Feed the Future Innovation Lab for Collaborative Research on Grain Legumes
LEGUME INNOVATION LAB

2016 ANNUAL TECHNICAL PROGRESS REPORT
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Project Code and Title: S01.A3 Improving Genetic Yield Potential of Andean Beans with Increased Resistances to Drought and Major Foliar Diseases and Enhanced Biological Nitrogen Fixation (BNF)

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I. Abstract of Research and Capacity Strengthening Achievements

Common bean (*Phaseolus vulgaris*) is the most important grain legume consumed in Uganda and Zambia. The project has successfully identified local lines that are quicker cooking and these are being tested in on-farm trials with local producers in Uganda. Breeding programs in both countries continue to identify sources of disease resistance to many of the more serious pathogens that attack beans and are using these lines as parental material to further improve local varieties. Changes in climate are leading to less predictable rainfall patterns and the project has identified Andean breeding lines that perform better than local varieties under these conditions. Novel methodologies are being developed to screen more efficiently for cooking time and modern molecular tools have been deployed to map genomic regions that control anthracnose resistance. Genomic mapping with SNP markers and RNA sequencing has been used to pinpoint genomic regions that control anthracnose resistance, and enhanced symbiotic nitrogen fixation and candidate genes underlying these basis functions have been identified. The potential to enhance N-fixation in beans grown under low fertility conditions typical of subsistence farmers is now within the reach of local breeders. Training of future bean researchers continues to be a major objective by providing the environment to develop both scientific and leadership skills.

II. Project Problem Statement and Justification

Beans are the second most important food legume crop after ground nuts in Zambia and are a major source of income and cheap protein for many Zambians. Most of the bean crop (62%) is produced on 60,000 ha in the higher altitudes, cooler and high rainfall zones of the northern part of Zambia. Andean beans are predominant and land races are the most widely grown although a few improved cultivars are also grown as sole crops or in association mainly with maize. Bean production is constrained by several abiotic and biotic stresses that include diseases, pests, low soil fertility and drought. All the popular local landraces in Zambia are highly susceptible to pests and diseases that severely limit their productivity. This is reflected in the very low national yields ranging from 300 to 500 kg/ha that result in annual deficit

of 5,000MT. To avert future food shortages and feed the growing population of 13M, there is critical need for increasing the productivity of most food crops including beans as Zambia ranks 164 out of 184 countries in the Human Poverty Index. Beans are an important crop in Uganda and are grown on over 660,000 ha of land and consumed throughout the country. Beans are a major source of food and income for the rural smallholder farmers especially the women and children. The majority of bean production in Uganda is dependent mainly on the use of inferior landrace varieties which are generally low yielding due to susceptibility to the major biotic and abiotic (drought, low soil fertility) stresses. These stresses gravely undermine the potential of the bean as a food security crop, a source of income, and as a main source of dietary protein for the majority of Ugandans. Drought affects 60% of global bean production and the severity of yield reduction depends on the timing, extent, and duration of the drought stress. The development of improved varieties and germplasm with high yield potential, healthy root systems, improved SNF with resistance to multiple diseases, and sustained or improved water use efficiency under limited soil water conditions are needed to increase profit margins, lower production costs. The project will use QTL analysis and SNP-based genome-wide association mapping to uncover regions associated with drought tolerance, disease resistance, enhanced BNF and faster cooking time.

III. Technical Research Progress

Objective 1: Integrate traditional and marker-assisted selection (MAS) approaches to combine resistances to economically important foliar diseases, drought and improved symbiotic nitrogen fixation (SNF) and assess acceptability of fast cooking, high mineral content in a range of large-seeded, high-yielding red mottled, white and yellow Andean bean germplasm for the Eastern Africa highlands (Zambia and Uganda), and the U.S.

1.1. Evaluation of integrated nursery in Uganda

During 2016, the program in Uganda continued to assemble and utilize different nurseries which included the following;

- A set of 50 lines (50 seeds each) for common bacterial blight (CBB) acquired from the University of Nebraska
- A drought nursery comprising of 60 entries (500 seeds each) from the University of Nebraska.
- A set of 10 lines for Rust acquired from Uyole, Tanzania
- A drought Nursery comprising of 96 Andean (DAB)-lines from CIAT

These nurseries have been evaluated this year and those showing resistant potential have already been utilized in breeding program for introgression of specific resistances into the Ugandan farmer preferred and yet susceptible germplasm. The specifics of the some of the acquired germplasm have been appended at Annex 2.

1.2. Evaluation of Integrated Nursery in Zambia

In Zambia a traditional or conventional approach to combine resistances for ALS and CBB into preferred seed types was undertaken at Misamfu. The resulting lines were evaluated in other sites within the country where bean production is important. After a number of selection cycles, 50 lines were selected based on their performance over time and were planted at 3 sites within the country. Out of the 50 lines planted; 28 lines were selected at Misamfu, 23 in Kabwe and 21 at Msekera and eleven were common at all three sites. These same lines have been earmarked for on-farm testing. Most of the lines selected were medium to large seeded sizes as these are the preferred types among the small-holder farmers of Zambia. Average disease score of 2.0 and 2.5 for ALS and CBB respectively indicated that the lines were also resistance to these important diseases.

1.3.*Identification of resistance sources in Uganda*:
A disease nursery was screened against different pathogens, rust, ANT, and ALS in a screenhouse and under field conditions in Uganda. Using either field condition for prevailing diseases and/or screenhouse conditions with inoculum from different pathogens, a number of nurseries and/or germplasm sets were screened using different pathotypes for different pathogens. From these we were able to establish the reaction of different germplasm to the different pathogens and also identify some resistant genotypes which are currently being using to introgress resistances to susceptible but preferred market class varieties for Uganda. Data from some of the different nurseries that have been screened to date has been either reported in drafted journal papers, poster papers and/or student dissertations.

A germplasm collection of 138 lines comprising of 30 landraces, 20 released varieties in Uganda and 93 introduced lines including the 12 rust differentials were screened for rust in both in the screenhouse and field conditions. A second germplasm collection 64 lines inclusive of both ANT and ALS differentials was set out for field screening in the 2016A season. Unfortunately, we had a very severe drought so we lost most the germplasm and no data was taken for diseases incidences. A third germplasm collection of 132 common bean accessions were screened in both screenhouse and field for reaction to CBB. In screenhouse, genotypes were inoculated with a local isolate "Kawempe 1" in screenhouse while natural infestation was used in field. We noted variation of the different genotypes to Kawempe 1 and identified also resistant genotypes that have been utilized in crosses to introgress resistance to Uganda susceptible market class varieties. Another assembled germplasm collection of 80 lines from CIAT and local germplasm was screened for resistance to BCMV using a mixture of inoculum obtained from diseased leaved obtained from Hioma, Kawanda and Namulonge. Presence or absence of either BCMV or BCMNV in all inoculated and screened lines was detected using the Double Antibody Sandwich (DAS) ELISA. Lines selected for resistance to rust include: Mexico 309, CNC, P1181996, Mexico 235, Redlands Pioneer, Ouro Negro and Aurora; Selected resistant lines that are resistant to CBB include; NE2-14-8, NE17-14-29, NE14-09-78 and VAX3; Selected resistant lines that are resistant to BCMV include; SCR 48, SCN 9 and SCN 6.

1.4.*Cross sources of resistance for ANT, ALS, CBB rust and drought tolerance into large seeded lines with contrasting colors in Uganda*: The project has continued to introgress different resistance genes into the backgrounds of some of the most preferred Andean bean varieties in Uganda. For all the resistant genotypes that have been identified for the various pathogens, crosses have been initiated with Uganda market class and consumer preferred varieties to introgress resistant genes for respective traits. We have also started generating population for the new crosses these include, populations for rust, CBB resistance and BCMV resistance. Some genetic studies for resistance to the different stresses in relation to the Andean Ugandan market class genotypes have been undertaken. Below are some of the different crosses that have been initiated and /or on-going. Genotypes Mexico 309, CNC, P1181996, Mexico 235, Redland pioneer, Ouro Negro and Aurora identified for resistance to rust have been crossed with Uganda market class bean lines including NABE 15, NABE 16, NABE 19 and NABE 21 to try and introgress rust resistance into their background. The progenies are under evaluation. Four CBB resistant genotypes i.e. NE2-14-8, NE17-14-29, NE14-09-78 and VAX3 have already been utilized in crosses with four Ugandan Andean susceptible market class varieties, NABE 15, NABE 16, NABE 17 and NABE 19 to try and introgress CBB resistance. Genetic studies have also been undertaken to determine the mode and nature of inheritance for this resistance. Three identified BCMV resistant genotypes namely SCR 48, SCN 9 and SCN 6 were crossed with four Ugandan Andean susceptible market class varieties, K132, NABE 15 NABE 17, NABE 18 to introgress BCMV resistance also in this case, genetic studies have also been undertaken to determine the mode and nature of inheritance for BCMV resistance in these genotypes. To introgress drought tolerance into farmer and market bean cultivars, use was made of already known drought tolerant

sources. Evaluations and selections are being made from the advancing of the progenies arising from 15 crosses that were have been made between Ugandan market class varieties K132, NABE 4 and NABE 15 with introduced drought tolerant germplasm that included: SEN 98, SEN 99, SCR 48, SCN 6 and SCN 9. To date, nine promising lines from nine different crosses have been selected and are currently undergoing preliminary yield trials (PYT) on-station at NaCRRI. Additional Crosses are planned using genotypes that have been identified from the ADP panel. A few selected climbers in each country will be crossed to sources for ALS, ANT, CBB, and rust resistance. This activity is yet to be undertaken but will be initiated in the coming season.

1.5. ***Cross lines with superior disease resistance to those with shorter cooking time and high mineral bioavailability*****:** The initial 23 ADP lines that were selected for shorter cooking time were tested for adaptability, preference and fast cooking time with 9 farmer groups composed of 326 farmers (96 men and 230 women) in three agroecologies in Uganda. From these only seven lines namely ADP 0512, ADP 0009, ADP 0001, ADP 0468, ADP 0521, ADP 0098, and ADP 0522 have been identified as suitable and with fairly shorter cooking time. These will be advanced for further evaluation and also crossed with other Andean Uganda market class varieties in the coming season.

1.6. Drought tolerance: Mr. Dramadri also planted the ADP panel consisted of 250 genotypes, 233 from the global ADP panel and 17 local genotypes and field evaluated during the months May-August, targeting the end of first rainy season at NaCRRI-Namulonge. The aim of the research was to use genomic and phenometric tools for improving selection and breeding for drought tolerance in the large seed bean. The field experiment consisted of two treatments (irrigated and non-irrigated), in two replications planted in the field at NaCCRI. In order to prepare and plan for future field experiments, field evaluations were necessary to assess the performance of the ADP under Ugandan conditions specifically targeting terminal drought stress, optimize the use of photosynq for measuring photosynthetic traits in common bean under field conditions, and multiply seed for the subsequent experiments. During the months of May-August, NaCRRI received unusual high rainfall and no drought stress was observed. These moist conditions however led to multiple disease condition and data was collected on all agronomic traits and on major common bean disease such as ALS, Rust, CBB, and BMCV. In addition, the initial plans of setting field irrigation facilities to provide supplementary irrigation were not implemented or needed. The major finding from this initial trial is that another location in Uganda is needed for drought screening due to the unpredictability of rainfall even in the dry season at Namulonge and the lack of trained field staff prevented the use of the photosyn as most field workers are actual laborers and could not be trained to assist in using the devise. This work will continue at two field locations in Uganda in fall 2016 as part of Mr. Dramadri dissertation research.

1.6.1. Screen the drought nursery in Uganda to intermittent drought stress: A nursery of 60 bean lines that was obtained from Dr. Urrea, UNL was screened under terminal drought protocol during off-season period and irrigation employed. The yield obtained from replicated trail in both the irrigation and non-irrigated trials is attached in Annex 2. From these preliminary results lines ADP-102, ADP-41, ADP-47, ADP-61, ADP-617, ADP-660 and ADP-678 were noted to perform fairly well in drought conditions. These could be suitable varieties for utilization in drought prone and the semi-arid regions of Uganda and could potentially be good sources of resistance for drought tolerant genes for breeding purposes.

1.6.2. Other drought tolerance screening trials: A second preliminary yield trail was conducted for 169 lines that had been obtained from CIAT. This trial was to confirm data obtained in the first yield trial. In addition, there was need to also increase on the amount of seed available to enable multilocation yield trials. Results obtained and shown in Annex 2 are indicative of yield variation with a range of 3625kg.

The large variation in yield between the different genotypes will be exploited to select and utilize best adapted and highest yielders for future release and/or utilization in our breeding program. Further selections made in the next evaluation trials will depend on resistance to diseases and farmer preferred traits. Selected lines from these two trials will undergo multilocation trials to evaluate their reaction in the different agroecologies.

1.6.3. In another germplasm evaluation trial, 421 individual plants that were selected from 35 segregating drought large seeded bean populations obtained from South Africa. These were then established in trials as 421 single row families and evaluated. From these trials a total a total of 416 lines were selected (Annex 2) and only 5 lines are so far deselected this was mainly because of the superior performance exhibited by the families. Also the other purpose of the trial was to increase seed available to enable establishment of replicated trials in future evaluations. So far selections made were mainly based on the early maturity and market trait characteristics. We intend to do further selection in the coming season basing on yield, disease resistance and drought tolerance. We still consider these set of materials unique due that fact that they are the first large seeded drought tolerant genotypes being evaluated in the country. We further anticipate that we will be able to obtain some fast track material for utilization in drought prone areas within this region and also materials that will be utilized in the drought breeding program for the larges seeded varieties.

1.6.4. A 25-entry uniform drought nursery was grown in Michigan in 2016. Weather conditions were favorable for the development of drought in the first 45-days following nursery establishment and the local check varieties outyielded most of the drought tolerant lines, underscoring the importance of local adaptation. The nursery was coordinated by Drs. Urrea and Porch.

1.7. Nebraska: The common bacterial blight nursery dispatched to Uganda and Zambia was screened for CBB reaction at the West Central Research and Extension Center, North Platte, NE, in an augmented replicated field trial. The plot size consisted of 1 row 3 m long spaced 0.56 m. The resistant XAN 159; the moderately resistant Neb 1 Sel. #27, and ABC-Weihing; and the susceptible Orion lines were used as reference checks. At flowering, plants were sprayed with a bacterial solution of 3 x 107 cfu ml^{-1} using a backpack sprayer with the CBB Nebraskan strains SC-4A and LB-2. The lines were evaluated at the pod filling stage using a 1-9 scale, where 1= immune and 9= very susceptible. Data is being analyzed. In 2016 the ADP lines were tested for response to terminal drought (irrigation was stopped at flowering stage). Data is being processed. Harvest was finished few days ago. The drought tolerant lines (ADP) dispatched to Uganda and Zambia were tested at both locations under normal and drought conditions in 2016. The ADP panel grown under normal and drought stress will be cooked. Seeds will be soaked overnight (16 hours) then, placed in the Mattson Bean Cooker, and beans will be cooked when 80% of the weighted plungers drop. Based on data collected in Nebraska from 2013 (common bacterial blight, experiments on drought, and cooking time), 36 F1 combinations initiated in 2015 were advanced to F3 by bulking one pod per plant. The F3 generation will be planted in Puerto Rico for generation advancement and seed will be available to be distributed to Zambia and Uganda in 2017.

1.8. Farmer Evaluation of the Nutritionally Superior Bean Genotypes in Three Agro-ecological Zones in Uganda:

A subset of the ADP comprised of 23 genotypes was screened on-farm across three districts in Uganda in 2015. The genotypes represented various market classes and were selected for faster cooking times and superior nutritional quality profiles. A participatory variety selection approach was implemented where the farmers belonging to nine farmer groups participated in the collection of both qualitative data (preference scores) and quantitative data (disease reactions, plant architecture, and seed yield).

Farmers also rated seed quality preferences after harvest. In general, farmers preferred high yielding early maturing lines that exhibited tolerance to too little and/or too much water. A small seeded red mottled variety (Chijar) from Puerto Rico was consistently the most productive across all the agro-ecological zones used in the study with an average yield of 1,000 kg ha^{-1}.

In the 2016 growing season, the genotypes were planted in March to evaluate their performance during the short rainy season across the nine locations. The genotypes were further refined and based on yield data from the 2015 season only 15 experimental entries were planted along with the local check. The growers participated in collecting data on disease stress as well as agronomic data during harvest for all the 16 accessions. Farmers also rated the genotypes at harvest based on yield and seed quality. The most preferred genotypes were also evaluated for sensory quality in the communities. The seeds of genotypes from all accessions are being evaluated for cooking time, mineral profiles, and iron bioavailability to determine the stability of these traits and identify good germplasm for breeding to improve common bean for nutritional quality traits.

1.9. Crossing resistance sources in Zambia:

A common bacterial blight nursery consisting of 50 lines was planted and evaluated at two sites (Misamfu and Mpika) in Zambia. More than 66% of the lines showed some level of resistance to CBB. The lines were also evaluated for ANT and ALS and a number of lines showed combined resistance to all three diseases. In addition to the research to introgress CBB into local preferred lines Dr. Kamfwa at UNZA, has expanded that effort by crossing the light red kidney variety Badillo, which is resistant to CBB, high yielding and is well adapted to Zambia with the local landrace Kabulangeti, which is susceptible to CBB. The F4 population of the cross was planted in the field in 2016 growing season for seed multiplication and evaluation will be conducted during the 2016/17 season.

1.10. Evaluation of lines for BNF

In the 2016 growing season, 211 RILs of the Sowezi x AO-1012-29-3A, a light red kidney from University of Puerto Rico with resistance to seed weevils, (SA) population was planted at Misanfu Research Station, in Kasama and at University of Zambia Farm in Lusaka to evaluate for nitrogen fixation. Due to poor nodulation at both locations, no data on nitrogen fixation was collected in 2016. The SA population will be planted next year at Misanfu, using seed inoculated with rhizobium and evaluated for N-fixation. This represents a continuation of work initiated at MSU as part of Dr. Kamfwa's doctoral dissertation research.

1.11. Cooking time prediction in intact dry bean seeds using visible/near-infrared spectroscopy

In the period 2015-2016, advances in cooking time prediction have been made in the development and optimization of Vis/NIRS chemometric models using dry bean seeds of Phaseolus vulgaris with broad genetic diversity and planted in different years and locations. In addition, a hyperspectral imaging (HYPERS) technique, that combines the main features of imaging and spectroscopy to acquire spectral and spatial information from products simultaneously, was implemented and tested for evaluating cooking time in similar accessions of dry seeds tested by Vis/NIRS. The HYPERS technique involved the development of image preprocessing and image segmentation methods of bean seed from spectral images in the wavelength range of 400-1,000 nm. Also, due to the large data set generated by both Vis/NIRS and HYPERS techniques and in order to avoid over-fitted models, a wavelength selection procedure was implemented to select the best spectral or image properties for further prediction analyses. A goal of this experiment was to evaluate and compare the predictive power of Vis/NIRS (400-2,498 nm) and HYPERS (400-1,000 nm) techniques for predicting cooking time on independent and

combined sets of dry bean samples. Various spectral/image preprocessing methods were tested for improving the prediction accuracy. The evaluated accessions were:
(i). 446 bean samples of the ADP grown in 2013 at the Montcalm Research Farm, Michigan with wide variations in cooking time ranging from 17.7 to 96.4 min. The ADP collection included accessions from Africa, Europe, Asia, Central America, Caribbean, North America, and South America which were planted in Michigan;
(ii). 140 bean samples from four different market classes of agricultural importance to Eastern Africa, Southern Africa, the Caribbean and North America. The seed types were yellow; cranberry, light red kidney, red mottled and brown. They were planted in 2014 over 5 locations in two contrasting geographical regions. Two field locations were located in Northwestern United States (USDA-ARS; Othello, WA). The other three locations were located in Tanzania: Arusha (Selian Agricultural Institute), Mbeya (Uyole Research Station) and Morongo (Sokoine University of Agriculture). This subset of germplasm combined three bean accessions with wide variations in cooking time ranging from 19.9 to 160.1 min;
(iii). 52 bean samples of the previous subset which were stored and grown in 2015 at Washington, and with cooking times ranging from 17.1 to 61.9 min.
(iv). 113 bean samples obtained from Washington and Tanzania and grown at the Montcalm Research Farm in 2015. The cooking time of these samples ranged between 18.2 to 113.1 min.
In the model building process, we found that the combination of two preprocessing methods (i.e., continues wavelength transform followed by the two-wavelength ratio approach) give most consistent and reproducible predictions for cooking time, as compared with the best single preprocessing methods. Results showed that using independent sets of samples the prediction accuracy for Vis/NIRS models was of 66.9% (error = 9.4 min) for set (i) and 68.1% (error = 10.4 min) for set (iv). For HYPERS models the accuracy was of 65.6% (error = 11 min) for set (i), 75.6% (error = 10.5 min) for set (ii), 83.0% (error = 7.1 min) for set (iii), and 73.8% (error=9.3) for set (iv). On the other hand, even though the large diversity of the samples, predictions for the combination of these accessions also showed pretty decent results. The models were very consistent given prediction accuracies for Vis/NIRS of 63.8% (error = 9.3 min) combining sets (i)+(iv); and for HYPERS of 88.5% (error = 10.8 min) combining sets (ii)+(iii), and 75.4% (error = 8.3 min) combining the four data sets ((i)+(ii)+(iii)+(iv)). In this study, the models were built using partial least square regression methods that is the most common multivariate approach used for prediction and classification tests; however, applications or other more powerful approaches such as artificial neural networks and support vector machine may further improve the prediction performance and robustness of the models. We concluded that in spite of the large genetic diversity, source and planting years of bean samples, Vis/NIRS and HYPERS have great potential for predicting cooking time over a wide range of measurements; however, the robustness of sensing models seems to be affected by the genotypic diversity, planting year and distribution of the cooking time data used for model building, and hence, chemometric models should be constantly maintained and updated with new data. The development of a procedure for model updating and cross-year predictions using different genotypes is needed and it will be considered in our next studies.

1.12. Seed multiplication

In Uganda bean lines received for the different nurseries, for maintenance and seed multiplication purposes, a few seed were planted in the screen house and the rest planted in the field. The field also enabled us to evaluate for adaptability to local conditions and also make a quick assessment on susceptibility to diseases. In addition to the nurseries introduced into Zambia discussed above, five varieties, Zorro black, Eldorado pinto, Bunsi navy, Bellagio and Etna cranberry from the MSU program have since been integrated into the breeding program in Zambia and seed has been increased to have the varieties ready for further testing and crossing.

Objective 2: Characterize pathogenic and genetic variability of isolates of foliar pathogens collected in Uganda, and Zambia and identify sources of resistance to angular leaf spot (ALS), anthracnose (ANT), common bacterial blight (CBB), bean common mosaic virus (BCMV) and bean rust present in Andean germplasm.

2.1 ANT and ALS characterization and screening in Uganda: Continue with the collection of isolates of ANT, ALS, CBB, and Rust in different production regions of Uganda: Collections for different disease sample for different pathogens were collected and these included, 136 rust, 54 anthracnose, 24 BCMV and 60 ALS samples collected from different bean growing agroecologies within Uganda. These were later isolated for further characterization.

2.2 Increase seed of the differentials for ANT, ALS and rust in Uganda: Differentials for rust, ANT and ALS were obtained and multiplied in the field to increase the amount of seed availed. Unfortunately, some genotypes for ALS and anthracnose did not germinate and a few others did not put on as much seed as needed. There is still need to continue with seed multiplication for these differentials and also to obtain the genotypes that did not produce enough seed.

2.3 Initiate race characterization of Rust, CBB, BCMV, ANT and ALS in Uganda: A number of isolates were obtained from collected diseases samples for different pathogens and these were further characterized into different pathoypes using various techniques and indicated below.

2.3.1. Rust: A field survey was conducted in 15 Ugandan districts that represented the areas of high bean production. High incidence of bean rust and severity was observed in the low altitudes and in the Western Highlands of Uganda. Hoima district had the highest rust disease incidence of 70 to 76% and average severity of 6. Also there was high rust disease incidence and severity in the bean-maize–groundnut cropping system and fields cultivated with commercial cultivars or landraces. The mobile nursery protocol was used to determine the effectiveness of specific rust resistance genes in genotypes in Uganda. The mobile nursery did not work out as had been expected in Uganda and thus other molecular based techniques were thus sought for identification of resistant rust genes.

2.3.2. A total of 23 single rust isolates were obtained from the collected diseases samples collected in Uganda and inoculated on 11 bean rust differentials and Ouro Negro (Ur-14 gene) cultivar. From these isolates, six rust pathotypes including 2-0, 4-0, 50-0, 5-1, 4-33 and 63-19 were identified. The identification of rust resistant sources was conducted using both phenotypic and genetic characterization and the following bean lines including Mexico 309, CNC, P1181996, Mexico 235, Redland pioneer, Ouro Negro and Aurora were identified to have good levels of resistance to rust pathotypes existing in Uganda. These have been utilized in crosses to introgress rust resistance into Ugandan germplasm. A study was conducted to identify sources of broad-spectrum rust resistance in common bean germplasm including landraces, commercial cultivars and introduced genotypes in Uganda using a combination of phenotypic and genotypic screening with 22 simple sequence repeat (SSR) markers located on chromosome Pv04. A total of 138 genotypes were field screened from 2014 and 2015 using an alpha lattice design. Resistance of each genotype was compared to the presence and absence of amplified SSR markers. There were highly significant differences ($P < 0.001$) among the genotypes for disease incidence, AUDPC and total grain yield and a strong correlation ($P < 0.001$) between disease incidence and AUDPC in both years. The SSR markers, BARC_PV_SSR04725, bean_ssr_0778 and bean_ssr_2892 were associated ($P \leq 0.05$) with rust resistance. Fifteen genotypes which included the landraces Nabufumbo, and Kapchorwa white, and the commercial cultivar NABE 2 were identified as new sources of rust resistance that would be useful in future bean breeding programs in Uganda.

2.3.3. **Rust samples** were sent and analyzed at the University of Nebraska by Dr. James Steadman. The first analysis of resistance gene patterns relating to binary races: 63-1, 31-1, 23-1 and 29-1. This indicated that GN 1140 (Ur-7 gene) was susceptible, but all other Middle American differentials were resistant (Ur-3, Ur-5, Ur-3+, CNC, and Ur-11 genes). Also it was noted that all Andean gene sources with the exception of PI 260418 and in a few instances PC 50 and Redlands Pioneer were susceptible. These are still preliminary findings that need to be confirmed. Rust samples from Kampala sent earlier this fall, with a proper APHIS permit was diverted to the United Arab Emirates. Thus, it was delayed 3.5 weeks in transit. Very few rust pustules had any viable spores. Nine urediniospores were isolated and binary races 23-1, 29-1, 63-1 and 31-1 were identified. Race 31-1 was found in six field samples while 63-1 was found in two field samples and 29-1 and 23-1 were only in one sample each. There is a concern that the surviving rust urediniospores may not be representative of all the spores originally sampled. Researchers from NE will travel to Uganda in Oct 2016 to collect more bean leaves with rust to send back to UNL in a 3-4 day period. Previous information on Zambia bean rust from 2015 revealed race 31-1 to be the primary race with 31-3 and 63-1 present in low numbers. We plan to evaluate rust again this year.

2.3.4. **CBB**: We obtained and utilized an already available pathotype "Kawempe 1" of CBB which we used to screen the available nursery and germplasm collection for resistant genotypes. We managed to obtain four CBB resistant genotypes namely NE2-14-8, NE17-14-29, NE14-09-78 and VAX3.

2.3.5. **BCMV**: Eighty samples were screened using inoculum obtained from the disease plants in the field. From these three genotypes including SCR 48, SCN 9 and SCN 6 were identified as resistant, and fortunately these same genotypes have also been known to be tolerant to drought condition.

2.4. ***Leverage the NIFA nurseries and collect information on foliar pathogens on the ADP and UNL drought tolerant germplasm nurseries for reaction to different foliar pathogens on surviving lines and Uganda***: This has been undertaken especially for the UNL drought tolerant germplasm nursery for which we have already had the first drought evaluation trial, the preliminary results of which have been indicated in this report. We are now choosing the most relevant races of ANT, ALS and rust and strains of CBB for screening breeding nurseries in Uganda. The specific races/stains have been selected for Rust, CBB and BCMV and have been utilized in the screening process to identify resistant genotypes. These same races will be utilized for the screening of progenies from the crosses that have been initiated.

2.5. ***Anthracnose race characterization, screening in Zambia:*** Progress on incorporating ANT resistance is underway using the variety Werna which is resistant to anthracnose and CBB. The F4 population of the cross between Kabulangeti and Werna was also planted in the field in the 2016 growing season for seed multiplication and will be evaluated for resistance at Misamfu and UNZA in 2016/17 season.

2.6. ***Root rot characterization in Zambia:*** Six bean lines from the initial 405 entries from the ADP and NE trials previously screened in Zambia were found to have resistant to root and crown rots (RCR) and other foliar diseases and were adapted to Zambia. The primary pathogens associated with dry bean root and crown rots were identified and characterized from samples collected in survival nursery trials evaluated in the period under review. A total of 405 fungi and oomycetes were recovered from the tissue samples. Classical isolation and molecular techniques were used in the identification and characterization of the primary RCR pathogens. The primary RCR pathogens were identified as Fusarium sp. with the predominant pathogens being *F. oxysporum* followed by *F. solani* and *F. equiseti*. This data is a critical starting point in breeding for resistance to the different RCR pathogens present in the bean production regions of Zambia.

Objective 3: Use single nucleotide polymorphism (SNP)-based genome-wide association mapping to uncover regions associated with drought tolerance, disease resistance, cooking time and BNF to identify QTLs for use in MAS to improve Andean germplasm.

3.1. Fast cooking lines with high mineral bioavailability will be grown in on farm trials and will be evaluated for farmer acceptability based on agronomic and cooking characteristics: This year the initial 23 ADP short cooking bean lines were reduced to 16 and these were re-evaluated with the same groups of farmers. From the second on-farm participatory evaluation trials, lines were reduced to seven and these were the ones that were eventually taken through for sensory test. Results of the on-farm trials will be reported by Mr. Dennis Katuuramu, a PhD student, Michigan State University.

3.2. Conduct sensory evaluation of lines with superior cooking time and mineral bioavailability in Michigan, Uganda: Sensory evaluation tests were conducted with 9 famer groups in Uganda in the regions of Hoima, Rakai and Kamuli for the seven ADP lines short cooking lines that had been selected by the famers in the participatory variety selection trials. The sensory evaluation results will be reported by the PhD student, Mr. Dennis Katuuramu.

3.3. Mapping resistance genes for anthracnose:

New sources of anthracnose resistance in a highly diverse panel of 226 Andean beans was screened with eight races of anthracnose to identify and map new sources of resistance using a genome-wide association study (GWAS) at MSU. Outputs from the GWAS indicated major QTL for resistance on three linkage groups: Pv01, Pv02, and Pv04 and minor QTL on Pv10 and Pv11. Candidate genes associated with the significant SNPs were detected on all five chromosomes. Prior work identified a major QTL linked to the Co-1 locus on Pv01 and a breeder friendly InDel marker was developed (50.2Mb) that was linked to four alleles at the Co-1 locus. Work continues to develop Indel and SSR markers at the other genomic positions on Pv02, Pv04, Pv08 and Pv11 where resistance genes were identified. A comprehensive transcriptome analysis was also conducted using Illumina sequencing of two near isogenic lines (NILs) differing for the presence of the Co-1 gene on Pv01 during a time course following infection with race 73 of *C. lindemuthianum*. From this, we identified 3,250 significantly differentially expressed genes (DEGs) within and between the NILs over the time course of infection. During the biotrophic phase the majority of DEGs were up regulated in the susceptible NIL, whereas more DEGs were up-regulated in the resistant NIL during the necrotrophic phase. Various defense related genes, such as those encoding PR proteins, peroxidases, lipoxygenases were up regulated in the resistant NIL. Conversely, genes encoding sugar transporters were up-regulated in the susceptible NIL during the later stages of infection. Additionally, numerous transcription factors (TFs) and candidate genes within the vicinity of the Co-1 locus were differentially expressed, suggesting a global reprogramming of gene expression in and around the Co-1 locus. Through this analysis, we reduced the previous number of candidate genes reported at the Co-1 locus from eight to three. These results suggest the dynamic nature of *P. vulgaris* – *C. lindemuthianum* interaction at the transcriptomic level and reflect the role of both pathogen and effector triggered immunity on changes in plant gene expression.

3.4. Mapping resistance genes for bruchid resistance:

The same SA population was sent to Dr. Beaver's Lab at University of Puerto Rico for evaluation for bruchid resistance. The evaluation has been completed and QTL analysis for bruchid resistance is currently being conducted in Zambia.

Objective 4: Develop phenometric approaches to improving the efficiencies of breeding for abiotic stress tolerance, especially drought

Much of the research focused on examining constitutive differences between drought tolerant and drought susceptible genotypes so that mechanisms contributing to drought tolerance might be discovered and further investigated. To support these efforts, research was conducted on the physiology of drought and heat stress in a selection of bean genotypes with varying degrees of stress tolerance including tepary bean. The response of different metabolites to drought stress was a major focus. Beans exposed to drought stress had no differences in free proline concentration in their leaves, either between treatments or among genotypes. For soluble carbohydrates, no differences among genotypes were found under control conditions, but the concentration of malic acid, glucose, fructose, inositol, and raffinose all increased in the leaf tissues of plants exposed to drought stress. Glucose, fructose, and inositol were all found in higher concentrations in more tolerant genotypes, so it is likely that their accumulation is correlated with drought tolerance. These compounds accumulated in sufficient quantities to osmotically adjust bean leaf tissues, and leaf water potential measurements revealed that those genotypes that accumulated more soluble carbohydrates under drought stress also had lower leaf water potentials while no differences among genotypes existed for leaf water potentials under control conditions. Abscisic acid was responsive to drought stress in beans, but what differences existed in its concentration among genotypes did not seem directly related to drought tolerance. Grafting experiments revealed that it is shoot identity that controls the concentration of ABA in root tissues under drought stress. Drought stress also affects a number of photosynthesis related traits in beans. Photosynthesis vs. intercellular CO_2 concentration curves revealed that none of the photosynthetic parameters derived were related to drought tolerance, but the maximum carboxylation rate of rubisco and the rate of electron transport could be related to general productivity. Based on measurements of gas exchange on control and drought stressed beans, lower stomatal conductances are associated with drought tolerant genotypes regardless of water treatment. Lower stomatal conductances would allow a plant to conserve more water during periods of drought stress. Grafting experiments showed that stomatal conductance is controlled mainly by factors located in the shoot tissue and not the root tissue. However, these factors are unrelated to leaf density or the density of stomata on leaf surfaces. Bean plants exposed to temperatures of 45 °C for two days showed measurable signs of heat stress. Measures of gas exchange, chlorophyll fluorescence, and oxidative stress were for the most part only affected by this high temperature and not by any temperatures below it. These measures also correlated well with visual signs of damage on leaf tissue caused by heat stress. The method was useful for screening a large group of germplasm for heat tolerance, but this heat tolerance only partially related to drought tolerance observed in the field. Plant breeders can utilize some of these methods to supplement field data and further characterize the stress tolerance of later generation bean lines.

Objective 5:

Institutional Capacity Building and Training continues at MSU for two doctoral students, Isaac Dramadri, and Dennis Katuuramu from Uganda. Two doctoral students graduated in FY16 (fall 2015); Kelvin Kamfwa from Zambia, and Jesse Traub, and one MS student Grady Zuiderveen student from the US all in Plant Breeding, Genetics and Biotechnology at MSU. Thesis title listed in Annex 1. In Uganda, three postgraduate students have been engaged and trained under the project. The students are at different levels of their research as indicated below;

Ms. Blessing Odogwu; is a PhD student at Makerere University undertaking studies under the research topic “Genetic diversity study of common bean rust in Uganda”. Blessing is currently completing her thesis write up and will submit by the end of 2016.

Mr. Alladassi Mahulé Elysé Boris is an MSc. Student at Makerere University, Uganda, and has conducted research on the "Genetics of resistance to Common Bacterial Blight disease of Common Bean (Phaseolus vulgaris L.) in Uganda". He has already completed his research work and submitted his thesis for examination.
Mr. Basil Evarist Kavishe is also an MSc. Student at Makerere University, Uganda who is conducting research on the "Resistance to bean common mosaic poty-viruses (BCMV and BCMNV) and its inheritance in selected Ugandan bean genotypes" Evarist is still conducting his research work and hopefully will completed by end of 2016.

- In addition to graduate student training in Uganda, we were able to train five (5) technicians and four (4) research assistants on the drought screening and capture of data using the irrigation and non-irrigation technique. Also five (5) technicians together with 326 farmers and three (3) personnel were taught on bean disease identification and possible control measures.
- In Zambia, the training of Seed Growers (farmers) in clean seed production and integrated pest and disease management for improved dry bean production and productivity. Seed growers were trained on best practices for seed and dry bean production by the staff from the Bean improvement program. A total of 118 males and 99 females attended the trainings. The trainings were conducted through workshops and seminars and farmer learning centers. The trainings were conducted in >11 Districts from Muchinga and Northern Province. These training were attended by members from Shangila seed grower association, Chinchi Wa babili seed grower association, Kabulamwiko seed grower association and others with a membership of 40 males 37 females, 69 males 87 females and 54 males and 50 females, respectively. These seed grower associations help multiply and supply clean reliable seed for over 230,000 households growing beans in the major bean growing areas in Zambia.
- Training of students on identification of root rots in the field and integrated pest and disease control measures. The station received students on industrial attachments where the NIFA RCR project was based receive students on attachment every year and they get to have an opportunity to learn and participate in the projects and activities on the station. A total of 66 students from 6 local Agriculture training institutions/colleges have been trained and made aware of RCR of dry beans and the methods of evaluation and sampling of plants for pathogen identification and integrated management of diseases and pests in dry bean in the period under review.
- One hectare (1.0ha) irrigation facility has been installed in Misamfu using LIL Sub-project funding which will benefit the breeding program, as field research can continue even in the off-season as opposed to waiting for the rainy season.

IV. Major Achievements

The project has made some significant achievement towards achieving the breeding objectives especially in the area of germplasm acquisition and utilization. We have also able to forge working relationships between NaCRRI and other institutes like Makerere University, Michigan State University, University of Nebraska, in country USAID Field Mission, USAID Feed the Future monitoring and evaluation teams, ARC-Grain Crops Institute- Potchefstroom- south Africa where we are able to have exchange visits for both students and researchers and also in the exchange of germplasm. We have also had engagements with postgraduate students, farmers, NGOs and Community Based Organization (CBOs) in bean growing agroecologies in Uganda. The research achievements so far obtained are inclusive but not limited to the following:

- Through the project we have been able to obtain and are utilizing four (4) nurseries including that of rust, CBB, and two sets of drought nurseries and two sets of differentials (Rust and ALS) from collaborating partners.
- To date we have been able to collect and evaluate a germplasm collection of slightly over 750 germplasm for different traits.
- We have identified 6, 5, 3, 7, and 7 tentative resistance bean sources for rust, CBB, BCMV, drought and short cooking time respectively.
- Made over 86 different crosses to introgress different diseases resistances and drought tolerance into the susceptible Uganda market class bean varieties.
- We have determined the incidences and severities of the different bean folia pathogen within major bean growing regions of Uganda.
- We have undertaken inheritance studies to determine modes of inheritance of rust and CBB and BCMV resistance for through preferred Andean bean genotypes in Uganda.
- Seed of different nurseries acquired were increased to obtain enough seed for screening purposes within Uganda.
- Several isolates of rust, CBB, BCMV, anthracnose, and angular leaf spot were obtained from bean diseases samples obtained from different bean production regions of Uganda. Some of these have been characterized.
- The project has continued screening of progenies obtained from crosses made to introgress resistances for drought, rust, CBB, BCMV and anthracnose into the preferred Andean market class bean varieties for Uganda.
- Preliminary and advanced yield trials conducted for promising drought tolerant line.
- We have built capacity for 4 Research Assistant and 5 Technicians drought screening, isolation and inoculation techniques for rust, anthracnose, CBB and BCMV, data collection and foliar disease management for beans and in addition trained and mentored 6 students (3 PhD and 3 MScs) in breeding methodologies and skills.
- We have engaged and trained 326 farmers, three (3) extension personnel on bean foliar disease management, on-farm trials management in Uganda while evaluating and making selections for the utilization of fast cooking bean varieties.
- New sources of resistance to ANT, ALS, CBB and rust have been identified in Uganda and Zambia.
- Several sources of drought tolerance were identified. A drought trial of 60 entries is being tested in 2016 at Uganda and Zambia under normal and drought stress conditions.
- Based on previous, 36 F1 hybrid combinations were initiated to combine multiple disease resistance and drought tolerance into African elite germplasm. Segregating populations will be distributed in 2017 for local selections in Uganda and Zambia
- Ur-3, Ur-5, Ur-3+, CNC and Ur-11 would be genes from the Middle American cultivars that would confer resistance in Uganda and except for one rust isolate that caused a susceptible reaction on Ur-3 can be used in Zambia for breeding.
- Breeder-friendly marker developed for anthracnose resistance
- Identified genomic regions controlling BNF and anthracnose resistance.
- 15 refereed publications in print or press.

V. Research Capacity Strengthening

The collaborative research has enabled us to build research capacity at NaCRRI not only in terms of breeding activities but also in developing human resource capacity. In this year we were able to continue training and mentoring one PhD and two MSc students. We are also able to train a three research assistant

and 5 technicians in Uganda on the use of modern technologies to capture field data and reduce on errors. Also the host country PI-Uganda, was facilitated to attend and participate in a common bean disease workshop on angular leaf spot and root rot where new insights and methods were shared on how to combat these two diseases. We also able to network with other renowned scientists and sharing research information and knowledge. For human capacity building, two short term trainings were organized for research assistants and technicians in Uganda. This was to strengthen their research capability in as far as data collection is concerned. There was training on the use of new data collection tools as part of breeding management system which tools are being utilized by the project.

VI. Human Resource and Institution Capacity Development

2. Degree Training

The PhD student (Ms. Blessing Adogwu), continued to undertake her research work on rust with the project. Through the Norman E. Borlaug Leadership Enhancement in Agriculture Program fellowship, she was also able to travel to MSU and University of Nebraska to undertake hands-on training of the use of molecular markers for screening purposes. In addition, two other MSc. students have been taken on by the project to undertake their researchers on under some of our project objectives. The first MSc. student is looking at breeding for resistance to CBB while the second student is conducting research on the BCMV disease. It hoped that the three students will make positive contribution towards new discoveries and also gain experience in research implementation. Details for the students are given below;

Student 1

i. Name of trainee: Blessing Odogwu
ii. Country of Citizenship: Nigeria
iii. Gender: Female
iv. Host Country Institution Benefitting from Training: University of Port Harcourt, Nigeria
v. Institution providing training: Makerere University/NaCRRI
vi. Supervising CRSP PI: Prof. James Kelly
vii. Degree Program: PhD
viii. Field or Discipline: Plant Breeding and Biotechnology
ix. Research Project Title: Breeding for rust resistance in common beans in Uganda
x. Start Date: January 2014
xi. Projected Completion Date: December 2017
xii. Is trainee a USAID Participant Trainee and registered on TraiNet?: No
xiii. Training status: Active

Student 2

i. Name of trainee: Boris Mahulé Elysé Alladassi
ii. Country of Citizenship: Benin
iii. Gender: Male
iv. Host Country Institution Benefitting from Training: University of Abomey-Calavi, Benin
v. Institution providing training: Makerere University/NaCRRI
vi. Supervising CRSP PI: None
vii. Degree Program: Masters Degree
viii. Field or Discipline: Plant breeding and seed systems
ix. Research Project Title: Genetic Analysis of Resistance to Common bacterial blight and association of candidate SNP markers of common bean (*Phaseolus vulgaris L.)* in Uganda
x. Start Date: December 2014

xi. Projected Completion Date: September 2016
xii. Is trainee a USAID Participant Trainee and registered on TraiNet?: No
xiii. Training status: Active

Student 3

i. Name of trainee: Basil Evarist Kavishe
ii. Country of Citizenship: Tanzania
iii. Gender: Male
iv. Host Country Institution Benefitting from Training: Sokoine University of Agriculture, Tanzania
v. Institution providing training: Makerere University/NaCRRI
vi. Supervising CRSP PI: None
vii. Degree Program: Masters Degree
viii. Field or Discipline: Plant breeding and seed systems
ix. Research Project Title: Resistance to bean common mosaic virus and its inheritance in selected Ugandan bean genotypes
x. Start Date: December 2014
xi. Projected Completion Date: September 2016
xii. Is trainee a USAID Participant Trainee and registered on TraiNet?:No
xiii. Training status: Active

Student 4

i. Name of trainee (First and Last Name): Kelvin Kamfwa
ii. Citizenship: Zambian
iii. Gender: M
iv. Training Institution: MSU
v. Host Country Institution Benefitting from Training: University of Zambia
vi. Supervising Legume Innovation Lab PI: James D. Kelly and Karen A. Cichy
vii. Degree Program for training: Doctorate
viii. Program Areas or Discipline: Plant Breeding, Genetics and Biotechnology
ix. Thesis Title/ Research Area: Genetic dissection of biological nitrogen fixation in common bean using genome-wide association analysis and linkage mapping.
x. Start Date: August 2008
xi. Completion Date: December 2015
xii. Is trainee a USAID Participant Trainee and registered on TraiNet? Yes
xiii. Training Status: graduated

Student 5:

i. Name of trainee (First and Last Name): Grady Zuiderveen
ii. Citizenship: US
iii. Gender: M
iv. Training Institution: MSU
v. Supervising Legume Innovation Lab PI: James D. Kelly
vi. Degree Program for training: Masters
vii. Program Areas or Discipline: Plant Breeding, Genetics and Biotechnology
viii. Host Country Institution to Benefit from Training: US
ix. Thesis Title/ Research Area: SNP marker development for major resistance genes
x. Start Date: August 2013
xi. Completion Date: September 2015

xii. Is trainee a USAID Participant Trainee and registered on TraiNet? No
xiii. Training Status: graduated

Student 6:

i. Name of trainee (First and Last Name): Jesse Traub
ii. Citizenship: US
iii. Gender: M
iv. Host Country Institution to Benefit from Training: US
v. Training Institution: MSU
vi. Supervising Legume Innovation Lab PI: Wayne Loescher
vii. Degree Program for training: Doctorate
viii. Field or Discipline: Plant Breeding, Genetics and Biotechnology
ix. Thesis Title/ Research Area: Physiological differences among *Phaseolus vulgaris* cultivars differing in drought tolerance.
x. Start Date: August 2013 on Legume Innovation Funding
xi. Completion Date: January 2016
xii. Is trainee a USAID Participant Trainee and registered on TraiNet? No
xiii. Training Status: graduated.

Student 7:

i. Name of trainee (First and Last Name): Isaac Dramadri
ii. Citizenship: Uganda
iii. Gender: M
iv. Host Country Institution to Benefit from Training: Makerere University
v. Training Institution: MSU
vi. Supervising Legume Innovation Lab PI: James D. Kelly and Wayne Loescher
vii. Degree Program for training: Doctorate
viii. Field or Discipline: Plant Breeding, Genetics and Biotechnology
ix. Thesis Title/ Research Area: Physiological studies on drought tolerance in Andean beans.
x. Start Date: August 2013 on Legume Innovation Funding
xi. Projected Completion Date: September 2017
xii. Is trainee a USAID Participant Trainee and registered on TraiNet? Yes
xiii. Training Status: Active, Partial -BHEARD Fellowship from USAID Mission, Kampala.

Student 8:

xiv. Name of trainee (First and Last Name): Dennis Katuuramu.
xv. Citizenship: Uganda
xvi. Gender: M
xvii. Host Country Institution to Benefit from Training: Makerere University
xviii. Training Institution: MSU
xix. Supervising Legume Innovation Lab PI: Karen Cichy and James Kelly
xx. Degree Program for training: Doctorate
xxi. Field or Discipline: Plant Breeding, Genetics and Biotechnology
xxii. Thesis Title/ Research Area: Iron and Zinc Bioavailability in Andean Beans
xxiii. Start Date: August 2012
xxiv. Projected Completion Date: September 2017
xxv. Is trainee a USAID Participant Trainee and registered on TraiNet? NO
xxvi. Training Status: Active, Partial, USDA-ARS funding.

VII. Achievement of Gender Equity Goals

We have continued to undertake all project activities in consideration of gender equity in Uganda. For this to happen, we have ensured that both women and men are equitably represented and /or involved in executing project activities. This has been shown in all our project activities with the farmers and short term training. We have achieved more than the 30 percent women representation that has been set during project planning in Uganda. In Zambia we have identified NGO's that we can partner with for outreach and technology dissemination for female farmers which are: Kusefya pa Ngw'ena Women's Farmer Group, Shangila Seed Growers Association (SSGA) in Mpika and the Participatory Village Development in Isolated Areas (PaViDIA) in Mporokoso and Luwingu, PaViDIA is working towards empowering women in communities in Income Generating Activities (IGA) and seed and grain production for market sales to elevate income and reduce poverty. In Uganda the NGOs include: Community Enterprise Development Organization (CEDO), Integrated Seed Sector Development (ISSD)-Uganda, CARE, ADRA, SHUPO, SASAKAWA Global 2000; Nyakatozi Growers Cooperative Union, Appropriate Technology (Uganda); Seed companies such as (Pearl, Victoria, NASECO, East African Seed, FICA seed). Many organizations have as objectives to increase women's agriculture skills and leadership roles as well as access to credit for sustainable and profitable farming.

VIII. Explanation for Changes

There are no changes to set out activities but a few delays due to changes in the weather pattern, in many locations planting has been delayed to delays in on-set of rains. Other delays may be due to loss of diseases samples due to contaminations. We are currently relying on field screening but we hope that by mid next years all the new isolations would have been completed and characterization completed.

IX. Self-Evaluation and Lessons-Learned

Due to the delays in the rains and the reduction in the amounts received in Uganda, we need to think seriously of investing in a heavy duty irrigation facility as an institute. Also due to the large number of experiments that we are running currently we need to invest into electronic data capture and ease on the amount of work. Additionally, we need to invest in dereferencing all our farmers' trial sites. Apart from the setbacks in the poor isolation and characterization, we believe that that project is fairly on course. Considering the unpredictable rainfall patterns, we have learnt we cannot rely on off-season planting to conduct drought trials anymore. We may have to think of other innovative ways of evaluating drought germplasm in the field. We may need to start thinking of constructing rainout shelters in the field.

X. Scholarly Accomplishments – See Annex 1

XI. Progress in Implementing Impact Pathway Action Plan

The project is on track toward implementing the impact pathway. All activities listed under step 4.1 of the impact pathway have been met with the exception of disease characterization in country and those activities will be conducted during FY17. The achievements outlined above have encountered challenges mainly due to the severe drought that was experienced during the first season 2016 (March-July 2016), where we lost quite a significant number of experiments in Uganda. To solve the problem and save some of the seed, we invested in on-spot irrigation with improvised pumps and this save us some of our precious seed.

ANNEXES

Annex 1: Scholarly Accomplishments- Refereed Publications:

1. Isaacs, K.B., S.S. Snapp, J.D. Kelly and K. R. Chung. 2016. Farmer knowledge identifies competitive bean ideotype for maize-bean intercrop systems in Rwanda. Agriculture & Food Security 5:15. doi 10.1186/s40066-016-0062-8
2. Kelly, J.D., G.V. Varner, S. Hooper, K.A. Cichy, and E.M. Wright. 2016. Registration of 'Samurai' otebo bean. J. Plant Registrations 10:109-114. doi:10.3198/jpr2015.09.0051crc.
3. Mendoza, F.A, J. D. Kelly, and K. A. Cichy. 2016. Automated prediction of sensory scores for color and appearance in canned black beans (*Phaseolus vulgaris* L.) using machine vision. International Journal of Food Properties, doi:10.1080/10942912.2015.1136939.
4. Moghaddam, S.M., S. Mamidi, J. M. Osorno, R. Lee, M. Brick, J. Kelly, P. Miklas, C. Urrea, Q. Song, P. Cregan, J. Grimwood, J. Schmutz, and P. E. McClean. 2016. Genome-wide association study identifies candidate loci underlying agronomic traits in a Middle American diversity panel of common bean. The Plant Genome 9: doi: 10.3835/plantgenome2016.02.0012
5. Hoyos-Villegas, V., E. M. Wright and J.D. Kelly. 2016. GGE biplot analysis of yield associations with root traits in a Mesoamerican bean diversity panel. Crop Sci. 56:1081-1094. doi:10.2135/cropsci2015.10.0609
6. Zuiderveen, G.H., B. A. Padder, K. Kamfwa, Q. Song and J. D. Kelly. 2016. Genome-wide association study of anthracnose resistance in Andean beans. PLoS ONE 11(6): e0156391. doi:10.1371/journal.pone.0156391
7. Ai, Y., K A. Cichy, J. B. Harte, J. D. Kelly, and P. K.W. Ng. 2016. Effects of extrusion cooking on the chemical composition and functional properties of dry bean powders. Food Chemistry 211:538–545. doi:10.1016/j.foodchem.2016.05.095
8. Hoyos-Villegas, V., Q. Song, J.D. Kelly. 2016. Genomewide association analysis for drought tolerance and associated traits in common bean. The Plant Genome 9: doi:10.3835/plantgenome2015.12.0122
9. Hoyos-Villegas, V., Q. Song, E.M. Wright, S. E. Beebe and J.D. Kelly. 2016. Joint linkage QTL mapping for yield and agronomic traits in a composite map of three common bean RIL populations. Crop Sci. 56: doi:10.2135/cropsci2016.01.0063.
10. Heilig, J.A. J. S. Beaver, E. M. Wright, Q. Song, and J. D. Kelly. 2016. QTL analysis of symbiotic nitrogen fixation in a black bean RIL population. Crop Sci. 56: doi.
11. Nakedde, T., F. J. Ibarra-Perez, C. Mukankusi, J. G. Waines, and J. D. Kelly. 2016. Mapping of QTL associated with Fusarium root rot resistance and root architecture traits in black beans. Euphytica 212: 53-61. doi: 10.1007/s10681-016-1755-6
12. Padder, B.A., K. Kamfwa, H.E. Awale and J. D. Kelly. 2016. Transcriptome profiling of the *Phaseolus vulgaris* - *Colletotrichum lindemuthianum* pathosystem. PLoS ONE 11: e0165823. doi:10.1371/journal.pone.0165823.
13. Kelly, J.D. 2016. Developing improved high-yielding varieties of common bean. Ch.18. In: Achieving sustainable cultivation of grain legumes (ed. Sivasankar et al) Burleigh Dodds Science Publishing (in press).
14. Odogwu, B.A., S. T. Nkalubo, C. Mukankusi, T. Odong, H. E. Awale, P. Rubaihayo, and J. D. Kelly. 2016. Phenotypic and genotypic screening for sources of rust resistance in common bean germplasm in Uganda. Euphytica (in print).
15. Odogwu, B.A., S. T. Nkalubo, C. Mukankusi, P. Paparu, P. Rubaihayo, J. D. Kelly, and J. Steadman. 2016. Assessment of the common bean rust prevalence and variability in Uganda. African J. Plant Res. (in review).

Presentations, Dissertations, Patents and Awards:

Poster paper presentations

1. Alladassi M.E.B, S.T Nkalubo, C Mukankusi, J Kelly, and Urrea C. 2016. Identification of Common Bacterial Blight Resistant Sources for the Bean Breeding Program in Uganda. *Poster Presented during the Pan African Grain Legume and World Cowpea Conference 28 February – 4 March 2016, Livingstone, Zambia*
2. Berry, M., Wiesinger, J., Nchimbi-Msolla, S., Miklas, P., Porch, T., Fourie, D., and Cichy, K.A. (2016). Breeding for a Fast Cooking Bean: Study of Genotypes across Environments to Determine Phenotypic Stability in Phaseolus vulgaris. *Poster Presentation, Pan African Grain Legumes Research Conference, Livingstone, Zambia March 3*.
3. Cichy, K.A., Wiesinger, J., Mendoza, F., Hooper, S., Grusak, M.A., Glahn, R., and Kelly, J. (2016). A Nutritional Profile of Fast Cooking Bean Germplasm. *Poster Presentation, Pan African Grain Legumes Research Conference, Livingstone, Zambia March 4.*
4. Cichy, K.A. and Rueda, J.A. (2016). Beans as Ingredients in "Better for You" Foods at the *Michigan Agri-Business Association Winter Conference, Michigan Bean Shippers*.
5. Dramadri, I. and J. D. Kelly. 2016. Genome wide association analysis for drought tolerance responses in Andean common beans. *Poster presented National Association Plant Breeders-NAPB conference, North Carolina State Univ. Raleigh NC*.
6. Katuuramu, D.N., Kelly, J.D., Glahn, R.P., and Cichy, K.A. (2016). Field Evaluation of Nutritionally Superior Common Bean Genotypes with Farmers in Three Agro-ecological Zones in Uganda. *Oral Presentation, Pan African Grain Legumes Research Conference, Livingstone, Zambia Feb 29*.
7. Kelly, J.D. (2016). Genome-Wide Association Analysis of Traits Associated with Drought Tolerance in Common Bean. *Oral Presentation, Pan African Grain Legumes Research Conference, Livingstone, Zambia Feb 29*.
8. Odogwu A. B, Nkalubo S. T, Paparu P, Mukankusi C, Rubaihayo P, Steadman J and Kelly J. D. (2016). Yield loss Associated with Common Bean Rust on Germplasm Evaluation in Uganda. *Poster Presented during the Pan African Grain Legume and World Cowpea Conference 28 February – 4 March 2016, Livingstone, Zambia*;
9. Odogwu A. B., S.T. Nkalubo, C. Mukankusi, P. Rubaihayo, C. A. Urrea, J. Steadman and J. D. Kelly. (2016). New Sources of Resistance to Bean Rust Established with SSR Markers in Uganda. *Poster Presented during the Pan African Grain Legume and World Cowpea Conference 28 February – 4 March 2016, Livingstone, Zambia*
10. Wang, W, Cichy, KA, Kelly, JD, Mukankushi, CM. (2015). QTL Analysis for Fusarium Root Rot Resistance in Common Bean (Phaseolus vulgaris). *Biennial Bean Improvement Cooperative Meeting, Niagara Falls, Canada. November 1-4, 2015*

- Three scientific articles drafted and submitted/pending to scientific Journals for publication and these include; (i) Occurrence of *Uromyces appendiculatus* and response of selected common bean cultivars to the different races of the pathogen collected from Uganda (drafted but pending submission)
- MSc. Thesis by Mr. Alladassi Mahulé Elysé Boris entitled "*Genetics of resistance to Common Bacterial Blight disease of Common Bean* (*Phaseolus vulgaris L.) in Uganda*" submitted to postgraduate school Makerere University Uganda for examination.

Non-refereed Publications:

1. Acosta-Gallegos, J.A., Y. Jiménez Hernández, V. Montero Tavera1, M. A. Martínez Gamiño, M. D. Herrera, J. L. Anaya López, and J.D. Kelly. 2016. Release of pinto Raramuri dry bean for the semi-arid highlands of Central Mexico. Bean Improvement Cooperative Annual Report 59:253.
2. Berry, M., Wiesinger, J, Nchimbi-Msolla, S, Miklas, P, Porch, T, Fourie, D, and Cichy, K. 2016. Breeding for a fast cooking bean: a study of genotypes across environments to determine stability of the cooking time trait in Phaseolus vulgaris. Bean Improvement Cooperative Annual Report 59:33-34
3. Chilvers, M.I., J.L. Jacobs, A.M. Byrne, and J.D. Kelly. 2016. Screening Andean dry bean germplasm for root rot resistance. Bean Improvement Cooperative Annual Report 59:105-106.
4. Cichy, K.A. and F. Mendoza. 2016. Color retention in canned black beans. Bean Improvement Cooperative Annual Report 59:25-26.
5. Zuiderveen, G.H., B. Padder, K. Kamfwa and J. D. Kelly. 2016. Mapping the Co-1 locus conditioning anthracnose resistance in common bean. Bean Improvement Cooperative Annual Report 59:17-18.

Patents:

1. Plant Variety Protection Certificate 201500009 was issued for Snowdon White Kidney Bean on 2/26/2016.
2. Plant Variety Protection No. 201500008 was issued for Eldorado pinto bean on 7/6/2016.
3. Plant Variety Protection No 201500385 was issued for Powderhorn great northern bean on 6/3/2016

Thesis:

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3. Hoyos-Villegas, V. (2015). Identification of genomic regions and development of breeding resources associated with drought tolerance in common bean (Phaseolus vulgaris L.). Doctoral Dissertation, Michigan State University, East Lansing MI. 132pp.
4. Nakedde, T. (2015). Identification and mapping of QTL associated with Fusarium root rot resistance and root architecture traits in black beans (Phaseolus vulgaris L.). Master's Thesis, Michigan State University, East Lansing. MI. 119pp.
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6. Wang, W. (2016). QTL analysis and candidate genes identification associated with Fusarium root rot resistance in common beans (Phaseolus vulgaris). M.S. Thesis, Michigan State University.
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Annex 2: Description of the 138 Ugandan common bean germplasm screened for resistance to rust disease

S/N	‡Genotype	Genotype Type	Stress response	Gene pool
1	NABE 1	Commercial	Susceptible to multiple constraints	Andean
2	NABE 2	Commercial	BCMV resistant/ Drought tolerant	Mesoamerican
3	NABE 3	Commercial	Bean common mosaic virus BCMV resistant	Mesoamerican
4	NABE 4	Commercial	CBB resistant/ALS	Andean
5	NABE 5	Commercial	CBB resistant	Andean
6	NABE 6	Commercial	Unknown	Mesoamerican
7	NABE 11	Commercial	CBB resistant/ALS	Andean
8	NABE 13	Commercial	Root rot/low soil fertility tolerant	Andean
9	NABE 14	Commercial	Root rot/low soil fertility tolerant	Andean
10	NABE 15	Commercial	Anthracnose tolerant	Andean
11	NABE 16	Commercial	Anthracnose tolerant	Andean
12	NABE 17	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
13	NABE 18	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
14	NABE 19	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
15	NABE 20	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
16	NABE 21	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
17	NABE 22	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
18	NABE 23	Commercial	Anthracnose, BCMV, ALS tolerant	Andean
19	K131	Commercial	BCMV/black root/ anthracnose resistant	Mesoamerican
20	K132	Commercial	Unknown	Andean
21	DAB 474	Introduced	Drought tolerant	Andean
22	DAB 475	Introduced	Drought tolerant	Andean
23	DAB 478	Introduced	Drought tolerant	Andean
24	DAB 479	Introduced	Drought tolerant	Andean
25	DAB 480	Introduced	Drought tolerant	Andean
26	DAB 482	Introduced	Drought tolerant	Andean
27	TU	Introduced	Anthracnose differential	Mesoamerican

S/N	‡Genotype	Genotype Type	Stress response	Gene pool
28	TO	Introduced	Anthracnose differential	Mesoamerican
29	Michigan dark red kidney	Introduced	Anthracnose differential	Andean
30	Michelite	Introduced	Anthracnose differential	Mesoamerican
31	Widusa	Introduced	Anthracnose differential	Mesoamerican
32	PI207262	Introduced	Anthracnose differential	Mesoamerican
33	AB 136	Introduced	Anthracnose differential	Mesoamerican
34	G2333	Introduced	Anthracnose differential	Mesoamerican
35	SCN-4	Introduced	Drought tolerant	Mesoamerican
36	SCN-6	Introduced	Drought tolerant	Mesoamerican
37	SEN-80	Introduced	Drought tolerant	Mesoamerican
38	SCN-5	Introduced	Drought tolerant	Mesoamerican
39	SEN-34	Introduced	Drought tolerant	Mesoamerican
40	DOR-500	Introduced	Drought tolerant	Andean
41	SCR-5	Introduced	Drought tolerant	Mesoamerican
42	SCR-35	Introduced	Drought tolerant	Mesoamerican
43	SCN-10	Introduced	Drought tolerant	Mesoamerican
44	SCN-12	Introduced	Drought tolerant	Mesoamerican
45	SCN-37	Introduced	Drought tolerant	Mesoamerican
46	DOR-364	Introduced	Drought tolerant	Andean
47	SEN-95	Introduced	Drought tolerant	Mesoamerican
48	SCN-8	Introduced	Drought tolerant	Mesoamerican
49	SEN-46	Introduced	Drought tolerant	Mesoamerican
50	SCN-1	Introduced	Drought tolerant	Mesoamerican
51	SCR-26	Introduced	Drought tolerant	Mesoamerican
52	SEN-56	Introduced	Drought tolerant	Mesoamerican
53	SCR-18	Introduced	Drought tolerant	Mesoamerican
54	SEN-92	Introduced	Drought tolerant	Mesoamerican

S/N	‡Genotype	Genotype Type	Stress response	Gene pool
55	SCN-3	Introduced	Drought tolerant	Mesoamerican
56	SCR-25	Introduced	Drought tolerant	Mesoamerican
57	SEN-90	Introduced	Drought tolerant	Mesoamerican
58	California small white (CSW)643	Introduced	Rust differential,1983	Mesoamerican
59	PC50	Introduced	Rust differential,2002	Andean
60	US#3	Introduced	Rust differential,1983	Andean
61	NEP 2 (G5693)	Introduced	Rust differential,1983	Mesoamerican
62	Redland Pioneer	Introduced	Rust differential,2002	Andean/Mesoamerican
63	GN1140	Introduced	Rust differential,2002	Mesoamerican
64	Early Gallatin	Introduced	Rust differential,2002	Andean
65	#Mexico 309	Introduced	Rust differential,2002	Mesoamerican
66	Compuesto Negro Chimaltenango(CNC)	Introduced	Rust differential,2002	Mesoamerican
67	Montcalm	Introduced	Rust differential,2002	Andean
68	DAB 476	Introduced	Drought tolerant	Andean
69	DAB 477	Introduced	Drought tolerant	Andean
70	Mexico 235	Introduced	Rust differential,2002	Mesoamerican
71	Ecuador 299	Introduced	Rust differential,1983	Mesoamerican
72	Kentucky Wonder (KW) 814	Introduced	Rust differential,1983	Mesoamerican
73	CIAT Aurora	Introduced	Unknown	Unknown
74	51051	Introduced	Rust differential,1983	Mesoamerican
75	CNCPI181996	Introduced	Unknown	Unknown
76	Aurora	Introduced	Rust differential, 2002	Mesoamerican
77	Teebus	Introduced	Rust resistant	Unknown
78	#Ouro Negro	Introduced	Rust resistant	Mesoamerican
79	PI 181996	Introduced	Rust differential,2002	Mesoamerican
80	PI 260418	Introduced	Rust differential,2002	Andean
81	Golden Gate Wax (GGW)	Introduced	Rust differential,2003	Andean

S/N	†Genotype	Genotype type	Gene pool	S/N	Genotype	Genotype type	Gene pool
82	Kamuli Yellow	††Landrace	Unknown	101	Kamuli black	Landrace	Unknown
83	Lira Yellow	Landrace	Unknown	102	Kamula	Landrace	Unknown
84	Kajeru	Landrace	Unknown	103	Kaborole red	Landrace	Unknown
85	Kinbwogegwa	Landrace	Unknown	104	Lira Pink	Landrace	Unknown
86	Kamwenge Purple	Land race	Unknown	105	Kaborole Purple	Landrace	Unknown
87	Mukono cream	Landrace	Unknown	106	Kitinda	Landrace	Unknown
88	Kamuli Purple	Landrace	Unknown	107	Obuhiumbaobukere	Landrace	Unknown
89	Mpigi Pink	Land race	Unknown	108	Wakiso cream	Landrace	Unknown
90	Masindi red	Land race	Unknown	109	Masindi Purple	Landrace	Unknown
91	Mutike	Landrace	Unknown	110	Nambale (U00143)	Landrace	Unknown
92	Kanyebwa long	Landrace	Unknown	111	Ndume (U00069)	Landrace	Unknown
93	Nkalyebawere	Landrace	Unknown	112	Mukono cream	Landrace	Unknown
94	Mbarara Purple	Landrace	Unknown	113	Kamwenge cream	Landrace	Unknown
95	Kapchorwa White	Landrace	Unknown	114	Zebra	Landrace	Unknown
96	Kaborole Maroon	Landrace	Unknown	115	Kanyebwa (U00271)	Landrace	Unknown
97	Nabufumbo	Landrace	Unknown	116	Wakiso brown	Landrace	Unknown
98	Bumwufu	Landrace	Unknown	117	Mpigi white	Landrace	Unknown
99	Lira White	Landrace	Unknown	118	Kamuli White	Landrace	Unknown
100	Kahura	Landrace	Unknown	119	Kaborole cream	Landrace	Unknown
120	Mukono cream	Landrace	Unknown	131	Mukono black	Landrace	Unknown
121	Kankulyembaluke	Landrace	Andean	131	U00236	Landrace	Unknown
122	Kanyawama	Landrace	Unknown	132	Kamuli pink	Landrace	Unknown
123	Roba	Landrace	Unknown	133	Apac cream	Landrace	Unknown
124	Masindi yellow	Landrace	Andean	134	Masindi cream	Landrace	Unknown
125	Kamuli red	Landrace	Unknown	135	Kamwenge Maroon	Landrace	Unknown
126	Kamwenge red	Landrace	Unknown	136	Masaka red	Landrace	Unknown
127	Apac pink	Landrace	Unknown	137	Masaka yellow	Landrace	Unknown
128	Kanyamunyo	Landrace	Unknown	138	Nyekera	Landrace	Unknown
129	Apac pink	Landrace	Unknown				

Annex 2: Drought nursery and yield obtained under both irrigated and non-irrigated trial

NAME	ORIGIN	Nebraska Code	ADP CODE	Irrigated (kg/ha)	Non-Irrigated (kg/ha)
EG 21	AF-5	NE27-14-100	ADP-100	1267	279
JESCA	**AF-7**	**NE27-14-102**	**ADP-102**	**1528**	**1142**
OPS-RS4	AF-18	NE27-14-113	ADP-113	1388	0
OPS-RS1	AF-19	NE27-14-114	ADP-114	1043	60
A-800	AF-21	NE27-14-116	ADP-116	1027	112
JENNY	AF-28	NE27-14-123	ADP-123	892	0
RUHONDELA	TZ-25	NE27-14-25	ADP-25	559	115
MRONDO	**TZV-41**	**NE27-14-41**	**ADP-41**	**1011**	**824**
RH NO.12	TZV-45	NE27-14-45	ADP-45	384	28
MSOLINI	**TZV-48**	**NE27-14-47**	**ADP-47**	**1148**	**604**
WALLACC 773-V98	BC-149	NE27-14-603	ADP-603	779	158
1132-V96	BC-152	NE27-14-605	ADP-605	564	186
MAULASI	**TZV-62**	**NE27-14-61**	**ADP-61**	**695**	**582**
OAC LYRICK	BC-344	NE27-14-616	ADP-616	252	197
RED RIDER	**BC-347**	**NE27-14-617**	**ADP-617**	**945**	**536**
AC ELK	BC-351	NE27-14-618	ADP-618	1229	176
MAULASI	TZV-63	NE27-14-62	ADP-62	205	46
DOLLY	BC-401	NE27-14-624	ADP-624	494	0
BADILLO	BCV-34	NE27-14-626	ADP-626	0	0
H9659-21-1	BCV-500	NE27-14-627	ADP-627	1126	35
H9659-27-7	BCV-501	NE27-14-628	ADP-628	1471	253
CAPRI	**BC-95**	**NE27-14-641**	**ADP-641**	**2074**	**526**
CARDINAL	BC-108	NE27-14-643	ADP-643	881	398
RED KLOUD	BC-148	NE27-14-648	ADP-648	621	89
KARDINAL	BC-254	NE27-14-657	ADP-657	1359	223
KRIMSON	**BC-261**	**NE27-14-660**	**ADP-660**	**1280**	**914**
USCR-CBB-20	BC-264	NE27-14-663	ADP-663	855	214
VA-19	BC-277	NE27-14-667	ADP-667	712	99
CRAN-09	BC-318	NE27-14-668	ADP-668	814	136
HOOTER	**BC-397**	**NE27-14-678**	**ADP-678**	**936**	**532**
IJR	BCV-272	NE27-14-683	ADP-683	813	185
PINK PANTHER	BC-398	NE27-14-687	ADP-687	832	220
BUKOBA	TZ-7	NE27-14-17	ADP-7	146	0
NJANO-DOLEA	TZV-72	NE27-14-71	ADP-71	195	0
MASUSU	TZV-74	NE27-14-73	ADP-73	1925	295
KABLANKETI	TZV-84	NE27-14-80	ADP-80	0	83

KABLANKETI	TZV-85	NE27-14-81	ADP-81	728	17
KABLANKETI	TZV-92	NE27-14-88	ADP-88	445	24
W616560	TZV-95	NE27-14-91	ADP-91	1348	0
Bilfa 4	AF-2	NE27-14-97	ADP-97	62	0
MARQUIS	NE1-11-27	NE28-14-46	MARQUIS	654	260
MATTERHORN		NE28-14-45	MATTERHORN	867	41
MERLOT		NE28-14-49	MERLOT	691	72
NE14-09-26	10F-0025	NE28-14-5	SB-740	1034	0
NE14-09-16	10F-0018	NE28-14-3	SB-743	793	0
NE14-09-49	10F-0045	NE28-14-7	SB-747	1277	0
NE14-09-85	10F-0073	NE28-14-11	SB-754	702	197
NE14-09-19	NE 1419	NE28-14-16	SB-761	1196	69
NE14-09-87	10F-0075	NE28-14-12	SB-770	1848	237
NE14-09-106	10F-0090	NE28-14-13	SB-774	367	99
NE14-09-23	10F-0023	NE28-14-4	SB-776	489	262
NE14-09-6	10F-0012	NE28-14-1	SB-781	1291	55
NE14-09-111	10F-0095	NE28-14-14	SB-783	1617	237
NE14-09-50	10F-0046	NE28-14-8	SB-787	1177	92
NE14-09-113	10F-0298	NE28-14-15	SB-791	707	0
NE14-09-10	10F-0015	NE28-14-2	SB-793	714	0
NE14-09-78	10F-0069	NE28-14-10	SB-804	1072	123
NE14-09-46	10F-0043	NE28-14-6	SB-812	262	0
NE14-09-65	10F-0058	NE28-14-9	SB-815	260	251
STAMPEDE		NE28-14-50	STAMPEDE	1682	52

Preliminary yield (kg/ha) for drought bean lines from CIAT

S/N	Line	Yield kg/ha	S/N	Line	Yield kg/ha
1	SMC 45	1700	85	SER 384	1300
2	SMC 44	1950	87	SER 386	1700
3	SMC 146	1650	88	SER 387	1000
4	SMC 147	1750	90	SER 389	1500
5	SMC 148	1150	91	SER 390	900
6	SMC 150	1600	92	SER 391	1700
7	SMC 151	2250	93	SMC 165	1800
8	SMC 152	2150	94	SMC 166	900
9	SMC 153	2000	95	SMC 167	900
10	SMC 154	1400	96	SMC 168	1275
11	SMC 155	969	97	SMC 169	1000

S/N	Line	Yield kg/ha	S/N	Line	Yield kg/ha
12	SMC 156	1850	98	SMC 170	1250
13	SMC 157	1500	99	SMC 171	1000
14	SMC 158	1750	100	SMC 172	750
15	SMC 159	1700	101	SMC 173	1000
16	SMC 160	2500	103	SMC 175	688
17	SMC 149	1938	104	SMC 176	1500
18	SMC 161	1125	105	SMC 177	750
19	SMC 164	1750	106	SMC 178	500
20	SMN 57	1700	107	SMC 179	875
21	SMN 58	1750	108	SMC 180	1000
22	SMN 59	1500	109	SMC 181	1250
23	SMN 60	1813	110	SMC 182	1250
24	SMN 61	1950	111	SMC 183	1281
25	SMN 62	600	112	SMC 184	1250
26	SMN 63	1200	113	SMC 185	1281
27	SMR 99	2100	114	SMC 186	1250
28	SMR 100	2188	115	SMC 187	938
29	SMR 101	1600	116	SMC 188	1750
30	SMR 102	2208	117	SMC 189	1688
31	SMR 103	2250	118	SMC 190	1063
32	SMR 104	1958	119	SMC 191	875
33	SMR 105	1500	120	SMC 192	1250
34	SMR 106	2438	121	SMC 193	1750
35	SMR 107	1906	122	SMC 194	1438
36	SMC 162	4125	123	SMC 195	1375
37	SMR 108	1200	124	SMC 196	1188
38	SMR 109	1850	125	SMC 197	1063
39	SMR 110	1500	126	SMC 198	1000
40	SMR 111	1800	127	SMC 199	750
41	SMR 112	1300	128	SMC 200	500
42	SMR 113	3750	129	SMC 201	1125
43	SMR 114	1667	131	SMC 203	750
44	SMR 15	3250	132	SMC 204	1750
45	SMR 116	2875	133	SMC 205	750
46	SMR 117	1750	134	SMC 206	900
47	SMR 118	1163	135	SMC 207	1250
48	SMR 119	2750	136	SMC 208	1313

S/N	Line	Yield kg/ha	S/N	Line	Yield kg/ha
49	SMR 123	2450	139	SMC 211	1438
50	SMR 124	2500	140	SMN 64	1938
51	SMR 125	2875	142	SMR 132	813
52	SMR 126	2000	143	SMR 133	1469
53	SMR 127	2000	144	SMR 134	1250
54	SMR 128	1400	146	SMR 136	1250
55	SMR 129	1550	147	SMR 137	1250
56	SMR 130	1450	148	SMR 138	938
57	SMR 131	1333	150	SMR 140	750
58	SEC 45	1425	151	SMR 141	625
59	SEC 46	1550	152	SMR 142	1083
60	SEC 47	1250	153	SMR 143	1875
61	SEC 48	1525	154	SMR 144	1594
62	SEC 49	1250	155	SMR 145	1063
63	SEC 50	1750	156	SMR 146	813
64	SEC 51	2100	157	SMR 147	1000
65	SEC 52	1150	158	SMR 148	1000
66	SEC 53	1200	159	SMR 149	1000
67	SEC 54	1400	160	SMR 150	906
69	SEC 56	1050	162	SMR 152	2063
70	SEC 57	1950	164	SMR 153	1938
71	SEC 58	1450	165	SMR 155	1563
72	SEC 59	1250	166	SMR 156	1250
73	SEC 60	1785	167	SMR 157	1375
74	SEC 61	1950	168	SMR 158	1250
75	SEC 62	950	169	SMR 159	1286
76	SER 379	1100			
77	SER 380	900			
78	SER 381	850			
79	SER 382	600			
80	SER 383	1700			

Evaluation of families of the drought tolerant larges seed genotypes in 2015B

SN	Seed population	No. of families selected
1	PIC-008	13
2	PIC-040	17
3	PIC-012	12
4	PIC-033	13
5	PIC-009	15
6	PIC-027	12
7	PIC-101	11
8	PIC-007	12
9	PIC-004	12
10	PIC-023	12
11	PIC-036	12
12	PIC-011	12
13	PIC-105B	12
14	PIC-035	12
15	PIC-030	12
16	PIC-105A	12
17	PIC-098A	12
18	PIC-026	11
19	PIC-010	12
20	PIC-001	12
21	PIC-028	13
22	PIC-003	12
23	PIC-002	13
24	PIC-013	12
25	PIC-006	6
26	PIC-017	11
27	PIC-024	6
28	PIC-005	12
29	PIC-034	12
30	PIC-038	11
31	PIC-103	12
32	PIC-029	12
33	PIC-014	12
34	PIC-031	12
35	PIC-099B	12
	Total	**416**