Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

PROJECT TECHNICAL DESCRIPTION

COVER PAGE

Code and Title of Legume Innovation Lab Project: **SO1.A1: Genetic Improvement of Middle-American Climbing Beans in Guatemala.**
Name, institutional affiliation and contact information of Lead U.S. Principal Investigator and University: Juan M. Osorno, Dept. of Plant Sciences, North Dakota State University. Fargo-ND 58108
Name(s) and institutional affiliation of all Host Country (HC) and U.S. Co-PIs: Phil McClean, Dept. of Plant Sciences, North Dakota State University. Fargo-ND 58108 Julio C. Villatoro, ICTA-Guatemala Fernando Aldana, ICTA-Guatemala Karla Ponciano, ICTA-Guatemala Julio Martinez, ICTA-Guatemala Edgardo Carrillo, ICTA-Guatemala

Project Period:	**Total Funding for 4 year Project**	**Total non-federal cost share commitment by U.S. institution(s)**
October 1, 2013 – September 30, 2017	$693,279	$46,772

HCs where project activities will be implemented:	**HC institutions to be sub-contracted (abbreviated names):**	**Percent of total project funding budgeted for each HC institution to be subcontracted**
Guatemala	Instituto de Ciencia y Tecnología Agropecuaria (ICTA)	54.56%

Authorized Lead U.S. University Representative:

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Signature:_____ **Date:**_____

SUMMARY PAGE (must print on one page)

Code and Title of Legume Innovation Lab Project:

SO1.A1: Genetic Improvement of Middle-American Climbing Beans in Guatemala.

Name and Institutional Affiliation of the U.S. Lead Principal Investigator:

Juan M. Osorno, Dept. of Plant Sciences, North Dakota State University. Fargo-ND 58108

Abstract (Limit: 1800 characters including spaces—about 200-250 words):

The highlands of Guatemala are a unique bean producing region where intercropping (milpa) is still the main production system, mostly with maize-bean association. The system uses climbing beans that grow around the corn stalks either simultaneously or in a relay system. Unfortunately, on-farm productivity of these climbing beans is approximately one third of their genetic yield potential mostly due to the lack of improved cultivars that are able to withstand biotic and abiotic stresses. This low productivity significantly impacts food security and nutritional quality of the region, especially in women and children. Historically, climbing beans have received less attention and breeding efforts in comparison with the bush-type beans commonly grown in the lowlands, as shown by the significant yield gap between regions. In addition, the Guatemalan climbing beans are a unique group of germplasm which has not been studied extensively and could offer new genetic variation for traits of economic importance. The Legume Innovation Lab is starting a new project focused in the highlands of Guatemala with the goal of developing improved varieties of climbing beans that would increase the productivity in the region. The main objectives of the project are: I) Development of varieties with improved disease resistance and agronomic performance, II) Characterization of the genetic diversity of this unique set of germplasm, III) A better understanding of the current status and needs of the intercropping systems in the region, IV) Train the next generation of plant breeders for Guatemala, and V) Establish a long-term plan to increase the productivity of bean in the region.

Summary Checklist ***(select as many as appropriate)***

No	Project involves the use of proprietary transgenes or the generation of genetically modified organisms (GMOs)
No	Project involves human subjects and requires approval
No	Project involves animal use and requires approval
No	Project involves the use of agricultural pesticides and requires a Pesticide Evaluation and Safe Use Action Plan
Yes	Project involves M.S. or Ph.D. degree training of HC personnel at a U.S. university (How many?) _2_____

A. Technical Approach (maximum of twelve pages, excluding the budget and budget narrative)

1. Problem Statement and Justification

With approximately 11 million habitants, Guatemala is mostly a rural country, with 60% of the population living in farms and 50% of the population being indigenous. Maize and beans are the main staple food in most households with a per capita consumption of 9.4 kg per year. Since few other sources of protein are available, this amount is not enough to ensure an acceptable nutritional quality, especially within poor households. Dietary recommendations from the government suggest a 75%:25% daily proportion of maize:beans for a good nutritional balance between carbohydrates and protein intake; however, collected information suggest that the actual proportion in rural households is approximately 97%:3%. As expected, the lack of protein intake has reduced the nutritional quality in many households, significantly affecting children. Severe malnutrition cases and even deaths are reported in rural areas, mostly in the highlands. Two main reasons may explain this deviation from the recommended proportion: higher productivity of maize vs. beans and consequently, lower prices for maize compared to beans.

Beans are grown on 31% of the agricultural land and mostly in the low to mid-altitude regions (0-1500 masl) in a monoculture system. Contrastingly, intercropping (locally known as Milpa) is the main production system in the highlands, where maize-bean is the most common crop association. The system uses climbing beans that grow around the corn stalks. Two main methods are used: direct planting, in which both maize and beans are planted simultaneously, and relay, in which the maize is planted first and the beans are planted at a later date in order to avoid strong competition between the two crops. The main bean producers are small landowners largely in the highlands. These farmers plant 66% of the total area planted to beans in the country, yet the production is only 53% of the total national bean production. In contrast, large landowners (>45 ha) in lowland areas produce 28% of the beans on only 18% of the area planted to beans.

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

A previous project leaded by Dr. Jim Kelly from Michigan State University in the early 2000s started some work on climbing beans but the project was interrupted at the initial stages due to some funding issues. Therefore, a new focused effort on this unique group of beans is needed to improve the food security conditions in the area. In addition, this is a group of germplasm that has not been intensively studied and therefore, it may be an untapped source for new genes for resistance/tolerance to biotic and abiotic stresses that could be useful for the entire breeding community. There has been even some informal discussion among breeders that this could be a separate race within the Mesoamerican gene pool that some have called “Guatemala race” given its unique characteristics of plant types and seed colors and sizes that makes it different from the other three races from this gene pool.

There is an existing collection of approximately 600 accessions of climbing beans collected across all bean production regions in Guatemala. This collection is kept by ICTA and has been characterized morphologically and with few molecular markers (6 SSR primers). In addition, some field notes concerning disease resistance (natural pressure) and other agronomic traits of economic importance have been collected as well. Initial results suggest that ½ of the collection consist of dupplicates; however, it is important to note that only six SSR primers were used and therefore, more markers are needed in order to gain genetic resolution and ensure that no genetic diversity is being lost by reducing this collection to a core. In addition, some initial crosses among climbing beans and selections have been made by Dr. Fernando Aldana (ICTA-Quetzaltenango) and the rest of the ICTA group. These lines will be used intensively in this study.

Guatemala is one of the focus countries for FTF and this project would fit within the future research priorities established by USAID and Feed the Future. Women are a crucial component of the production systems observed in this region and children often help in the daily farming activities as well (e.g. school calendar is based on harvest seasons). We believe this project will have impact not only in the highlands of Guatemala but in many other areas with similar environmental conditions and intercropping systems.

2. Objectives

1. Development of germplasm with improved disease resistance and agronomic performance.
2. Characterization of the genetic diversity of this unique set of germplasm.
3. A better understanding of the current socio-economic status and needs of bean production within the context of intercropping systems in the region.
4. Capacity building: training the next generation of plant breeders for Guatemala.
5. Establish a long-term plan to increase the productivity of climbing bean in the region.

3. Approaches and Methods

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

The bean breeding program at ICTA has selected a group of 10 accessions from the germplasm collection that offer agronomic traits if interest such as plant growth type, seed yield, disease resistance, earliness, and seed quality, among others. We will start field testing of these 10 accessions across 10-20 locations. Most locations will be tested under the intercropping system and few under monoculture. Agronomic data will be collected across all locations. At the same time, genetic purification of selected lines will be done since it has been observed that most of these accessions have phenotypic variability. After the first year of field testing, the best 2 lines will be selected for field testing in grower's fields at three locations. In addition, one of the improved lines selected by Dr. Aldana at advanced breeding stages (known as Bolonillo-Texel) will be also tested at grower's fields. If Bolonillo-Texel has good acceptability it could be released sooner, which would allow for a significant impact of this project earlier than planned by releasing an improved variety of climbing bean thanks to the previous efforts made by the ICTA bean breeding project. Seed from promising lines will be multiplied and released to the public as a first-generation of improved climbing beans while a more formal breeding program is being established (see objective 2). In final

stages, the lines will be also evaluated for optimal performance under different agronomic configurations by changing population densities, fertilizer, etc. This could be part of the research of a graduate student.

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

Given the uniqueness of this group of germplasm, it is necessary to ensure we are collecting all the genetic variability within this collection so it can be used in the future in breeding programs. Preliminary results using six microsatellite (SSR) markers strongly suggest that ½ of the collection is just duplicates, showing monomorphic bands among accessions. Therefore, the core collection of approximately 300 accessions will be re-evaluated with a larger number of markers at NDSU. A new set of 6000 Single Nucleotide Polymorphism (SNP) markers is available as product from the BeanCAP project (www.beancap.org). This set of markers is highly precise, reliable, and allow higher resolution and differentiation among genotypes compared to SSR markers. With the goal of having a better understanding of the organization of the genetic diversity of this group, we will screen the core 300 accessions with the 6k beancap chip and do a genetic diversity study of possible genetic relationships among the accessions. In addition, an assessment of variation within the 10 selected lines will be made in order to account for the heterogeneity not only among but within accessions and possibly, extrapolate that information to the rest of accessions. Preliminary phenotypic observations on the field suggest that there is a high amount of genetic heterogeneity within accessions. Evaluations for disease resistance have been made in the field under natural pressure; however, it is difficult to assess the levels of resistance when 2 or more diseases are present simultaneously in the same field. Therefore, the core collection will be also evaluated in the U.S. (greenhouse) for reaction to bean rust (in collaboration with UNL), anthracnose (NDSU), ascochyta leaf blight (NDSU), and bean common mosaic virus (UPRM). In addition, the core 300 will be evaluated in the field in Guatemala for resistance to Mexican weevil and resistance to the same fungal diseases mentioned above under natural disease pressure, as well as for other agronomic traits previously evaluated in order to confirm results.

This core 300 collection could be used as a diversity panel that could be used for Genome Wide Association Studies (GWAS). This will allow identifying genomic regions associated with traits of agronomic/economic importance within this unique group of germplasm. This approach has been successful already in common bean, identifying regions associated with growth habit, seed color, seed size, days to flowering, among others. A similar approach could be used as a thesis topic to identify candidate regions associated with disease resistance genes for example.

The results obtained in this first phase will allow making informed decisions about the potential parents for the first set of crosses. Some crosses could also involve bush-type beans in order to broad the genetic base of the climbing beans. In addition, RIL populations of interspecific crosses between common bean (*Phaseolus vulgaris* L.) and runner bean (*P. coccineus* L.) will be screened for resistance to ascochyta blight with the goal of finding genomic regions associated with resistance. The F1 seeds will be planted in the greenhouses in Guatemala and then the selection process will start at the F2 generation in the field. The breeding method will be chosen depending on the phenotypic variation observed at the F2 generation, but most probably, the pedigree and bulk methods will be the main choice. After 4 years of breeding efforts, we should have breeding populations at intermediate breeding stages (F4 to F5 generation).

Objective 3: A better understanding of the current socio-economic status and needs of bean production within the context of intercropping systems in the region.

Even though the intercropping system is the most common production system in the highlands of Guatemala, there is almost no data about the current status of the bean crop in regards

to household consumption, common and preferred seed types produced, agronomic practices, among many other factors. Even more important, there is no information about the current needs of the growers of the region in regards to bean production. Therefore, this project plans to do a small-scale socio-economic study that will try to answer some of these questions. The results will help to design future strategies for the improvement of the bean productivity and consumption in the region. First, an effort to find previous surveys made by governmental and non-governmental institutions will be made. Second, a grower survey will be deployed in the main regions where climbing beans are produced. Results of this survey will be shared not only within the project but with other projects currently working in Guatemala (e.g. Nutrifrijol) and government agencies. A second phase of this study will evaluate the acceptability of new varieties by growers and in the last two years of the project, an assessment of adoption, dissemination, and impact will be made. Julio Martinez is the lead rural social economist from ICTA and will be the leader of these activities, in coordination with other ICTA personnel.

Objective 4: Capacity building: training the next generation of plant breeders for Guatemala.

Capacitation of new personnel is crucial for the long-term success of any project. Informal conversations with Dr. Elias Raymundo, general director of ICTA, show the concern he has about the fact that several lead scientist within the institution will retire in the near future and efforts are underway to make sure an early career selection is being made at the national level. A "seed program" lead by ICTA aims to identify outstanding young people that would be the future leaders and scientists within the institution. Dr. Raymundo expressed the need for more breeders and plant pathologists both at the M.S. and Ph.D. level. With this in mind, we plan to have two individuals from Guatemala to come and do graduate studies at NDSU (Plant Sciences) with the goal that those individuals will be incorporated into agricultural research back into Guatemala. Research topics will be directly related to the research objectives described above. We foresee research projects focused on the analyses of genetic diversity, genetic resistance to diseases, and production systems, among others. The graduate students will be provided a broad range of training in conventional and molecular plant breeding techniques so that they can assume roles of leadership in bean research programs in the target countries. In addition, an informal workshop will be made at NDSU for some members of the bean breeding program at ICTA during the 3rd year. The goal of this training/workshop will be to show the ICTA group how bean production is made in North Dakota (the largest producer in the U.S.) and also received training on molecular markers and other genomic tools that could help in the breeding process.

Objective 5: Establish a long-term plan to increase the productivity of climbing bean in the region.

Even though this project is planned for four years, it is important to design plans and strategies for the long-term success of the climbing bean project in Guatemala. Therefore, a meeting during the 3rd year of this project will focus on collecting all the experiences gained during this project in order to discuss the best future strategy for the climbing bean breeding program at ICTA. This meeting will be held in Guatemala and it will involve all the participants of this group but also we will make an effort to invite other potential players for the future of this project. The goal is to design a medium and long-term project that will ensure continuous genetic improvement of climbing beans primarily for Guatemala, but potentially for other regions where climbing beans are commonly grown.

4. Collaboration with Host Country Institutions

This project will be made in collaboration with the Institute of Agricultural Science and

Technology (ICTA) in Guatemala. Julio Cesar Villatoro is the lead scientist of the bean breeding program and his project has approximately 5-6 people. Mr. Villatoro has been a long-term collaborator in previous projects funded by the Legume Innovation Lab mostly focused on bush-type beans for production in the lowlands. Mr. Villatoro will coordinate all the trials across locations and will lead the main breeding activities of screening and crosses at the Chimaltenango station and collaborating with the team doing the field trials in farmer fields (coordinated by a separate group at ICTA).

Dr. Fernando Aldana will lead all the trials made in the Quetzaltenango region and will be also collaborating with the team doing the field trials in farmer fields in this region. Dr. Aldana will also work on the promotion and dissemination of the new varieties as well as in the planning of crosses and selections.

Julio Martinez, rural socio-economist from ICTA will lead all the small-scale socio-economic study and provide feedback and results to the rest of the group periodically.

Karla Ponciano will lead the work on the characterization of the genetic diversity of the core 300 in close collaboration with the personnel from NDSU.

5. Coordination with other International Grain Legume Research Programs/Projects

USAID already has presence in the region working with bush-type beans for the lowlands during the last 25 years in collaboration with the bean breeding program at Zamorano-Honduras (project S01.A4), led by Dr. James Beaver. The marker tool developed by this project could also be used in this project since Dr. Phil McClean is a Co-PI on both projects. Dr. Juan Carlos Rosas at the Escuela Agricola Panamericana (EAP) in Honduras also expressed interest in collaborating in any way possible with this project. In addition, there are opportunities for germplasm exchange between these two projects with germplasm from the highlands in Haiti and Tanzania. In this way, the impact of the research may go beyond the Guatemalan highlands. Finally, we expect to have close collaboration with the Nutrifrijol project to be funded by the USAID mission in Guatemala as an Associate Award to the Legume Innovation Lab. Dr. Jim Steadman at the University of Nebraska-Lincoln expressed interest in helping with the screening of this germplasm collection for rust. Also, Drs. Jim Beaver and Jim Kelly accepted to serve in this project as external advisors. In fact, Dr. Beaver was present at the planning meeting for this project held in Quetzaltenango in November last year and he will also screen the collection for resistance to BCMV. Project personnel already collaborate with UPRM in the Caribbean through the testing of breeding lines in winter nurseries. In addition, germplasm lines from CIAT are used frequently by U.S. and host country bean breeding programs as sources of valuable traits. We will remain open to other potential collaborations with other projects and institutions.

6. Outputs

- The development and release of improved climbing beans with better agronomic performance (4 years).
- A better understanding of the organization of the genetic diversity within this unique set of germplasm (2 years).
- Identification of genomic regions associated with traits of agronomic/economic importance (4 years).
- An information database of the current market situation and production needs of climbing beans in the highlands of Guatemala (2 years).

- Training of the next generation of plant breeders (4 years).
- Establishment of a long-term breeding approach (4 years).

7. Capacity Building of Partner Host Country Institutions

Two individuals from Guatemala will come and do graduate studies at NDSU (Plant Sciences) with the goal that those individuals will be incorporated into agricultural research back into Guatemala. Degree training at NDSU is less expensive than most U.S. universities which represents an efficient use of funds. Research topics will be directly related to the research objectives described above. We foresee research projects focused on the analyses of genetic diversity, genetic resistance to diseases, and production systems, among others. The graduate students will be provided a broad range of training in conventional and molecular plant breeding techniques so that they can assume roles of leadership in bean research programs in the target countries. In addition, an informal workshop will be made at NDSU for some members of the bean breeding program at ICTA during the 3rd year. The goal of this training/workshop will be to show the ICTA group how bean production is made in North Dakota (the largest producer in the U.S.) and also received training on molecular markers and other genomic tools that could help in the breeding process.

B. Alignment with USAID Feed the Future Goals and Strategic Research Objectives

1. *Alignment- Guatemala* is one of the priority focus countries for the Feed the Future program. The principal objective of this project is the development and release of climbing bean germplasm in in Guatemala with improved disease and pest resistance, improved agronomic performance, and seed quality. This contributes to the FTF research themes of enhancing the productivity and improving the nutrient use efficiency of grain legumes. Increased availability of beans should also improve nutrition in the highlands of Guatemala. The development of breeder-friendly molecular markers should help to improve the efficiency and effectiveness of selection of important traits. Formal training activities will increase the potential number of bean researchers in the country. Informal training activities (workshops) will permit bean researchers from Guatemala to see bean production in developed countries and to use molecular tools for genetic improvement to improve the reliability and quality of research results.

2. *Gender Equity*- Women are actively involved not only on the crop production within the farms in Guatemala, but also in the decisions regarding what it is consumed in the household. Therefore, this project will have a significant impact in women by allowing them to have greater availability of beans for household consumption, hence improving the cereal:legume ratio discussed previously. On the other hand, this project will make efforts to recruit women as potential graduate students involved in the capacity building/training portion of this program. Karla Ponciano from ICTA has already expressed an interest in graduate school.

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

C. Impact Pathway Plan

(Present a plan for achieving scalable and sustainable developmental impact that benefits stakeholders of grain legume value chains, especially women and resource-poor grain legume farmers in target Feed the Future countries and regions. See attached guidance on Impact Pathway to be provided by the Legume Innovation Lab MO (Dr. Mywish Maredia, Impact Assessment Advisor) when preparing the plan. In particular, identify outputs and entities along the impact pathway to which these will be "handed off" for further adaptive research and dissemination. Estimate potential impact in both qualitative and quantitative terms of the outputs from the proposed research and training activities in both target developing countries and the U.S. In those projects where a technology is likely to be developed and released within the coming years, the MO may request that the project team collect "base-line' data so as to be able to document adoption and future impact (ex-post). In such cases, the project will be expected to include the cost of base-line data collection in its 4 year project budget.)

D. Project Budget

1. Budget Narrative

Host Country Institutional Budget Split

Host Country Institution (ICTA-Guatemala): 54.76%
U.S. Institution (NDSU): 45.24%

Personnel Cost

U.S. Institution (NDSU): Salary for 3 months per year will be included for the Co-PI (McClean) starting at $16,000 per year plus 2% increase the following years. In addition, 1/3 of the annual salary for a Postdoctoral scientist ($15,000) is also included. This scientist will help with the research portion of the project and will help in training/advising the graduate students that will be part of the capacity building portion of the projects well as informal training and workshops. Total amount for salaries is $125,945. Fringe benefits for the Co-PI are calculated at 30% of the salary (19,784) and 35% for the postdoctoral scientist (21,000). Total amount of fringe benefits is $40,784.

Host Institution (ICTA): Salaries for hourly personnel that will help with the grower's surveys during the first year 2014 ($3,000). No fringe benefits are needed since they will be temporary workers.

Travel

U.S. Institution (NDSU): A total of $48,000 ($12,000 per year) to travel to host country. Three trips per year for PI and one trip for Co-PI per year. This will cover airfare, hotel, meals, and ground transportation to the field testing locations.

U.S. Institution (NDSU): For year 2016, a total of $5,000 will be allocated to invite two project advisors to visit the project in Guatemala. Fund will cover mostly their travel expenses.

Host Institution (ICTA): A total of $59,500 will be used mostly for travel within Guatemala to the different locations where field experiments will be grown. Most travel will be made by car. Meals and hotels will be provided when traveling overnight. $18,500 for 2014, $15,000 for 2015, $11,000 for 2016, and $15,000 for 2017.

Equipment

None.

Supplies

U.S. Institution (NDSU): A total of $34,000 will be used for lab reagents and materials, genotyping services, greenhouse fees and materials needed for disease screening in the greenhouse.

Host Institution (ICTA): $64,200 will be used mostly for all the materials needed for field trials, which include agrochemicals, fertilizers, stakes and poles, rope, envelopes, clips, etc. In addition, office supplies will be needed for the grower surveys as well as for some photocopies of printed material with information regarding the new varieties.

Training/Capacity Building

U.S. Institution (NDSU): A total of $159,753 will cover the assistantships of two full-time graduate students at NDSU.

U.S. Institution (NDSU): Host a training workshop for personnel from ICTA. During year 2016, $15,000 has been allocated for travel of the Guatemalan bean breeding group to a workshop that will be held at NDSU. These funds will cover for airfare, hotel, meals, and ground transportation within the region.

Indirect Cost

U.S. Institution (NDSU): Indirect costs are 45% of the direct costs. By USAID policy, degree and non-degree training (capacity building) are excluded from indirect costs as defined in ADS 253.

Host Institution (ICTA): The agency in charge of managing the ICTA funds (FUNDIT) charges 10% for indirect costs, for a total of $12,670.

Indirect cost on sub-subcontracts

U.S. Institution (NDSU): $11,250 that corresponds to 45% of the first $25,000 subcontracted to ICTA.

Cost Share $46,772

U.S. Institution (NDSU):
PI Salary $35,979
30% fringe benefits $10,793

"Cash contributions represent the institution's cash outlay, including the outlay of money contributed to the institution by nonfederal third parties. The waiver of indirect cost and employee effort exceeding the salary received from the agreement are examples of eligible cost sharing contributions."
(NDSU Policy, Section 814, Cost Sharing)

Attribution to Capacity Building ($188,518)

Estimated as 19.2% of the total direct cost (NDSU), for a total of $48,716
Estimated as 80% of the total direct costs (NDSU for host institution, for a total of $139,802)