trade and business associations, and community-based organizations (CBOs) receiving USG assistance									
	Type of organization									
	Private enterprises (for profit)	0	0	0	0	0	0	0	0	0
	Producers organizations	0	0	0	0	0	0	0	0	0
	Water users associations	0	0	0	0	0	0	0	0	0
	Women's groups	0	0	0	0	0	0	0	0	0
	Trade and business associations	0	0	0	0	0	0	0	0	0
	Community-based organizations (CBOs)	0	0	0	0	0	0	50	50	0
	New/Continuing (total)	0	0	0	30	30	30	50	50	0
	New	0	0	0	5	5	5	12	12	0
	Continuing	0	0	0	25	25	25	38	38	0

Performance Indicators, continued

5	4.5.2(12) Number of public-private partnerships formed as a result of CRSP assistance									
	Number by type of partnership (total)	0	0	0	7	7	7	14	14	0
	Agricultural production	0	0	0	7	7	7	14	14	0
	Agricultural post harvest transformation	0	0	0	0	0	0	0	0	0
	Nutrition	0	0	0	0	0	0	0	0	0
	Multi-focus	0	0	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0	0
6	4.5.2(2) Developmental outcomes:									
	Number of additional hectares under improved technologies or management practices									
	Number under specific technology types (total)	0	0	0	20000	20000	20000	34000	34000	0
	crop genetics	0	0	0	19500	19500	19500	33500	33500	0
	animal genetics	0	0	0	0	0	0	0	0	0
	pest management	0	0	0	0	0	0	0	0	0
	disease management	0	0	0	0	0	0	0	0	0
	soil-related	0	0	0	500	500	500	500	500	0
	irrigation	0	0	0	0	0	0	0	0	0
	water management	0	0	0	0	0	0	0	0	0
	post-harvest handling and storage	0	0	0	0	0	0	0	0	0
	processing	0	0	0	0	0	0	0	0	0
	climate mitigation or adaptation	0	0	0	0	0	0	0	0	0
	fishing gear/technique	0	0	0	0	0	0	0	0	0
	other	0	0	0	0	0	0	0	0	0
	total w/one or more improved technology	0	0	0	0	0	0	0	0	0
	New/Continuing hectares									
	New	0	0	0	2000	2000	2000	4550	4550	0
	Continuing	0	0	0	18000	18000	18000	29450	29450	0
	Sex of person managing hectare									
	Male	0	0	0	18000	18000	18000	26950	26950	0
	Female	0	0	0	2000	2000	2000	5550	5550	0
	Association-applied	0	0	0	0	0	0	1500	1500	0

Performance Indicators, continued

7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	0	0	0	35	35	35	119	119	0
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	0	0	0	20	20	20	65	65	0
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	0	0	0	10	10	10	37	37	0
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	0	0	0	5	5	5	17	17	0
8	4.5.1(24) Numbers of Policies/Regulations/Administrative Procedures in each of the following stages of development as a result of USG assistance in each case: (Stage 1/2/3/4/5)									
	Sector (total)	0	0	0	0	0	0	0	0	0
	Inputs	0	0	0	0	0	0	0	0	0
	Outputs	0	0	0	0	0	0	0	0	0
	Macroeconomic	0	0	0	0	0	0	0	0	0
	Agricultural sector-wide	0	0	0	0	0	0	0	0	0
	Research, extension, information, and other public service	0	0	0	0	0	0	0	0	0
	Food security/vulnerable	0	0	0	0	0	0	0	0	0
	Climate change adaptation or natural resource management (NRM) (ag-related)	0	0	0	0	0	0	0	0	0
	Stages of development									
	Stage 1 of 5: Number of policies / regulations / administrative procedures analyzed	0	0	0	0	0	0	0	0	0
	Stage 2 of 5: Number of policies / regulations / administrative procedures drafted and presented for public/stakeholder consultation	0	0	0	0	0	0	0	0	0
	Stage 3 of 5 : Number of policies / regulations / administrative procedures presented for legislation/decree	0	0	0	0	0	0	0	0	0
	Stage 4 of 5 Number of policies / regulations / administrative procedures prepared with USG assistance passed/approved	0	0	0	0	0	0	0	0	0
	Stage 5 of 5: Number of policies / regulations / administrative procedures passed for which implementation has begun	0	0	0	0	0	0	0	0	0

Notes:

These indicators are developed under the Feed the Future Monitoring System. Please provide 'total' numbers and also disaggregate where applicable. Just providing 'totals' will not be approved.

This table corresponds to the Feed the Future Performance Indicators data collection sheet under the FTFMS system. Where an indicator does not apply to the type of work done under the project, leave it blank.

Please follow the indications in the Legume Innovation Lab Indicators Handbook that will be provided to you by the Management Office. Contact Mywish Maredia (maredia@anr.msu.edu) for further information.

There is additional guidance on the USAID website http://feedthefuture.gov/sites/default/files/resource/files/ftf_handbookindicators_apr2012.pdf