Feed the Future Innovation Lab for
Collaborative Research on Grain Legumes
(Legume Innovation Lab)

FY 2017 Annual Project Technical Progress Report
(October 1, 2016 – September 29, 2017)

Project Code and Title: SO1.A1- Genetic Improvement of Middle-American Climbing Beans for Guatemala.

Lead U.S. Principal Investigator and University: Juan M. Osorno, Dept. of Plant Sciences, North Dakota State University. Fargo-ND 58108.

Collaborating Host Country and U.S. PIs and Institutions:
Phil McClean, Dept. of Plant Sciences, North Dakota State University. Fargo-ND
Julio C. Villatoro, ICTA-Guatemala
Edgardo Carrillo, ICTA-Guatemala
Angela Miranda, ICTA-Guatemala
Jessica Moscoso, ICTA Guatemala
Karen Agreda, ICTA Guatemala

I. Abstract of Research and Capacity Strengthening Achievements

The final year of this project allowed the completion of multiple research efforts initiated at the beginning of this cycle. The most impactful accomplishment of this project is the release of two new climbing bean varieties (ICTA-Labor Ovalle and ICTA-Utatlan), adapted to the conditions of the highlands in Guatemala and the Milpa intercropping system, which is the most common cropping method in the region. With the help of partner projects such as Buena Milpa and MASFRIJOL, at least 7500 lbs of each variety were distributed to growers during FY2017 and they are being currently grown in farmer's field during the 2017 growing season. Studies focused on the molecular characterization of the genetic diversity of the ICTA germplasm collection and a new collection obtained through a grower's survey, allowed a better understanding of the organization of the genetic diversity. Results have shown that this Guatemalan germplasm is very unique and distinct from the rest of genetic material from Central America, suggesting a separate genetic race. This confirms something that has been suggested before based on results using a handful of Guatemalan climbing beans, but the scale and resolution done in this project allows to be sure of this genetic distribution. These results may change the way in which the organization of bean genetic diversity from Central America will be presented in future papers. The identification of pathogenic races of bean rust and anthracnose in Guatemala is another big accomplishment because it will allow to design effective breeding strategies for genetic resistance to these pathogens by combining the most appropriate genes for durable resistance. A total of six and three races of anthracnose and rust were found, respectively. Screening of the ICTA climbing bean collection with some of these races as well as races of economic importance in the US, allowed the identification of new potential sources of resistance to

both diseases that will be useful not only in Guatemala but in elsewhere. In addition, genetic mapping studies are helping to understand if resistance is controlled by genes already known/reported, or if new genes are being identified. Results showed that some genes appear to be in genomic locations previously reported but some other genomic regions are completely new. Finally, three students have completed their M.S. degrees and are returning to their home countries to apply all the concepts and training received at NDSU. This is a very important capacity building accomplishment. Their research was shared at multiple scientific conferences and collectively, allowed them win four awards for either best poster or oral presentations at these conferences. This is a testimony of the high quality of these students and the research and training they received.

II. Project Problem Statement and Justification

With approximately 11 million habitants, Guatemala is mostly a rural country, with 60% of the population living in farms and 50% of the population being indigenous. Maize and beans are the main staple food in most households with a per capita bean consumption of 9.4 kg per year. Since few other sources of protein are available, this amount is not enough to ensure an acceptable nutritional quality, especially within poor households. As expected, the lack of protein intake has reduced the nutritional quality in many households, significantly affecting children. Chronic malnutrition is frequent among children under 5 years old in the western highlands, with 67% of children affected, making Guatemala the country with the highest malnutrition level in the western hemisphere. One out of every three children from ages six to 59 months in the western highlands shows some degree of anemia. Approximately 18% of reproductive-age women exhibit anemia, with 29% prevalence among pregnant women and 23% prevalence among breastfeeding women.

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. 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 may 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.

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, agronomically, and with few

molecular markers (6 SSR primers). Initial results suggest that ½ of the collection consist of duplicates. In addition, some initial crosses among climbing beans and selections have been made by the ICTA group. These lines will be used intensively in this project.

III. Technical Research Progress

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

Collaborators:
NDSU: Juan M. Osorno and Phil McClean.
ICTA: Julio Cesar Villatoro, Angela Miranda, Jessica Moscoso, Karen Agreda, Edgardo Carrillo.

1.1: Validation plots and release of at least 1 climbing bean cultivar (ICTA): After 3 years of farmer's field testing (see previous annual reports), two varieties have been officially released during FY2017. ***ICTA Utatlan,*** a climbing bean adapted to the high altitude of Guatemala's western highlands (1,500 to 3,000 meters above sea level) and the milpa cropping system practiced in these mountainous regions, matures a month earlier than other climbing bean varieties and produces greater yields than the local landrace bean usually planted in the highlands. This early maturing and additional 200 kg/ha (ha=2.47 acres) sets ICTA Utatlan apart for resource-poor smallholder farmers, who often suffer during the seasonal hunger period between June and September, when the previous season's food stores are depleted and the new crop is not yet ready for harvesting. ***ICTA Labor Ovalle,*** a small, black Bolonillo seed type with a shiny appearance that is also adapted to growing in the elevated mountain regions of western Guatemala and produces an average yield 172 kg/ha greater than the local landrace bean, has also been received enthusiastically by highland farmers. As a Bolonillo seed type, ICTA Labor Ovalle is considered a preferred market class that is highly valued in the marketplace. Additionally, both farmers and buyers have praised its excellent taste, shorter cooking time, and wonderful broth color—all characteristics valued by buyers, making it an excellent cash crop for smallholder farmers who want to increase their household income. Bolonillo beans sell for about $1.50/lb., making it a profitable bean. Officially released in March 2017 at the ICTA (Instituto de Ciencia y Technologia Agricolas) Centro Regional de investigacion del Altiplano Occidental, just outside Quetzaltenango, Guatemala, at the Liberacion Oficial de Variedades de Semillas de Frijol event, both of these bean varieties were initially developed by Dr. Fernando Aldana, a bean breeder at ICTA Quetzaltenango (now retired).

The last breeding stages, seed purification and production, and release were made with support from the Feed the Future Innovation Lab for Collaborative Research on Grain Legumes project, *Genetic Improvement of Middle-American Climbing Beans for Guatemala*, in cooperation with ICTA and the Feed the Future Buena Milpa and MASFRIJOL projects. Event participants received 1.5 kg. of each bean seed at the event for planting. Buena Milpa distributed approximately 7,000 pounds of each seed during the 2017 planting season, and ICTA is producing more seed of these varieties for distribution to farmers in the 2018 season. The Feed the Future MASFRIJOL project also

received 200 pounds of each variety for distribution.
A third line named ICTA-Texel is the last stages of seed purification before it can be released. Phenotypic variation for pod color and seed shape was found in the seedstock and therefore, efforts are currently underway to ensure homozygosity within this variety. This line offers a great combination of high seed yield but reduced climbing aggressiveness, which is a negative trait present in many high yielding climbing bean genotypes.

1.2: Breeding pipeline (ICTA/NDSU): The breeding pipeline continues to move genetic material through different stages. During FY2017, 23 new crosses were made. A total of 57 advanced lines obtained from individual plant selections and purifications made during the last 2 years (objective 1.3) were evaluated in replicated field trials at the ICTA stations in Chimaltenango and Quetzaltenango. This number includes individual plant selections made within heterogeneous lines (based on overall disease resistance/tolerance, pod load, color, and seed type). An average of 3 individual plants were selected within lines of interest. This material was planted again during FY2017 at ICTA-Quetzaltenango for field evaluation under trellis conditions (Monoculture instead of intercropping to facilitate visual selection). Phenotypic selection will be practiced again. Selected advanced lines will be given to ICTA to continue field testing in subsequent years beyond FY2017 if additional funding is available after this 4-year cycle.

1.3: Genetic purification of selected advanced lines (ICTA/NDSU): A final effort to purify the advanced lines will be made if genetic heterogeneity is visually detected. During the 2016 growing season, ?? plants with apparent superior performance (e.g. disease resistance, seed yield, pod distribution, seed quality, climbing aggressiveness, earliness, etc.) were tagged and individually harvested as a single plant selections. The seed from each individual plant selected was grown in the off-season nursery at San Jeronimo in FY2017 for: i) seed increase, and ii) further evaluations. A total of ?? individual plants were selected and planted during the 2017 growing season at ICTA-Quetzaltenango and are currently being selected based on agronomic traits at the time of this report.

1.4: Third crossing block (ICTA/NDSU): Another set of crosses was made during the 2017 growing season at the ICTA-Chimaltenango station in order to keep feeding the breeding pipeline (Objective 1.2). At least 40 new parental combinations were attempted in order to create new segregant populations that can be used for selection in later generations. All this material contributes to the breeding pipeline (objective 1.2) that will help to establish a long-term breeding program that will continue developing improved climbing beans adapted to the region in the future. It is important to note that besides the breeding efforts made by CIAT on climbing beans, this is the second breeding program focused on climbing beans in the western hemisphere.

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

Collaborators:
NDSU: Juan M. Osorno and Phil McClean.
ICTA: Julio Cesar Villatoro and Angela Miranda.

2.1 Evaluation of core collection with the 6k SNP chip (NDSU): After some discussion within the research group and some cost analysis, it was decided to genotype the ICTA climbing bean collection using a newer GBS approach that allows for far more markers than the 6k chip. By using a two-restriction enzyme procedure (*Mse*I and *Taq*α1), a total of 102,000 SNP markers were obtained. After SNP calling and filtering, 45,128 SNPs remained for the genetic diversity study. Besides 369 accessions from the ICTA climbing bean collection, the following plant material was also analyzed in order to be able to make comparisons among the different genetic groups:

- 260 Guatemalan accessions from the new collection obtained from the grower's survey.
- Mesoamerican Diversity Panel (MDP):
    - 100 accessions of race Mesoamerica.
    - 100 accessions of race Durango-Jalisco.
- Andean Diversity Panel (ADP):
    - 135 accessions mostly of race Nueva Granada.
- 12 wild accessions from Guatemala (USDA-GRIN).

2.2 SNP Evaluation of the new Guatemalan collection (NDSU): A total of 452 samples of beans were donated by local farmers as part of the grower's survey made during FY2015 (Objective 3). This came in the form of donations from 1-2 seeds to several dozen seeds. These are seeds represent the beans that are currently being grown throughout the highlands of Guatemala, the target region of the project. This is a major new resource that needs full characterization both phenotypically and genotypically. In addition, an additional 48 samples were provided by an additional ICTA collection made during 2014. Of the 500 samples, 420 contained only a single seedtype (black, red, white). Sequence-based SNP data from this new collection will be compared with the SNP data from the original collection housed at ICTA. A major advantage of this newer collection is that passport data (GPS coordinates, location, altitude, etc.) is available while this was lost for the original collection as mentioned in previous documents. We will attempt to do a geographical correlation between both collections using the gentotypic data obtained from both groups.

Similarly to the ICTA old collection explained above, a subset of 260 accessions of this new collection were also screened with the 45,128 SNPs previously mentioned. The main goal was to characterize the genetic diversity contained in this new collection and compare it with the old one. Results showed that Guatemalan climbing beans are a unique genetic group that can be genetically differentiated from other races/subgroups

within the Middle American gene pool and even among gene pools (Figures 1, 2 and 3). In addition, estimates of intra-race genetic diversity are similar to other races from the Middle American gene pool (Table 1). Data was also used to do Genome-Wide Association studies (GWAS) and showed significant genomic regions associated with traits such as seed shape, adaptation (altitude), and disease resistance, among others. All these results allowed obtaining the following conclusions:

- Guatemalan climbing beans did not group with any of the previously defined races of common bean.
- Race Guatemala represents a new source of genetic diversity.
- Genomic regions were associated with several traits of economic importance.
- Genomic regions were associated with local adaptation in the Guatemalan climbing beans.

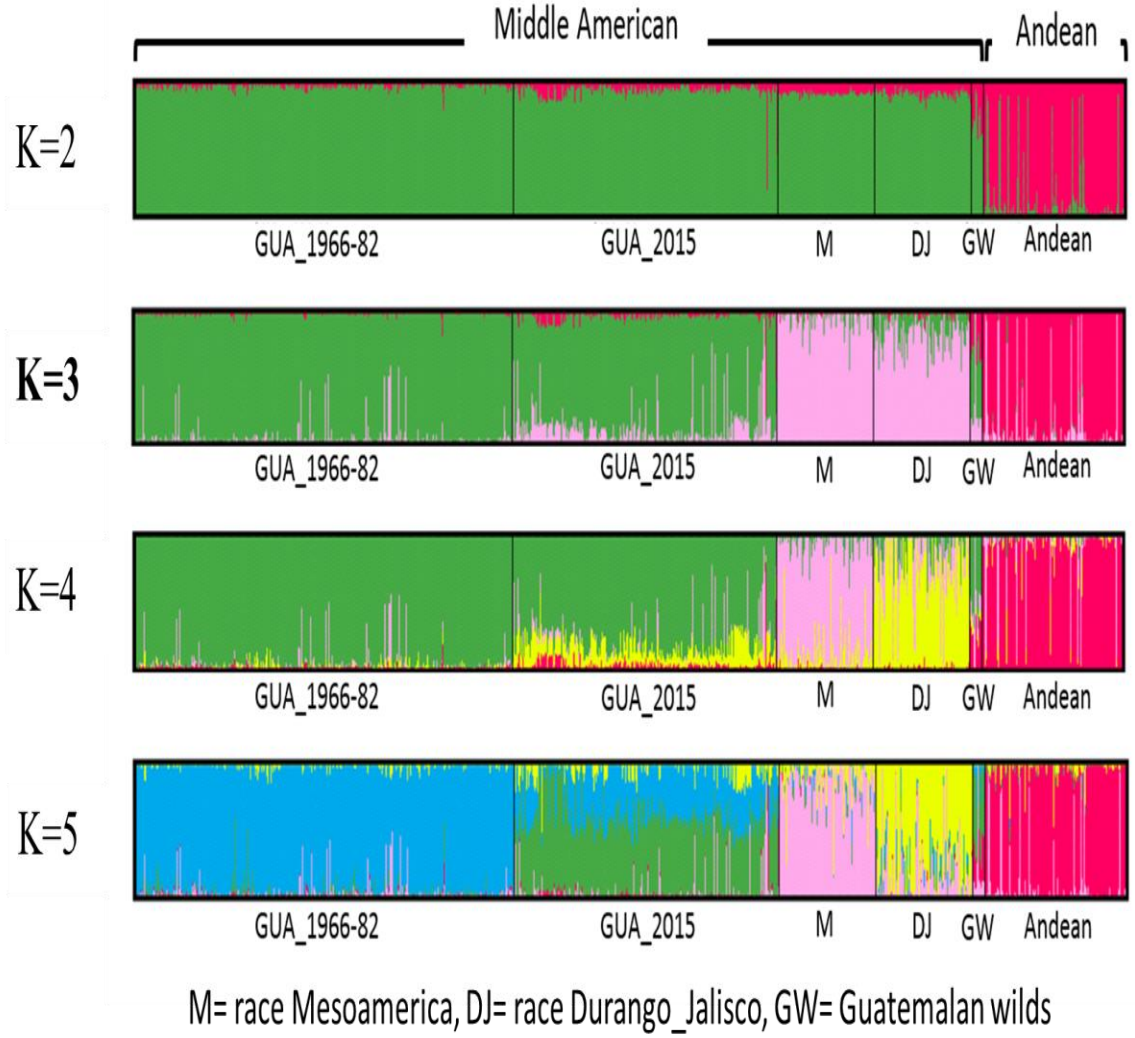

Figure 1. Population structure of different populations of beans. GUA_1966-82 represents the old collection and GUA_2015 represents the new collection. K=3 was the structure with the highest level of significance.

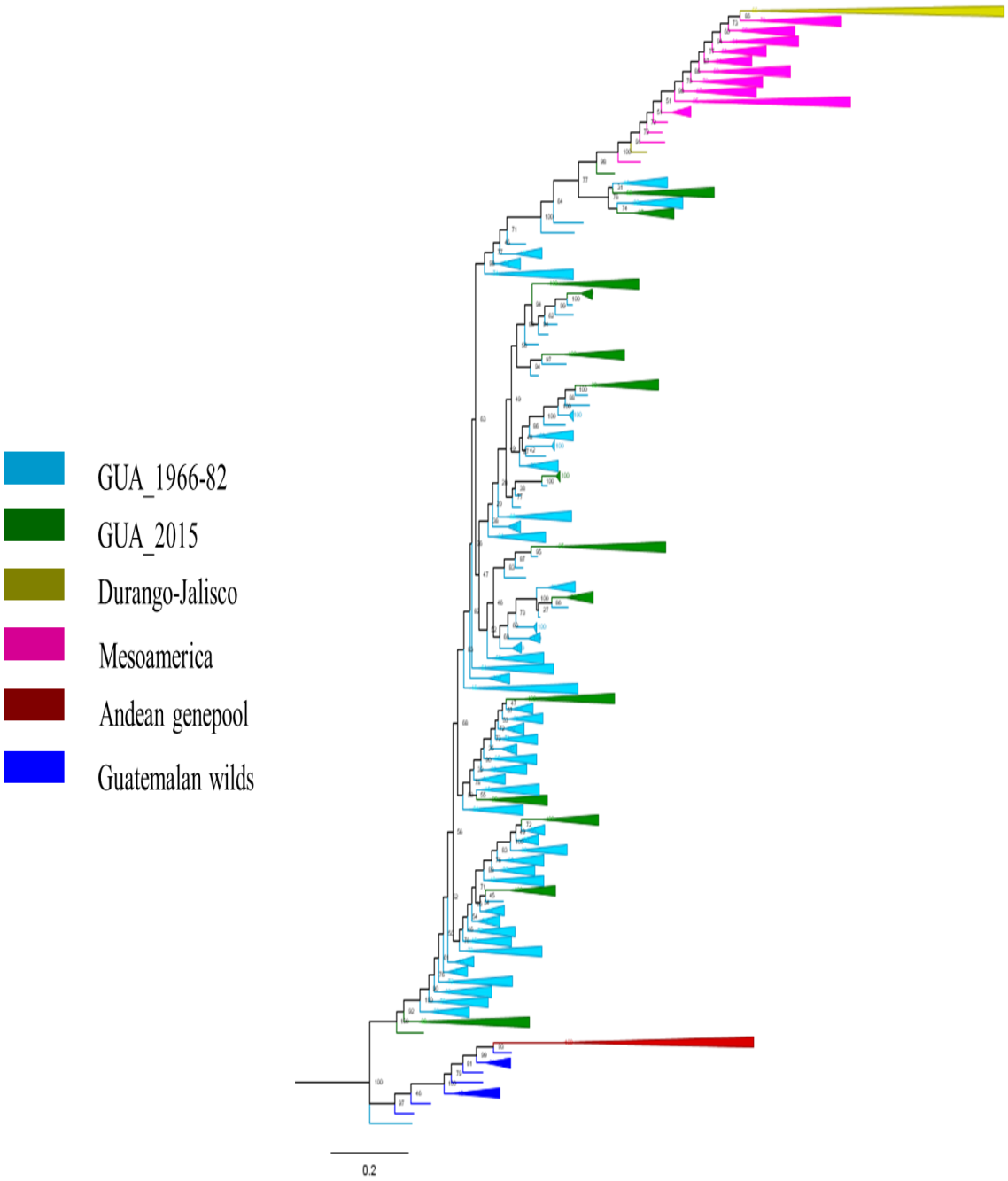

Figure 2. Condensed phylogenetic tree showing the groups of genetic diversity based on SNP similarity.

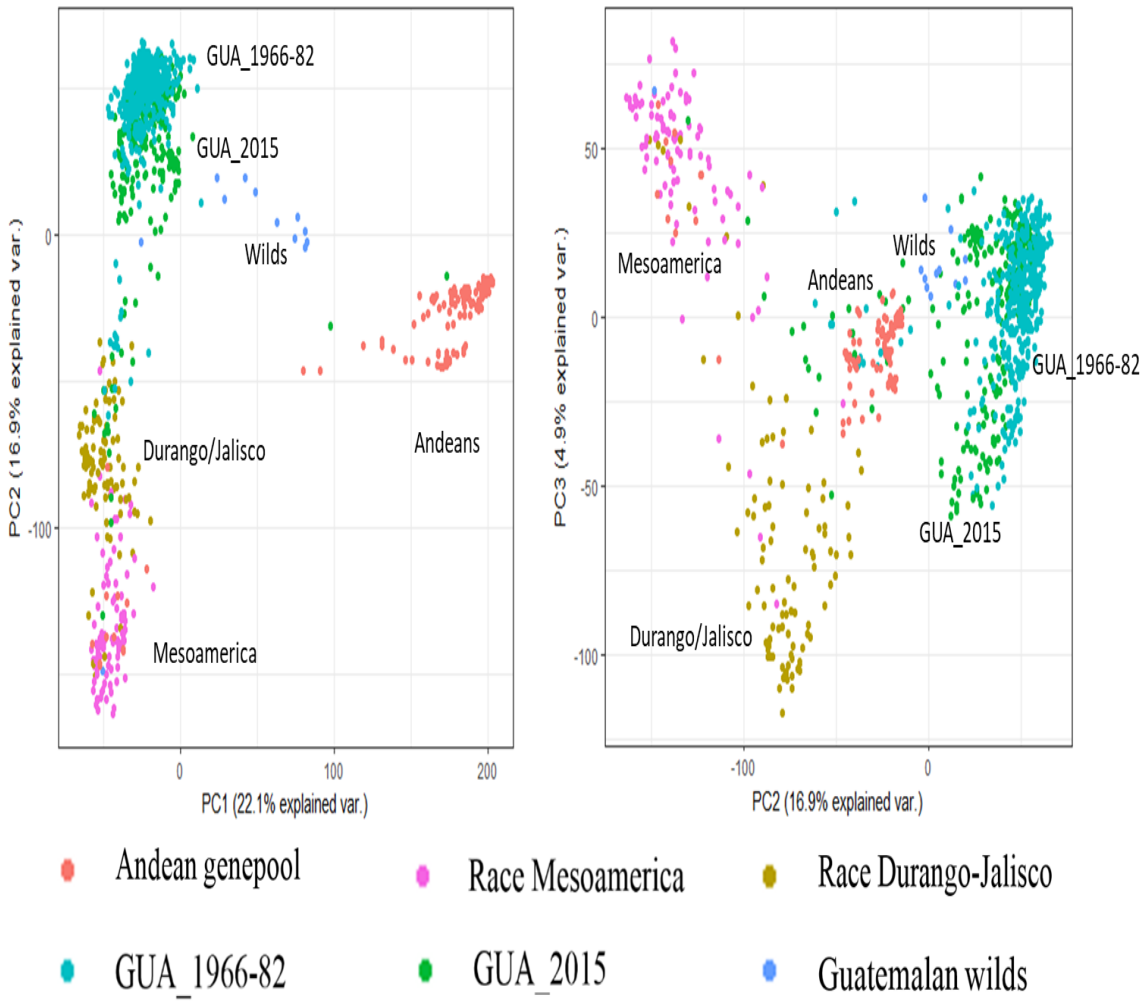

Figure 3. Principal component analyses showing groups of genetic diversity. GUA_1966-82 represents the old collection and GUA_2015 represents the new collection

Table 1. Genetic diversity statistic parameters for different bean sub-populations. GUA_1966-82 represents the old collection and GUA_2015 represents the new collection MA=Middle American; H_e=Expected heterozygosity; H_o=Observed heterozygosity; PIC=polymorphic information content; ΔH=Diversity loss.

Subpopulation	Genotypes (n)	% Polymorphic SNPs	H_e	H_o	PIC values	ΔH
MA genepool	819	100.00	0.38	0.34	0.30	-
GUA-1966-82	369	99.28	0.31	0.32	0.25	0.11
GUA-2015	260	99.83	0.36	0.35	0.28	-0.03
Mesoamerica	95	97.27	0.34	0.35	0.26	-
Durango-Jalisco	95	96.87	0.35	0.36	0.27	-
Guatemalan wild	12	94.83	0.35	0.31	0.28	-
Andean genepool	138	99.93	0.24	0.17	0.20	-
Entire population	971	100.00	0.41	0.31	0.32	-

2.3 Field evaluation of the newer ICTA collection of climbing beans (ICTA/NDSU): A final evaluation of selected accessions from the new germplasm collection obtained from the grower survey (see objective 3.2) was done at the ICTA station in Chimaltenango during the growing season of 2017 to allow a re-evaluation of the material and also the production of a newer batch of seed of genotypes with traits of interest based on the initial evaluation during the 2016 growing season. Approximately 200 accessions were selected in 2016 and planted in 2017. Within this group, 24 of these accessions are *P. coccinueus*, 152 *P. dumosus*, and 24 *P.vulgaris* and they are currently being harvested at the time of this report.

Each accession was planted in short rows (~2 m) in a trellis system mostly for phenotypic observation. The following traits were recorded: disease reaction under natural conditions (Ascochyta, Rust, Anthracnose), earliness, biomass/climbing aggressiveness, seed yield potential, and pod distribution (upper vs. homogeneous distribution). Selected germplasm will be used in future crosses.

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

Collaborators:
NDSU: Juan M. Osorno.
ICTA: Julio Cesar Villatoro, Jessica Moscoso, Angela Miranda.
MSU: Mywish Maredia and David DeYoung.

Approaches and Methods:

3.1 Final statistical analyses of survey data and publication of results (ICTA/MSU/NDSU): Final statistical analyses and publication of results were the remaining activities of this objective. The survey activity was very successful thanks to a great collaboration established with the project lead by Mywish Maredia (SO4.1). They have far more experience with surveys than any person in our team, so we appreciate their willingness to help. In the same way Gustavo Mejia, a social economist at ICTA-Quetzaltenango was of key importance in coordinating this activity. Results of this survey are available in a separate staff paper/report titled "An Overview of Bean Production Practices, Varietal Preferences, and Consumption Patterns in the *Milpa* System of the Guatemalan Highlands: Results of a Farm Household Survey". Staff Paper No. 2017-08, Department of Agricultural, Food and Resource Economics Michigan State University. This report is available under request.

The study of climbing bean farmers in the five departments (Quiche, Huehuetenango, San Marcos, Chimaltenango and Quetzaltenango) of the *Altiplano* region of Guatemala confirms the importance of beans as a crop for own consumption in the study area. On average, households planted 0.4 hectares to beans in the study region. Beans, planted as part of the traditional intercropped system called *milpa,* are most commonly planted simultaneously (or directly) with corn in the plots of farmers interviewed while relay (*milpa relay)* was a second common planting method in the study area. In terms of area planted, most farmers ranked beans as the first or second most important crop. A majority of farmers do not sell harvested grain. Indeed for many farmers own bean production is not sufficient to cover annual household bean consumption, and they rely on purchased beans to fill this deficit. Bean consumption among households in this region is highest after harvest (often between October and January in the region) and lowest in July, August and September. The study confirms that men and women farmers have slightly different preferences for bean seed varietal traits and women are willing to pay more for bean seed of varieties with their preferred traits than men. On average, farmers indicated they are willing to pay only a 10% premium for bean seed of preferred variety over the

price of grain. Thus any efforts to increase the use of new improved varieties of beans to promote productivity growth in this region will need to be based on subsidized seed dissemination efforts to make the seeds affordable by smallholder farmers in this region of Guatemala. A staff paper (2017-08) from Michigan State University reports in more detail the findings of this activity.

3.2 Conditioning and storage of seed samples collected during the survey (ICTA): During the deployment of the survey during FY2015, growers were asked to provide a small seed sample of the variety or varieties they commonly grow in their farms. After seed increases made during the 2016 and 2017 growing seasons, seed will be conditioned and stored at the cold seed room available at the ICTA-Chimaltenango station. A total of 490 new accessions will be stored and made available to the bean scientific community.

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

4.1. Graduate Students (NDSU): Out of the three students under this project, one has completed her M.S. degree and two more will be completed in late November 2017.

4.2. Long-term breeding plan (ICTA/NDSU): A document describing a long term plan to continue breeding activities for climbing beans was developed by the ICTA bean team in collaboration with NDSU. This document will help to be a future roadmap regardless of the availability of funds in the future. If future funding opportunities arise, this document will facilitate the writing of a new project that will keep the momentum gained during this 4 year cycle.

4.3. Plant Breeding workshop (ICTA/NDSU): Because of schedule conflicts with other meetings and activities, this workshop was canceled. We hope to make another attempt in the future if funds become available.

IV. Major Achievements

Objective 1:

- Release of two new varieties: ICTA-Labor Ovalle and ICTA-Utatlan. The most impactful accomplishment of this project for the future productivity and food security in the western highlands.
- Creation and maintenance of a breeding pipeline for climbing beans: Only two breeding programs focused on climbing beans exist in the western hemisphere (CIAT and ICTA). However, the CIAT program focuses on Andean climbing beans while the one at ICTA is focused on Middle American climbing beans.
- Newer elite lines that may be released in the near future: ICTA-Texel is another climbing bean with high yield and reduced climbing aggressiveness that could be released in the near future.

Objective 2:

- Genetic characterization of two germplasm collections of climbing beans using 42k SN P markers: Results confirmed the presence of a new distinct race within the Middle American gene pool known as race Guatemala. Results also allowed the identification of important genomic regions associated with traits of agronomic/economic importance for future breeding purposes.

Objective 3:

- Results from the grower survey will allow a better understanding of the current situation of bean production and consumption in the western highlands of Guatemala. This information will be critical for planning new strategies for food security in the region.

Objective 4:

- Three individuals from ICTA obtained their M.S. degrees and are returning to their home countries to apply all the skills and training received. This is a great contribution to capacity building within ICTA Guatemala.
- The long-term breeding plan is a master document that will help in the planning of future projects for breeding climbing beans in the region.

V. Research Capacity Strengthening

A capacity strengthening grant was obtained to help ICTA to implement a drip irrigation system at the Chimaltenango station. This system was used for the first time during the 2017 growing season and this field has been permanently assigned to bean research. However, some crop rotation will be needed in order to avoid the increase in fungal and insect populations causing root diseases/problems that may affect bean agronomic performance or hinders selection at this site. In addition, the seed cold storage conditions were improved thanks to a new air conditioning unit and a new dehumidifier. This equipment will ensure that hi quality research will continue at ICTA for many years and germplasm obtained through this funding cycle will be conserved in the best possible conditions.

VI. Human Resource and Institution Capacity Strengthening

1. **Short-Term Training**
   i. Nothing to report.

2. **Degree Training in the US or elsewhere**
   i. Name of trainee: Luz de Maria Montejo
   ii. Country of Citizenship: Guatemala
   iii. Gender: Female
   iv. Host Country Institution Benefitting from Training: ICTA-Guatemala
   v. Institution providing training: NDSU
   vi. Supervising LIL PI: Juan M. Osorno and Phil McClean
   vii. Degree Program: M.S. Plant Sciences
   viii. Field or Discipline: Plant breeding/pathology

Research Project Title: Rust resistance in Guatemalan climbing bean germplasm collection.
Projected/Actual Completion Date: September 2017

ix. Is trainee a USAID Participant Trainee and registered on TraiNet? Yes
x. Training status (Active, Completed, Pending, Discontinued, or Delayed): Completed

xi. Name of trainee: Maria Gabriela Tobar-Piñon
xii. Country of Citizenship: Guatemala
xiii. Gender: Female
xiv. Host Country Institution Benefitting from Training: ICTA-Guatemala
xv. Institution providing training: NDSU
xvi. Supervising LIL PI: Phil McClean and Juan M. Osorno
xvii. Degree Program: M.S. Plant Sciences
xviii. Field or Discipline: Plant breeding/genomics

Research Project Title: Molecular characterization of germplasm collection of Guatemalan climbing beans
Projected/Actual Completion Date: November 2017

xix. Is trainee a USAID Participant Trainee and registered on TraiNet? Yes
xx. Training status (Active, Completed, Pending, Discontinued, or Delayed): Active

xxi. Name of trainee: Carlos Maldonado-Mota
xxii. Country of Citizenship: Guatemala
xxiii. Gender: Male
xxiv. Host Country Institution Benefitting from Training: ICTA-Guatemala
xxv. Institution providing training: NDSU
xxvi. Supervising LIL PI: Juan M. Osorno and Phil McClean
xxvii. Degree Program: M.S. Plant Sciences
xxviii. Field or Discipline: Plant breeding/pathology

Research Project Title: Anthracnose resistance in Guatemalan climbing bean germplasm collection.
Projected/Actual Completion Date: November 2017

xxix. Is trainee a USAID Participant Trainee and registered on TraiNet? Yes
xxx. Training status (Active, Completed, Pending, Discontinued, or Delayed): Active

VII. Achievement of Gender Equity Goals

The ICTA bean breeding program includes at least three women in their team (Angela Miranda, Jessica Moscoso, and Karen Agreda), some of them in leading positions (Angela is the new program leader now that Julio Villatoro has been named ICTA subdirector). They are in charge of all the activities at San Jeronimo and Quetzaltenango. In addition, 2 women who are ICTA employees (Gabriela Tobar and Luz Montejo) just completed their graduate degrees (M.S. in Plant Sciences) at NDSU.

VIII. Implementation of Data Management Plan

A revised data management plan was submitted to the Legume Innovation Laboratory Management Office. Scientists interested in using a data set generated with support from the Legume Innovation Lab should contact the PI or Co-PI responsible for generating the data set to confirm how and for what purpose the data was collected. The PI or Co-PI responsible for maintaining the data set will deposit the information in the USAID Development Data Library (DDL).

IX. Scholarly Accomplishments

Agreda, K.A., Osorno, J.M., McClean, P.E., Villatoro, J.C., Miranda, A.N., Moscoso, J.R. 2017. Phenotypic Evaluation of Native Accessions of Climbing Beans Collected in the Guatemala Highlands. Oral session presented at: Programa Cooperativo Centroamericano Para el Mejoramiento de Cultivos y Animales PCCMCA. San Salvador, El Salvador. May. 15th to 19th. [In Spanish]

Agreda, K.A., Osorno, J.M., McClean, P.E., Villatoro, J.C., Miranda, A.N., Moscoso, J.R. 2017. Phenotypic Evaluation of Native Accessions of Climbing Beans Collected in the Guatemala Highlands. Poster session presented at: Grain Legume Research Conference. Ouagadougou, Burkina Faso. Ag. 13th to 18th.

DeYoung, D., Reyes B., Mejia G., Tucux M., Vasquez M., Santos J.J., Villatoro J.C., Montejo L.M., Moscoso J.R., Osorno J.M., and Maredia M. 2017. Gender Differences in Varietal Preferences and Willingness to Pay for Quality Bean Seeds: Evidence from the Guatemalan Highlands. Poster Session presented at: Feed the Future Innovation Lab for Collaborative Reserch on Grain Legumes. Ougadougou, Burkina Faso. August 13-18th.

Maldonado-Mota C.R., Pastor-Corrales M.A., Hurtado-Gonzales O.P., Moghaddam S.M., Schroder S., McClean P.E., Pasche J., Lamppa R., Tobar-Piñon M.G., Villatoro-Merida J.C., Miranda A.N, Moscoso J.R., Agreda K., and Osorno J.M. 2017. Identification of new sources of resistance to anthracnose in climbing bean germplasm from Guatemala. Poster Session presented at: Feed the Future Innovation Lab for Collaborative Reserch on Grain Legumes. Ougadougou, Burkina Faso. August 13-18th.

Maldonado-Mota C.R., Pastor-Corrales M.A., Hurtado-Gonzales O.P., Moghaddam S.M., Schroder S., McClean P.E., Pasche J., Lamppa R., Tobar-Piñon M.G., Villatoro-Merida J.C., Miranda A.N, Moscoso J.R., Agreda K., and Osorno J.M. 2017. Virulence diversity of Colletotrichum lindemuthianum in Guatemala and GWAS to identify genomic regions associated with anthracnose resistance in common bean. Oral session presented at: The Biennial Bean Improvement Cooperative Conference, East Lansing, Michigan, United States. Oct. 29th to Nov.1st

Maldonado-Mota C.R., Pastor-Corrales M.A., Hurtado-Gonzales O.P., Moghaddam S.M., Schroder S., McClean P.E., Pasche J., Lamppa R., Tobar-Piñon M.G., Villatoro-Merida J.C., Miranda A.N, Moscoso J.R., Agreda K., and Osorno J.M. 2017. Identification of new sources of resistance to anthracnose in climbing bean germplasm

from Guatemala. 2017. Oral session presented at: Plant Sciences Symposium, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, March 31st to April 1.

McClean, P.E. 2017. Targeted Improvement of the Mayan Milpa Cropping System in Guatemala. Invited speaker at CROPS conference at HudsonAlpha Institute of Biotechnology, Huntsville, AL.

Montejo L.M., Steadman J., Villatoro J.C., Moscoso J., Agreda K., Osorno J.M. 2016. Rust Resistance in the Guatemalan Climbing Bean Germplasm Collection, Preliminary results. Poster session presented at: ASA-CSSA & SSSA Annual meeting. Phoenix, Arizona, U.S. Nov. 6 th to 9 th

Montejo L.M., Steadman J., Villatoro J.C., Moscoso J., Agreda K., McClean P., Osorno J.M. 2017. Rust Resistance in the Guatemalan Climbing Bean Germplasm Collection. Oral session presented at: Plant Science Graduate Students Symposium. University of Saskatchewan, Saskatoon, Canada. March 31st to April 1st.

Montejo L.M., Steadman J., Villatoro J.C., Moscoso J., Agreda K., McClean P., Osorno J.M. 2017. Rust Resistance in the Guatemalan Climbing Bean Germplasm Collection, Final Results. Oral session presented at: Grain Legume Research Conference. Ouagadougou, Burkina Faso. Ag. 13th to 18th.

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Tobar- Piñón M.G., Mogghadam S.M., Lee R.K., Villatoro J.C., Osorno J.M., McClean P.E. 2017. Genetic Diversity of the Guatemalan Climbing Bean Collections. Bean Improvement Cooperative Conference. East Lansing MI, USA. Oct. 29th to Oct. 31st.

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Montejo-Domínguez, L. de M. 2017. Rust resistance in the Guatemalan climbing bean collection. M.S. Thesis. North Dakota State Univ. 76 p.

Maldonado-Mota, C. 2017. Identification of new sources of resistance to Anthracnose in climbing bean germplasm from Guatemala. M.S. Thesis. North Dakota State Univ. 70 p.

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X. Achievement of Impact Pathway Action Plan

Our project has been able to accomplish all the items and activities proposed in our impact pathways. The only exception was the plant breeding workshop which could not be done because of several schedule conflicts with other meetings and activities.