Improving Genetic Yield Potential of Andean Beans with Increased Resistances to Drought and Major Foliar Diseases and Enhanced Biological Nitrogen Fixation (BNF) (S01.A3)

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I. Abstract of Research and Capacity Strengthening Achievements

Common bean (*Phaseolus vulgaris* L.) is the most important grain legume consumed in Uganda and Zambia. The development of improved bean varieties and germplasm with high yield potential, healthy root systems, improved biological nitrogen fixation (BNF) with resistance to multiple diseases, and sustained or improved water use efficiency under limited soil water conditions are needed to increase profit margins and lower production costs. An improved understanding of plant traits and genotypes with resistance to multiple stresses from abiotic (drought) and biotic (root and foliar pathogens) sources will provide unique genetic materials for enhanced plant breeding methods and sources to study plant tolerance mechanisms in common bean. Improvements in current understanding of the physiology of drought and evapotranspiration and the genetics of drought tolerance in common bean and the development of effective molecular and quantitative methods for the selection of drought tolerance are needed. 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 shorter cooking time. Results of this project would contribute to improved yield, farm profitability and human resources in the host countries and indirect benefit to participating U.S. institutions and bean producers.

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 5,000 MT. To avert future food shortages and feed the growing population of 13 M, 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 more than 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 percent 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 BNF 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 biological nitrogen fixation (BNF) 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), Ecuador and the U.S.**

Assemblage of different nurseries in Uganda

Different bean nurseries were assembled either through direct collection from within the country, importation from other countries or reassembling of already existing germplasm. The nurseries collected and assembled are inclusive of the following;

1. Assembled a germplasm collection of 150 accessions for screening against rust
2. Anthracnose and root rot nursery comprising of 56 lines pyramided with two–three anthracnose genes (either *Co-4*^{2}, *Co-4*^{3} *Co-5,* and /or *Co-9*) and one root rot resistant gene (*Pythium*)
3. Anthracnose differentials of 12 bean lines
4. Angular leaf spot (ALS) differential set of 12 bean lines
5. Drought nursery comprising of 51 lines obtained from CIAT
6. High iron and zinc nursery comprising of 62 lines

7. The Andean diversity panel (ADP)
8. Bean stem maggot (BMS) nursery with 16 BSM tolerant lines
9. Assembled 330 root rot resistant/tolerant lines
10. Collected 318 bean accessions from different agroecologies within Uganda

Development of a drought screening protocol

A screen house based watering regime protocol for drought has been adopted in NaCRRI.

Seed increase or the different nurseries

For the different nurseries acquired, field screening, characterization and multiplication of the acquired germplasm were conducted on station at NaCRRI. Depending on available seed one to two, meter rows were established and seed planted at spacing of 50 and 10 cm between and within rows respectively. The seed obtained will be utilized in further characterization and breeding activities to introgression resistance within the farmer preferred Andean varieties.

Screen the disease nursery to different pathogens in greenhouse in Uganda.

This has not yet been undertaken considering that isolation of diseased plant samples has just been initiated. Diseased sample collection is still being undertaken in the different agroecologies within the country.

Screen the drought nursery in Uganda to intermittent drought stress.

A germplasm set of 318 accessions were screened in the field and 144 selected for drought screening in screen house using the adopted drought screening protocol. This will be undertaken in the next financial year.

Cross sources of resistance to different stresses made with large seeded lines with contrasting colors in Uganda

A set of 22 crosses were made between Andean market class varieties from Uganda and drought, bruchid and stem maggot imported germplasm. These will be evaluated in the field next season.

Conduct sensory evaluation of elite lines with superior cooking time and mineral bioavailablity in Uganda.

A total of 12 elite lines from the ADP are being multiplied and will undergo sensory evaluation on–farm next year (2015) using participatory variety selection trails. The application to conduct this sensory evaluation has been submitted to Michigan State University's Institutional Review Board and was approved as Exempt.

Drought and Disease Screening in Nebraska

1. Two bean nurseries Andean Bean Coordinated Agricultural Project (Bean-CAP) and 81 Andean Diversity Panel (ADP) were grown under drought (DS) and nondrought stress (NS) at Mitchell, NE in 2013. The NS and DS plots received 453 and 248 mm, of total water, respectively and a total of 63.2 mm of precipitation occurred after flowering when the stress was applied. Drought stress was moderate (DII = 0.47) in the Andean BeanCAP

nursery. Yield under NS and DS ranged from 1402 to 4011 kg/ha, and from 682 to 2847 kg/ha, respectively. Using geometric mean (GM) as the major selection index, Wallace 773-V98 was found to be well adapted to both NS and DS environments. Kardinal Kidney had a GM of 2787 kg ha^{-1} and the lowest yield reduction (8.8%). GM in Drake, K-42, UC Canario 707, Sacramento, Beluga, Red Kote, USDK-CBB-15, Silver Cloud, Charlevoix, USCR-9, CDRK and UC Nichols had a GM ranged from high of 1803 to 1313 kg ha^{-1}.

2. Drought stress was less severe (DII = 0.38) in the ADP nursery. Yield under NS and DS ranged from 11267 to 3791 kg/ha, and from 717 to 2572 kg/ha, respectively. Using GM as the major selection index, ADP-7 (Bukoba), ADP-626 (Dolly), and ADP-41 (Morondo) were found to be well adapted to both NS and DS environments. DAP-97 (Bilfa 4) had a GM of 2645 kg ha^{-1} and one the lowest yield reduction (12.5%). The same set of lines was evaluated in North Platte, NE for reaction to common bacterial blight and ADP-97 (Bilfa 4), ADP-113 (OPS-RS4), ADP-123 (Jenny), and ADP-626 (Badillo) had the lowest score (2.3). Cardinal had the lowest CBB (4.0) followed by VA-19 (4.9), and Capri, Michigan Improved Cran, Myasi, and Red Kanner with a score of 5.0, whereas Fiero and Drake had the highest scores of 8.3 in the BeanCAP nursery.
3. Both the ADP and BeanCAP Andean Panel were screened for reaction to CBB Nebraskan strains SC-4A and LB-2 at North Platte, NE, in 2014. H9659-21-1 had the lowest CBB score of 2.7 followed by Incomparable, RH No.1, and Witrood with a score of 2.9. Badillo, Kabuku, Njano-Dolea, OPS-RS4, INIAP 480, and Kisapuru had a score from 3.0 to 4.4. The ADP and BeanCAP lines were also evaluated to terminal drought where irrigation was stopped at flowering, plots were harvested and data are being processed. The data will be combined with the 2103 experiments to make comparisons and selections.

Conduct sensory evaluation of elite lines with superior cooking time and mineral bioavailablity in Michigan.

Dr. Fernando Mendoza, in Chemical Engineering and Bioprocess at Michigan State University began working on the LIL project on March 1, 2014. He specializes in nondestructive sensing techniques, imaging spectroscopy and image analysis techniques for the property characterization and evaluation of external and internal quality of foods. The objectives of the program were to

- Implement a color imaging system for calibrated color measurements of raw and processed dry bean seeds and for the evaluation of their overall surface appearance and morphological characteristics.
- Implement hyperspectral imaging and NIR techniques for the nondestructive quality characterization and evaluation of internal properties of raw and soaked beans and their relationships with physicochemical, sensorial and nutritional properties.

IV. Accomplishments for the period FY13–14

1. Sensory evaluations were performed on canned black beans aimed to develop standard scales or categories for scoring color and appearance traits. The quality charts were based on a five-point Hedonic scale represented by images on a chart (see Figures 9.1–9.2). The color chart represents the black bean color retention (or discoloration) from very light brown to very dark, and the overall appearance chart represents the seed shape, splits, clumps, color uniformity, and visual aspect, such as surface texture varying from "unacceptable" to "excellent" appearance. The proposed quality charts made easier the rating of large number of canned bean samples and improved the agreement among panelists' ratings.

2. A machine vision system was developed for the automatic inspection of color, appearance and morphological properties (shape and size) of raw and processed dry bean seeds. Computerized image analysis techniques, multivariate statistical analysis and pattern recognition methods were used for prediction and sorting of color and appearance traits among others in canned black beans. Figure 9.3 shows the implemented computer vision system. We concluded that the implemented machine vision technique is promising for assessing bean canning quality as predicted by expert human inspection. The implemented machine vision technique can successfully replace the subjective, tedious, and costly visual sensory analysis at research facilities and bean canning industries. Figure 9.5 shows the model performance for predicting color and appearance rates (a) and b), respectively, using color and texture image information. A manuscript reporting these findings is currently in preparation to be submitted in November 2014 to the *Journal of the Science of Food and Agriculture*.

3. A set of 230 Andean Diversity Panel genotypes grown at the Montcalm Research Farm in 2013 were evaluated for cooking time. In addition whole, raw seed was also scanned with NIR. The NIR data consist of data from 1050 wavelengths from 400 nm to 2498 nm. The NIR data were used try to predict genetic variability for cooking time in the ADP lines. Preliminary analysis using multiple regression models and sequential forward selection for selecting the best Vis/NIR wavelengths showed descent prediction results for cooking time when a large number of latent variables were used in the model. Large number of variables could be explained by the complexity of the bean microstructure and their interactions with the light. Figure 9.7 presents the prediction performance increasing number of latent variables (or wavelengths). Figure 9.8 depicts the relationships between the measured and predicted cooking time (min) when 40 wavelengths are used. The standard error of prediction was in average 10±1 min, and hence, improved measurements using transmittance mode instead of reflectance would be the next design to test in this study.

4. Currently a hyperspectral imaging technique has been used for testing different bean types (more than 500 types) with the aim to improve the prediction of internal traits in canned beans from raw seeds. The algorithms for image segmentation and analysis using a huge amount of spectral and spatial data are being developed.

Conduct evaluation of elite lines for cooking time in Nebraska.

In 2013, the ADP and BeanCAP Andean panel grown under normal and drought stress in NE were cooked. Seeds were soaked overnight (16 hours) then, placed in the Mattson Bean Cooker, and beans were cooked when 80 percent of the weighted plungers dropped. On average, the beans under normal conditions cooked at 65' and bean under drought stress at 106'. Under environments, normal and drought stress, RH No.11, Soya, and RH No.2 had the lowest cooking time under both environments (58', 61', and 62' and 59', 52', and 51' for normal and drought stress, respectively). Musanze, UCD 0801, and Bilfa 4 were affected by the drought stress with a cooking time of 171', 176', and 182' compared to the normal conditions of 58', 100', and 51', respectively. Cooking time of the same entries grown in 2014 under both normal and drought stress will also be tested.

<u>**Objective 2.**</u> **Characterize pathogenic and genetic variability of isolates of foliar pathogens collected in Uganda, Zambia and Ecuador 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.**

Initiate the collection of isolates from the different production regions of Uganda

A survey was conducted in two agroecologies, nine (9) districts and 18 subcounties, where a total of 192 diseases bean samples were collected comprising of Rust (84), ALS (52), CBB (11), Anthracnose (26) and Root rot (19) see Table 1. During this sample collection and survey GPS positions for these locations were also taken. Samples are currently undergoing isolation and purification. This survey exercises will be continued next financial year to cover the other agroecologies.

Increase seed of the differentials for ANT, ALS and rust in Uganda

For each of the collected germplasm, one two-meter line was planted for seed increase and initial characterization.

Race characterization of ANT, ALS and Rust in Uganda.

Diseased samples were collected and are undergoing isolation and purification and single spore isolation. Characterization of these isolates will be conducted in FY 15. Isolates of ANT sent to Michigan State University were characterized as race three.

Utilize the mobile nursery protocol to determine the effectiveness or rust resistance genes in genotypes.

A total of 140 bean accessions including 80 land races, 19 released varieties and 41 introduced lines were screened in the field for rust without inoculation. The experiment was laid out in the field using an alpha lattice design with three replicates. Natural field inoculation was relied on by planting susceptible K123 as spreaders for rust disease. Data were taken on resistance/susceptibility, disease incidence, disease severity, size and type of pustule, number of plants per row. The performance of the accessions is shown in Table 2 and from this data, it was noted that at least 20 genotypes did not show any symptoms for rust disease at NaCRRI. The table shows a whole range of variations in the genotypes reaction to rust, BCMV and root rot disease.

These results will be verified in the second screening experiment. Also the rust differentials have been requested for from the University of Nebraska and will be arriving in the country in the near future. It is hoped that the mobile nursery technique will be employed next year to determine the rust pathotypes present.

Increase seed of these selected genotypes for inclusion in the mobile nursery.

This activity will be undertaken on acquisition of the rust differentials from Nebraska

Choose the most relevant races of ANT, ALS and rust and strains of CBB for screening breeding nurseries in Uganda.

This activity is yet to be initiated because isolates have still to be characterized.

Activities underway in Zambia

1. Sixty (60) lines were evaluated for reaction to root rot and foliar diseases at Misamfu, Zambia. Within this group 31 lines showed root rot resistance; two lines showed resistance to ALS; three lines were resistance to CBB; two lines showed resistant to Rust
2. The line PI 321094-D showed resistance to Root rot, ALS, CBB and Anthracnose
3. ADP 188 (G1375) showed resistance to CBB, RR, and Rust resistance, the line also showed intermediate reaction to CBB in North Platte, Nebraska.
4. NE 34-12-50 showed resistance to CBB, ALS and Rust, and to CBB in Nebraska, and had the highest yield per plot in Zambia. These materials will be used as parents in future breeding efforts at ZARI.
5. Seed for Rust differential will be received from Nebraska and will be used for rust screening in Zambia.
6. In the ALS Nursery Planted at Misamfu in a RCBD, with three reps comprising 45 lines, 15 lines showed resistance to ALS, while 24 were resistant to ALS and about 28 lines showed resistance to CBB while most of the lines did not show symptoms of rust.

Activities underway at University of Nebraska

At UNL a technician was hired to help with the greenhouse identification of rust races. A future visit to Zambia in Nov 2014 is planned to explain how to collect and send samples of rust for our analysis and to explain our plan for identifying and incorporating resistance and interaction of the FtF and NIFA projects; and to address other foliar diseases such as CBB, BCMV and abiotic problems such as drought as a contribution of germplasm for your and the local bean breeding activities.

<u>Objective 3.</u> 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.

In Michigan a genome-wide association study (GWAS) using a global Andean diversity panel (ADP) of 237 genotypes of common bean, *Phaseolus vulgaris* was conducted to gain insight into the genetic architecture of several agronomic traits controlling phenology, biomass, yield components and seed yield. The panel was evaluated for two years in field trials and genotyped with 5398 single nucleotide polymorphism (SNP) markers. After correcting for population structure and cryptic relatedness, significant SNP markers associated with several agronomic traits were identified. Positional candidate genes, including *Phvul.001G221100* on the *Phaseolus vulgaris* (Pv) chromosome 01 that associated with days to flowering and maturity, were identified. Significant SNPs for seed yield were identified on Pv03 and Pv09, where several previous studies have also reported quantitative trait loci (QTL) for yield. The geographic distributions of minor alleles with a larger positive effect on seed yield for the two significant SNPs on Pv03 and Pv09 was widespread among genotypes in the ADP. These yield QTL that have been identified in several environments and genetic backgrounds are potential candidates for marker-assisted breeding. We identified QTL with enhanced resolution and the study provided additional insights into the genetic architecture of important agronomic traits in common bean.

<u>Objective 4.</u> Develop phenometric approaches to improving the efficiencies of breeding for abiotic stress tolerance, especially drought

Physiological responses to drought stress in several different bean varieties were investigated at Michigan State University to determine how the responses differed among varieties. Among the lines investigated were several varieties of common bean, *Phaseolus vulgaris*, and a variety of tepary bean, *Phaseolus acutifolius*. Measurements using a new technique (i.e., MultispecQ or PhotosynQ) are continuing to evaluate the utility of phenometric instrumentation which is under development in the David Kramer laboratory and progress is quite promising (for details on current experiments, see http://photosynq.org/). Using more conventional gas exchange measurements, we also examined the rates of photosynthesis and conductance of plants exposed to well-watered or drought stress conditions. Known drought tolerant varieties, such as SER-16 and tepary bean, had lower rates of photosynthesis and conductance under well-watered conditions compared to elite varieties like Jaguar, which is especially drought susceptible, and Zorro. When these same varieties were exposed to progressively increasing drought stress, drought tolerant varieties perceived drought stress sooner in the dry down process and closed their stomata earlier than the elite varieties. With closed stomates, the tolerant varieties' conductance and photosynthesis rates decreased further, and they conserved more water. These results suggest that drought tolerant varieties follow a conservative strategy toward managing stress. Also, although they may not be as productive as elite varieties under ideal conditions, tolerant varieties are primed and quicker to respond to a drought event. Other selected sets of physiologically contrasting genotypes from breeders are currently being tested under controlled greenhouse conditions using both MultispecQ and conventional gas exchange instrumentation.

Because compatible solutes play a role in adjusting water potentials and protecting cellular components under time of stress, we investigated their concentration in plants exposed to drought stress. Although the amino acid proline accumulates in response to drought in certain plant species, in bean plants free proline levels did not differ between control and drought-treated plants. When examining other metabolites, e.g., malic acid, fructose, glucose, and sucrose, their concentration in leaf tissues was significantly greater in drought-stressed plants than in controls. The varieties tepary and Zorro accumulated more sugars and organic acids under drought stress than the varieties Jaguar and SER-16. This pool of sugars and organic acids could allow them to osmotically adjust their tissues under stress and provide them with a ready source of energy to help them recover after the passage of the stress. Consistent with their higher accumulation of sugars and organic acids, the leaf water potentials of tepary and Zorro were more negative under drought stress than the other varieties.

Heat stress is similar to and shares some of the same response mechanisms with drought stress, and the two are often coincident in the field, so we investigated the bean varieties' responses to progressively increasing temperatures over the course of weeks. The chlorophyll fluorescence parameter photosystem II efficiency was higher in the variety Jaguar than the other varieties under all temperature regimes. This difference means that Jaguar was dissipating less of its absorbed energy as fluorescence. A thiobarbituric acid reactive substances assay on bean leaves showed an increase in reactive oxygen species activity as the temperature increased, which indicate an increase in oxidative stress caused by the heat. While there were no differences among the common bean varieties at any given temperature regimes, the tepary bean variety showed a higher concentration of thiobarbituric acid reactive substances at all temperature treatments. Measures of electrolyte leakage indicated that Jaguar's cellular membranes were more disrupted at higher temperatures compared to the other bean varieties. Although tepary's electrolyte leakage was initially high at the lower temperatures, this parameter was unaffected as the temperature increased, suggesting tepary's ability to better withstand temperature stress. At the end of a week of forty degrees Celsius temperatures, the tepary and SER-16 varieties recovered when the temperature was lowered to 25C and continued to live and grow. Jaguar and Zorro did not recover under the same conditions; the majority of those plants died when exposed to such high temperatures. Overall, the varieties tended to respond to heat stress in the same fashion as they responded to drought stress. Tepary and SER-16 followed a more conservative, adaptable strategy while Zorro and Jaguar followed a faster growing, less responsive strategy.

Abscisic acid is a major plant hormone key to drought signaling. After treating plants with increasing ABA concentrations and measuring conductance, variety SER-16 closed its stomates at lower ABA concentrations than Jaguar or Zorro. These results suggest that SER-16 is more sensitive to ABA, and more broadly, that significant differences to ABA responsiveness exist among the common bean germplasm.

Objective 5. Institutional Capacity Building and Training for doctoral student from Zambia (Kelvin Kamfwa–KK) and Uganda (Isaac Dramadri–ID), and one MS (Grady Zuiderveen–GZ) student from the U.S. all in Plant Breeding, Genetics and Biotechnology.

Activities conducted by Kelvin Kamfwa in Zambia and Michigan

1. ZZ planted the ADP in Zambia at two locations. First planting was in December 2013 at University of Zambia farm located in Lusaka. On this site, data on resistance to common bacterial blight (CBB) were collected. Genotypes with enhanced resistance to CBB were identified. The second planting was in January 2014 at Misanfu Agricultural Research center in Kasama. Data on agronomic and BNF traits were collected at this location.

2. In March 2014, three genotypes from the ADP with enhanced CBB resistance that were identified from evaluations in Zambia were crossed in the greenhouse at Michigan State University to four land races that are widely grown in Zambia. These landraces include Kabulangeti, Serenje, Lusaka and Lundazi. We now have F_2 seed for six populations resulting from these crosses. We are advancing these populations and hope to recover genotypes with enhanced disease resistance in the genetic backgrounds of the four landraces listed above.

3. Evaluations for BNF were conducted on the ADP in the greenhouse in March and September of 2014. Samples collected from these two greenhouse experiments have been sent to UC Davis for ^{15}N natural abundance analyses. This was the last evaluation for BNF to be conducted on the ADP.

4. Two $F_{4:5}$ populations of recombinant inbred lines were planted in June, 2014 in the field at Montcalm Research center for seed increase. Seed will be used to conduct field and greenhouse evaluations for BNF.

5. 150 samples collected from three tissue types at three growth stages of six ADP genotypes were sent to A&L laboratories, Indiana for total nitrogen analyses. This for an experiment aimed at understanding the dynamics of nitrogen fixation and remobilization in common beans.

6. Other activities by ZZ are listed under objective three.

Activities conducted by Isaac Dramadri in Michigan

1. ID has been advancing a recombinant inbred line population or 110 RILs derived from cross of Portilla/Red Hawk to conduct studies or drought tolerance. Portilla is a large seeded drought tolerant variety from Ecuador and Red Hawk is a Michigan State University kidney bean that is drought susceptible. Population was advanced two generations (F3–F4) and a limited sample of seed has been sent to Uganda. The population has been sent to USDA–ARS in Beltsville for genotyping with single nucleotide polymorphism (SNP) BARCBean6K_3 Beadchip. The population is photoperiod sensitive so it will only be evaluated under field evaluations in Uganda to identify and map QTL for drought tolerance.

Activities conducted by Grady Zuiderveen in Michigan

1. GZ is conducting studies to determine the exact location of race 73 anthracnose resistance in the new black bean cultivar Zenith and identify a new molecular marker that could then be utilized in the breeding program. To that end, the phenotypic data have been collected on a RIL population between Jaguar and Puebla and DNA has been extracted and sent to Beltsville for SNP analysis.

2. The second objective to collect phenotypic data on the ADP in regard to resistance to various races of anthracnose commonly found in Africa. The phenotypic data will be used to conduct association mapping. To date, phenotypic data on five different races have been collected, and additional races are being screened to locate genomic regions

conditioning resistance. This will be the first GWAS study to identify the location of anthracnose resistance in a diverse group of bean genotypes.

Activities conducted by Jesse Traub in Michigan

Listed under Objective four

V. Major Achievements

For the first time, standard charts for rating color and appearance in canned black beans have been proposed.

A machine vision system was successfully developed to automatically predict the quality ratings of color and appearance in canned black beans as a professional visual perception. Developed models allow for prediction accuracies of 93.7 percent for color and 87.1 percent for appearance and sorting of canned beans in “acceptable” and “unacceptable” quality groups by color and appearance simultaneously with accuracies higher than 89 percent. The implemented machine vision technique can successfully replace the subjective, tedious, and costly visual sensory analysis at research facilities and bean canning industries.

VI. Research Capacity Strengthening

The project will enhance scientific capacity in Uganda and Zambia through graduate student training and short-term workshops. The project has two PhD students for Africa and training of 16 staff (10 male and six female) in disease and pest identification in Uganda and Zambia. The project is planning to send participants to the other workshops being planned by the S01.A4 project.

Dr. Stanley Nkalubo, NaCRRI, Uganda and Mr. Kennedy Muimui, ZARI, Zambia spent two weeks at Michigan State University [August 17–30, 2014] to participate in Molecular Plant Breeding class and visit bean breeding facilities and field plots, the major bean production area and attend grower field days and meet all MSU collaborators and students on Legume Innovation Lab in addition to WorldTAP program, Management Office and Kramer Lab.

VII. Human Resource and Institution Capacity Development

<u>Short-Term Training 1</u>

Two short training programs were conducted during this year with assistance from Dr. J. Kelly during his visit to Uganda in May. The first was the training of researchers, research assistants and technicians in the field of breeding and screening for various bean diseases. He also visited the screen houses and field experiments giving advice where appropriate.

1. **Purpose of Training:** To introduce the Research Assistants and Technicians with the country’s bean program to advanced method of diseases screening and breeding techniques used in bean breeding

2. **Type of Training:** Power point presentation and field illustrations
3. **Country Benefiting:** Uganda
4. **Location and dates of training:** NaCRRI–Namulonge , Uganda, 5–6th May 2014
5. **Number receiving training (by gender):** Male—11 and Female—04
6. **Home institution(s) (if applicable):** NaCRRI
7. **Institution providing training or mechanism:** Michigan State University

Short-Term Training 2

1. **Purpose of Training:** To introduce the PIs from Uganda and Zambia to new advances in plant breeding (i.e. Use of marker-assisted selection breeding techniques) to enable application during project implementation
2. **Type of Training:** PowerPoint presentation and hands-on computer, field and laboratory practicals
3. **Country Benefiting:** Uganda and Zambia
4. **Location and dates of training:** Michigan State University; 17–29th August 2014.
5. **Number receiving training (by gender):** Two (2)—Male
6. **Home institution(s) (if applicable):** NaCRRI and ZARI
7. **Institution providing training or mechanism:** Michigan State University

Short-Term Training 3

1. **Purpose of Training:** Seed production principals and regulations
2. **Description of training activity:** To train small-scale farmers in seed production to enhance quality.
3. **Location:** Mporokoso District, Northern province, Zambia
4. **Duration:** 4 days
5. **Date:** 2nd–5th September, 2014
6. **Participants/Beneficiaries of Training Activity:** Small-scale Bean Seed producers
7. **Attendance of beneficiaries (male and female):** 29 (10 females and 19 males)
8. **PI/Collaborator responsible for this training activity:** Kennedy Muimui
9. **Funding sources:** LIL project and PABRA/SABRN
10. **Training justification:** High quality seed is a prerequisite for high productivity for small-scale farmers. Access to improved seed by small-scale farmers will improve productivity and production through the use of improved technologies. By training community seed producers will help make seed available within these communities.

Short-Term Training 4

1. **Type of Training:** Bean Seed production Principals and Regulations Training
2. **Description of training activity:** To train small-scale farmers in seed production to enhance quality.

3. **Location:** Mbala District, Northern province, Zambia
4. **Duration:** 4 days
5. **Date:** 20th–24th October, 2014
6. **Participants/Beneficiaries of Training Activity:** Small-scale Bean Seed producers
7. **Attendance of beneficiaries (male and female):** 30 (14 females and 16 males)
8. **PI/Collaborator responsible for this training activity:** Kennedy Muimui
9. **Funding sources:** LIL project and PABRA/SABRN
10. **Training justification:** High quality seed is a prerequisite for high productivity for small-scale farmers. Access to improved seed by small-scale farmers will improve productivity and production through the use of improved technologies. By training community seed producers will help make seed available within these communities.

Short-Term Training 5

1. **Purpose of Training:** Seed production principals and regulations
2. **Description of training activity:** To train small-scale farmers in seed production to enhance quality.
3. **Location:** Luwingu District, Northern province, Zambia
4. **Duration:** 5 days
5. **Date:** 27th–31st October, 2014
6. **Participants/Beneficiaries of Training Activity:** Small-scale Bean Seed producers
7. **Attendance of beneficiaries (male and female):** 28 (eight females and 20 males)
8. **PI/Collaborator responsible for this training activity:** Kennedy Muimui
9. **Funding sources:** LIL project and PABRA/SABRN
10. **Training justification:** High quality seed is a prerequisite for high productivity for small-scale farmers. Access to improved seed by small-scale farmers will improve productivity and production through the use of improved technologies. By training community seed producers will help make seed available within these communities.

Degree Training 1

1. **Name of Trainee (First and Last Names):** Kelvin Kamfwa
2. **Citizenship:** Zambian
3. **Gender:** M
4. **Training Institution:** Michigan State University
5. **Host Country Institution Benefitting from Training:** University of Zambia
6. **Supervising Legume Innovation Lab PI:** James D. Kelly and Karen A. Cichy
7. **Degree Program for Training:** Doctorate
8. **Program Areas or Discipline:** Plant Breeding, Genetics and Biotechnology

9. **Thesis Title/ Research Area:** Genetic dissection of biological nitrogen fixation in common bean using genome-wide association analysis and linkage mapping.
10. **Start Date:** August 2008
11. **Projected Completion Date:** September 2015
12. **Is Trainee a USAID Participant Trainee and Registered on TraiNet?** Yes
13. **Training Status:** Active

Degree Training 2

1. **Name of Trainee (First and Last Names):** Grady Zuiderveen
2. **Country of Citizenship:** U.S.
3. **Gender:** M
4. **Training Institution:** Michigan State University
5. **Supervising Legume Innovation Lab PI:** James D. Kelly
6. **Degree Program for Training:** Masters
7. **Program Areas or Discipline:** Plant Breeding, Genetics and Biotechnology
8. **Host Country Institution to Benefit from Training:** U.S.
9. **Thesis Title/ Research Area:** SNP marker development for major resistance genes
10. **Start Date:** August 2013
11. **Projected Completion Date:** September 2015
12. **Is Trainee a USAID Participant Trainee and Registered on TraiNet?** No
13. **Training Status:** Active

Degree Training 3

1. **Name of Trainee (First and Last Names):** Jesse Traub
2. **Citizenship:** U.S.
3. **Gender:** M
4. **Host Country Institution to Benefit from Training:** U.S.
5. **Training Institution:** Michigan State University
6. **Supervising Legume Innovation Lab PI:** Wayne Loescher
7. **Degree Program for Training:** Doctorate
8. **Field or Discipline:** Plant Breeding, Genetics and Biotechnology
9. **Thesis Title/ Research Area:** Physiological differences among *Phaseolus vulgaris* cultivars differing in drought tolerance.
10. **Start Date:** August 2013 on Legume Innovation Funding
11. **Projected Completion Date:** May 2015
12. **Is Trainee a USAID Participant Trainee and Registered on TraiNet?** No
13. **Training Status:** Active.

Degree Training 4

1. **Name of Trainee (First and Last Names):** Isaac Dramadri
2. **Citizenship:** Uganda
3. **Gender:** M
4. **Host Country Institution to Benefit from Training:** Makerere University
5. **Training Institution:** Michigan State University
6. **Supervising Legume Innovation Lab PI:** James D. Kelly and Wayne Loescher
7. **Degree Program for Training:** Doctorate
8. **Field or Discipline:** Plant Breeding, Genetics and Biotechnology
9. **Thesis Title/ Research Area:** Physiological studies on drought tolerance in Andean beans.
10. **Start Date:** August 2013 on Legume Innovation Funding
11. **Projected Completion Date:** September 2017
12. **Is Trainee a USAID Participant Trainee and Registered on TraiNet?** Yes
13. **Training Status:** Active, Partial BHEARD Fellowship from USAID Mission, Kampala

Degree Training 5

1. **Name of Trainee (First and Last Names):** Blessing Odogwu
2. **Country of Citizenship:** Nigeria
3. **Gender:** Female
4. **Host Country Institution Benefitting from Training:** University of Port Harcourt, Nigeria
5. **Institution Providing Training:** Makerere University
6. **Supervising Legume Innovation Lab PI:** J.D. Kelly
7. **Degree Program:** PhD
8. **Field or Discipline:** Plant Breeding and Biotechnology
9. **Research Project Title:** Breeding for rust resistance in common beans in Uganda
10. **Start Date:** January 2014
11. **Projected Completion Date:** December 2017
12. **Is Trainee a USAID Participant Trainee and Registered on TraiNet?** No
13. **Training Status:** Active

Note. Although not sponsored, the project in Uganda has taken one PhD student (Ms. Blessing Odogwu), who will conduct her research work as part of a project objective which addresses bean rust, a newly emerging threat to bean production in Uganda. Her work will is focusing on identifying rust disease pathotypes present in Uganda, its extent of infestation and also if possible identify local source of resistance within the country. This study is expected to contribute to the generation of knowledge on the prevalence, genetic and pathogenic diversity, rate, extent and pattern of spread of rust in Uganda.

VIII. Achievement of Gender Equity Goals

In Zambia, we have identified NGOs that we can partner with for outreach and technology dissemination for female farmers, who 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 increasing women's agriculture skills and leadership roles as objectives in addition to access to credit for sustainable and profitable farming.

IX. Explanation for Changes

Some of the project activities in Uganda and Zambia were delayed due to late acquisition of funds. The activities that were delayed included collection of disease samples, isolations and characterization. These activities will be carried over to the next financial year. This was a particular problem in Zambia as they have only one major growing season as compared to two seasons in Uganda. Also collection, screening, multiplication and use of germplasm for hybridization processes were delayed and have been postponed to next financial year. Given the expulsion of USAID from Ecuador no activities were conducted in that country.

X. Self-Evaluation and Lessons Learned

Apart from the delay encountered in the signing of agreements and the initial transfer of funds to NaCCRI, there have not been major challenges and collaboration has started off on a positive note. We have managed to even get a PhD student on a *Norman E. Borlaug* Leadership Enhancement in Agriculture Program (LEAP) fellowship. This fellowship is going to be managed by Michigan State University under the mentorship of Prof. James Kelly. We have managed to get the project moving have at least and all the planned activities have at least been initiated.

XI. Scholarly Accomplishments

Cichy, K.A., A. Fernandez, A. Kilian, J.D. Kelly, C.H. Galeano, S. Shaw, M. Brick, D. Hodkinson, and E. Troxtell. 2014. QTL analysis of canning quality and color retention in black beans (*Phaseolus vulgaris* L.). *Molecular Breeding* 33:139–154. doi: 10.1007/s11032-013-9940-y.

Ferreira, J.J., A. Campa, and J.D. Kelly. 2013. Organization of genes conferring resistance to anthracnose in common bean, pp. 151–181. *In* R. K. Varshney and R. Tuberosa (eds.) *Translational Genomics for Crop Breeding, Volume I: Biotic Stresses*. John Wiley & Sons, Inc.

Kamfwa, K. K. A. Cichy, and J. D. Kelly. 201x. Genome-Wide association study of agronomic traits in common bean. *The Plant Genome*. (under review)

Kelly, J.D., G.V. Varner, K.A. Cichy, and E.M. Wright. 2014. Registration of “Powderhorn” great northern bean. *J. Plant Registrations* 8:1–4. doi:10.3198/jpr2013.05.0020crc.

Mendoza, F.A., K. Cichy, R. Lu and J.D. Kelly. 2014. Evaluation of canning quality traits in black beans (*Phaseolus vulgaris* L.) by visible/near-infrared spectroscopy. *Food Bioprocess Technol.*7:2666–2678. doi: 10.1007/s11947-014-1285-y

Miklas, P.N., J. D. Kelly, J. R. Steadman and S. McCoy. 2014. Registration of Partial white mold resistant pinto bean germplasm line USPT-WM-12. J. *Plant Registrations* 8:183–186.

Mukeshimana, G., Y. Ma, A. E. Walworth, G-q. Song, and J. D. Kelly. 2013. Factors influencing regeneration and *Agrobacterium tumefaciens*-mediated transformation of common bean *(Phaseolus vulgaris L.*). *Plant Biotechnol.* Rep. 7:59–70. doi: 10.1007/s11816-012-0237-0

Mukeshimana, G., L. Butare, P.B. Cregan, M. W. Blair and J.D. Kelly. 2014. Quantitative trait loci associated with drought tolerance in common bean. *Crop Sci.* 54:923–938. doi: 10.2135/cropsci2013.06.0427.

Mukeshimana, G., A.L. Lasley, W.H. Loescher and J.D. Kelly. 2014. Identification of shoot traits related to drought tolerance in common bean seedlings. *J. Amer. Soc. Hort. Sci.* 139:299–309.

Musoni, A., J. Kayumba, L. Butare, F. Mukamuhirwa, E. Murwanashyaka, D. Mukankubana, J.D. Kelly, J. Ininda, and D. Gahakwa. 2014. Innovations to overcome staking challenges to growing climbing beans by smallholders in Rwanda. p. 129–136. *In*: B. Vanlauwe et al. (eds.), *Challenges and Opportunities for Agricultural Intensification of the Humid Highland Systems of Sub-Saharan Africa*. Springer International Publishing Switzerland doi 10.1007/978-3-319-07662-1_11.

Vandemark, G.J., M.A. Brick, J.M. Osorno, J.D. Kelly, and C.A. Urrea. 2014. Edible Grain Legumes. p. 87–123. *In:* S. Smith, B. Diers, J. Specht, & B. Carver (eds.). *Yield Gains in Major U.S. Field crops.* CSSA Special Pub. 33, Madison, WI.

XII. Presentations, Dissertations and Awards

Traub J, Kelly J, Loescher W. 2013. Varietal differences in physiology of drought stressed Phaseolus. Poster session presented at the American Society for Horticultural Science Annual Conference; July 22–25; Palm Desert, California.

Traub J, Kelly J, Loescher W. 2014. Enhancing drought tolerance in common bean, the most widely consumed legume: shoot and root components of Tolerance. Poster presented at American Society for Horticultural Science Conference, July 28–August 1, 2014 in Orlando, Florida.

Mukeshimana, G. 2013. *Dissecting the genetic complexity of drought tolerance mechanisms in common bean* (*Phaseolus vulgaris* L.). Doctoral Dissertation, Michigan State University, East Lansing MI. 210pp.

Kelly received Meritorious Achievement Award from Legume Innovation Lab–Michigan State University 2014 and the Ralph H. Smuckler Award for Advancing International Studies and Programs–Michigan State University, 2014.

XIII. 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 collection in country and that phase was delayed due to late arrival of funds to NaCRRI and ZARI in FY14. Those activities will be conducted during FY15.

XIV. Annexes

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

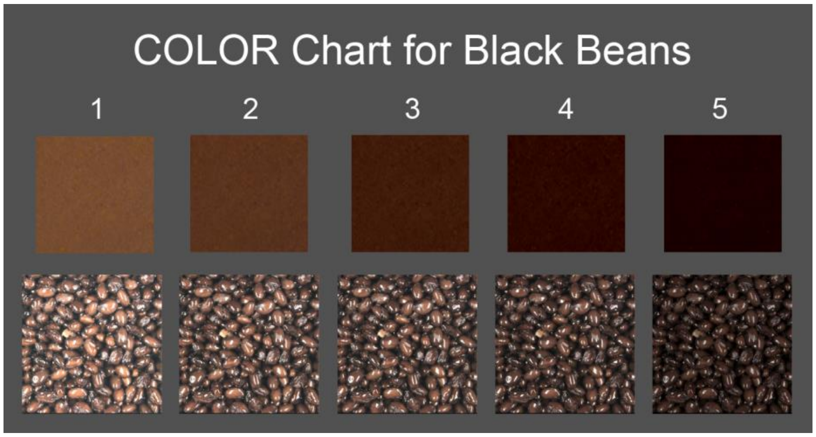

Figure 9.1. Color chart for canned black beans representing five typical categories observed in canned beans: (1) Very light brown, with 50 percent mix of seed colors very noticeable; (2) Slight dark brown or light gray, with 11 percent–49 percent color variation somewhat noticeable; (3) Average brown black: with 5–10 percent color variation; (4) Dark brown or medium black, with less than 5 percent color variation not very noticeable; and (5) Very dark: 100 percent uniform color. (Note that the color categories were reproduced using the same bean image with different tones).

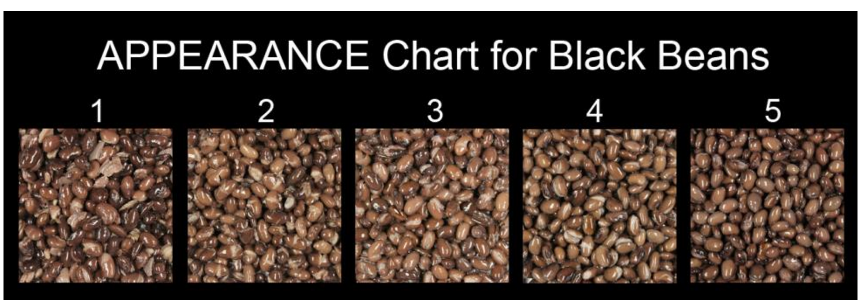

Figure 9.2. Appearance chart for canned black beans after drained and washed representing five typical quality categories observed in commercial canned beans: (1) Unacceptable: with severe split grains and grains blown apart; (2) Poor: with seeds bad split but holding together; (3) Average: showing 60 percent–69 percent of seeds intact; (4) Very good appearance: with grains moderately intact 70 percent–89 percent of seeds intact; and (5) Excellent appearance: with 90 percent of seeds intact.

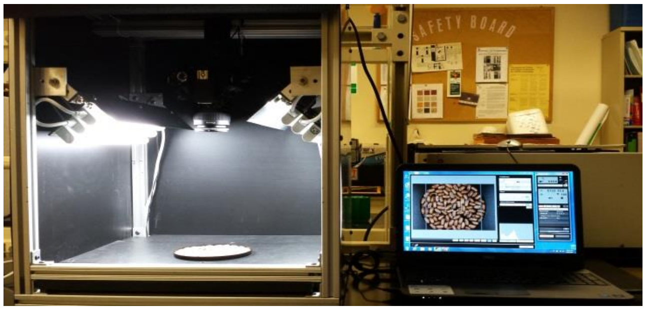

Figure 9.3. Computer vision system for visualization, acquisition and analysis of raw and processed beans

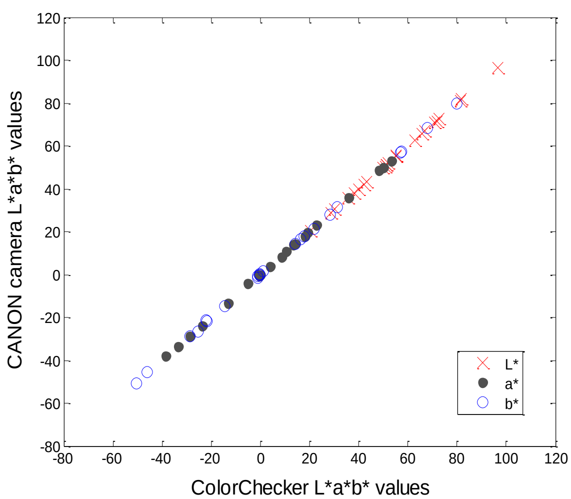

Figure 9.4 Relationship between CIE *L*a*b** (CIELAB D_{50} 2° observer) values for ColorChecker and CCD camera after transformations using a polynomial approach.

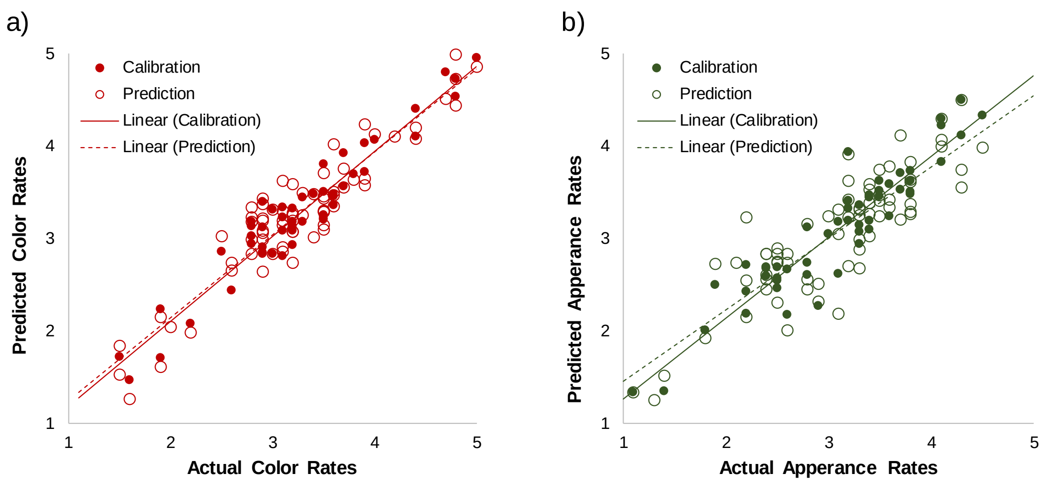

Figure 9.5. Predictions for visual color and appearance rates (a) and b), respectively) using color (full grain + brine) and image textural features (contrast, correlation, energy, homogeneity) extracted from *RGB*, *L*a*b**, *HSV* and gray intensity channels.

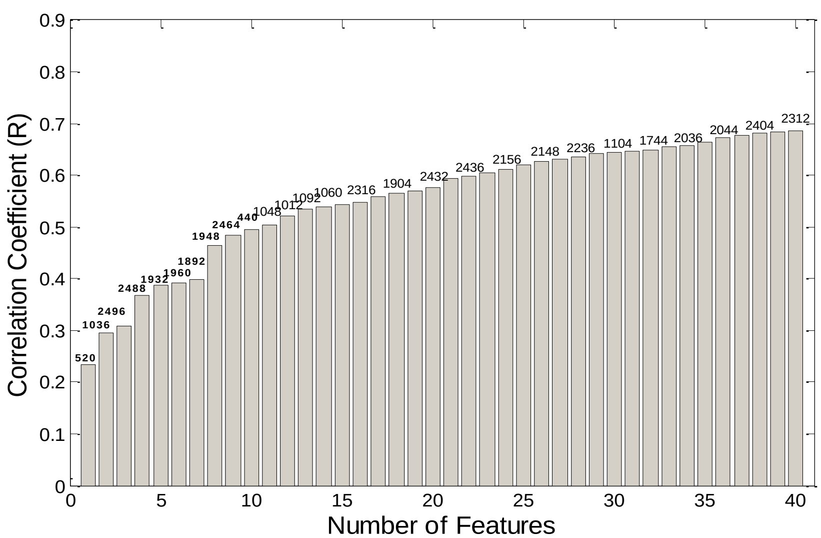

Figure 9.6. Prediction of cooking time increasing the number of latent variables in the model.

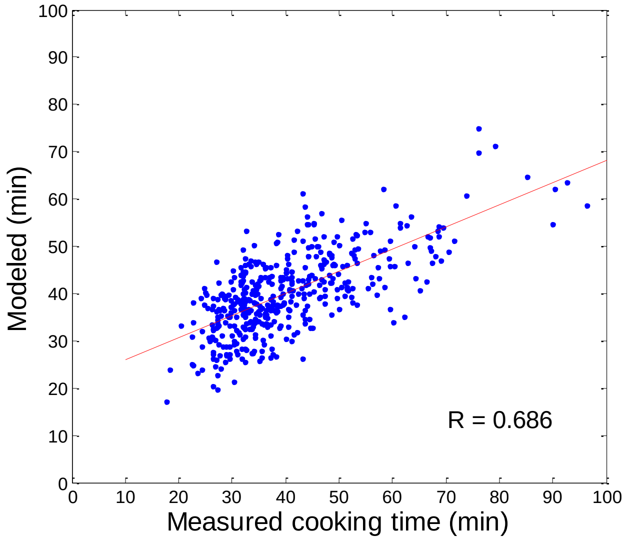

Figure 9.7. Relationship between measured and predicted cooking time using 40 latent variables in the multiple regression model.

Annex 2. Literature Cited

Mukankusi C. 2007. Improving resistance to Fusarium root rot [*Fusarium solani* (Mart.) Sacc. f. sp. *phaseoli* (Burkholder) W.C. Snyder & H.N. Hans.] in *Common bean* (*Phaseolus vulgaris* L.). Unpublished PhD thesis. University of KwaZulu–Natal, South Africa.

Nkalubo T.S., Melis R, Derera J, Laing D.M, Opio F. 2009. Genetic analysis of anthracnose resistance in common bean breeding source germplasm. *Euphytica* 167(3):303–312

Pastor-Corrales M.A. 2006. Breeding Better Beans: Increasing Disease Resistance in Common Beans. *Agricultural Research Magazine* (*USDA*), 54 (6):12–14.

Report on training provided to Host Country PI at Michigan State University in 2014:

The second training was done for the Host Country Principal Investigator (HCPI) in the field of breeding and marker-assisted breeding. The Host Country Ugandan PI attended and participated in the Marker-assisted Breeding Program at Michigan State University from 17–29th August, 2014. During the training the following topics were covered through lectures and practical application sessions 1) introductory plant breeding and breeding methods; 2) introduction to statistical terminologies of data and trial design and analysis; 3) mixed models in plant breeding; 4) population genetics; 5) Molecular biology techniques and marker-assisted breeding; 6) DNA sequencing; 7) Basic principles of linkage mapping and marker associated analysis; 8) Marker trait association analysis for qualitative vs quantitative traits; 9) Advances in QTL mapping and Marker trait association analysis; 10) Advances in linkage map construction 11) marker-assisted selection (MAS) breeding applications and genomic selection. During the week's training, there were daily practices on breeding data analyzing using R and Gen Stat statistical programs. At the end of the training, trainees were issued with certificates. During the second week, there were interfaces with some of the collaborators on the legume Innovation lab project during which we had discussion on the way forward for the project. Visits were made to the Michigan State University bean breeding program where lesson were drawn from Dr. Kelly’s 40 years bean breeding experience.

XV. Milestones

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

Report on the Achievement of "Milestones of Progress"

(For the Period: April 1, 2014 -- September 30, 2014)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2014

Project Title: 0

	Abbreviated name of institutions																	
	MSU			UNL			ZARI- Zambia			INIAP-Ecuador			NaCCRI-Uganda			Institution 6		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Milestones by Objectives	**4/1/14**	**Y**	**N***	**4/1/14**	**Y**	**N***	**4/1/14**	**Y**	**N***	**4/1/14**	**Y**	**N***	**4/1/14**	**Y**	**N***	**4/1/14**	**Y**	**N***
	(Tick mark the time period for achieving identified milestones by institution)																	
Objective 1: Integrate traditional and marker-assisted selection (MAS) approaches to combine resistances to economically important foliar diseases, drought and improved biological nitrogen fixation (BNF) and assess																		
1.1. Integrated Nursery of Elite Sources from Meso and Andean LIL breeding programs													x	x				
1.2. Evaluation of Integrated Nursery	x	x		x	x					x		x	x	x				
1.3. Identification of resistance sources	x	x		x	x		x	x		x		x	x		x			
1.4. Crossing and backcrossing resistance sources							x	x		x		x	x	x				
1.5. Evaluation of lines for BNF										x		x	x		x			
1.6. Population development for genetic studies							x		x	x		x	x	x				
1.8. Screening for cooking time							x	x				x						
1.9. Canning evaluation of lines									x	x		x	x		x			
1.10. Evaluation of elite lines for cooking time bioavailability							x		x				x		x			
1.11 Assembling a Legume Innovation Lab nurseries for drought tolerance (andean and mesoamerican). Coordinate with the S01.A4, CIAT, PABRA																		
1.12 Develop protocol across MA and A and disseminate and perhaps train local researchers. Drought (terminal, intermittent stress). BNF (sandy soils and low in organic matter)																		
1.13 Seed multiplication																		
1.14 Site identification. BNF (sandy soils and low organic matter content)																		
1.15 Field testing	x	x		x	x		x		x	x		x	x		x			
1.16 Evaluation of cooking time methodology	x	x																

Milestones, continued

2.1. Anthracnose race characterization, screening							x		x	x		x	x	x				
2.2. Angular Leaf Spot characterization, screening							x		x	x		x	x		x			
2.3. Rust characterization, screening				x		x	x		x	x		x	x	x				
2.4. Common Bacterial Blight Screening				x	x		x		x	x		x	x		x			
2.5 Compile data base of past pathogen collections	x		x	x			x		x	x		x	x	x				
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. SNP marker development linked to major resistance genes	x		x	x		x												
3.2. SNP marker associated with BNF	x	x																
3.3. SNP markers associated with drought																		
3.4. MAS for disease screening using SNP																		
3.5 Plant regional BNF and drought nurseries for genotyping	x	x					x	x		x		x	x	x				
3.6 Fingerprinting lines/populations with SNP markers																		
3.7 Association mapping	x	x		x		x												
Objective 4: Focus on phenometric approaches to improving the efficiencies of breeding for abiotic stress tolerance, especially drought																		
4.1 Assemble selected sets of physiologically contrasting genotypes from breeders																		
4.2 Conduct initial phenometric measurements and evaluations of contrasting genotypes																		
4.3 Identify differences among genotypes with contrasting responses to high light and high temperature stresses.	x	x																
4.4 Extend methodology to include drought stress	x	x																

Milestones, continued

Objective 5: Capacity Building																		
5.1. Graduate Student training	x	x																
5.2. Short term training for colloborators and technician (SNP Markers applications)				x		x	x		x	x		x	x	x				
5.3 Short term training of graduate students/collobarators on phenometrics and bioinformatics	x	x					x		x				x	x				
5.4 Train PhD or Msc students																		
5.5 On-country training (BNF). Collaborate with the MA Legume Innovation Lab. Decide the location.							x		x	x			x	x				
5.6 Short term training for technicians/project personnel in host countries on the use of different screening protocols (drought and diseases)																		
Signature/Initials:	James D. Kelly, Karen Cichy			James Steadman, Carlos Urrea			Kennedy Muimui			Eduardo Peralta			Stanley Nkalubo					
Date:	10-Oct-14						16-Oct-14											

Program terminated in Ecuador
Notes from MSU: No new markers for disease traits identified as we are still waiting for SNP data on our populations from USDA-ARS, Bean CAP project in Beltsville
Notes from Nebraska: UNL 2.3 and 2.5 - Planned trip to Zambia to collect rust samples will be taken Nov 7-14, 2014. Lines populations not developed for resistance genes yet. 5.2 - Planned trip to Zambia will allow short-term training.
Notes: from Uganda: The identification of resistant sources could not be achieved due to the fact that, we had a delay in project initiation and as such collection of diseased leaf samples was late. We have not yet screened for resistance to any diseases due to unavailability of isolates for ALS, Anthracnose and CBB. The disesead samples are being colected and isolated at the moment. Screening will follow in the near future. The BNF nursery has not been assembled as yet, so no field testing was done in this field.
Notes from Zambia: Funding was received after growing season so no characterization and collection of disease samples was done. This will be done coming season. Trainings to be conducted during the season when crop is the field.

XVI. Performance Indicators

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

Project Name:S01.A3 Improving Genetic Yield Potential of Andean Beans with Increased Resistances to Drought and Major Foliar Diseases and Enhanced Biological Nitrogen Fixation (BNF)

Summary of all institutions: INIAP - Ecuador, NaCCRI - Uganda, ZARI - Zambia

Indic. numbe	Output Indicators	FY 13 Target	FY 13 Revised	FY 13 Actual	FY 14 Target	FY 14 Revised	FY 14 Actual	FY 15 Target	FY 15 Revised	FY 15 Actual	FY 16 Target	FY 16 Revised	FY 16 Actual	FY 17 Target	FY 17 Revised	FY 17 Actual
		(only April 1, 2013 - September 30, 2013)			(October 1, 2013 - September 30, 2014)			(October 1, 2014 - September 30, 2015)			(October 1, 2015 - September 30, 2016)			(October 1, 2016 - September 30, 2017)		
1	4.5.2(6) Degree Training: Number of individuals who have received degree tr	0	0	0	2	0	0	4	2	0	0	0	0	2	0	0
	Number of women	0	0	0	1	0	0	2	1	0	0	0	0	0	0	0
	Number of men	0	0	0	1	0	0	2	1	0	0	0	0	2	0	0
2	4.5.2(7) Short-term Training: Number of individuals who have received short-term training															
	Total number	0	0	0	6	0	16	12	13	0	13	0	0	15	0	0
	Number of women	0	0	0	3	0	5	5	6	0	5	0	0	7	0	0
	Number of men	0	0	0	3	0	11	7	7	0	8	0	0	8	0	0
	Numbers by Type of individual	0	0	0	6	0	3	12	13	0	13	0	0	13	0	0
	Producers	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
	People in government	0	0	0	6	0	3	12	13	0	11	0	0	10	0	0
	People in private sector firms	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
	People in civil society	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4.5.2(13) Beneficiaries: (numbers of households)															
	New/Continuing (total)	0	0	0	250	0	207	350	150	0	460	0	0	550	300	300
	New	0	0	0	250	0	207	350	200	0	110	0	0	90	0	0
	Continuing	0	0	0	0	0	0	0	150	0	350	0	0	460	0	0
	Gendered Household Type	0	0	0	150	0	132	200	350	0	460	0	0	550	0	0
	Adult Female no Adult Male (FNM)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Adult Male no Adult Female (MNF)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Male and Female Adults (M&F)	0	0	0	150	0	132	200	350	0	460	0	0	550	0	0
	Child No Adults (CNA)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	4.5.2(11) Number of food security private enterprises (for profit), producers organizations, water users associations, women's groups, trade and business associations, and community-based organizations (CBOs) receiving USG assistance															
	Type of organization	0	0	0	12	0	7	42	22	0	78	0	0	110	0	0
	Private enterprises (for profit)	0	0	0	0	0	0	0	4	0	6	0	0	4	0	0
	Producers organizations	0	0	0	1	0	1	2	3	0	12	0	0	10	0	0
	Water users associations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Women's groups	0	0	0	1	0	1	5	0	0	13	0	0	25	0	0
	Trade and business associations	0	0	0	0	0	0	0	0	0	2	0	0	6	0	0
	Community-based organizations (CBOs)	0	0	0	20	0	15	35	15	0	45	0	0	65	0	0
	New/Continuing (total)	0	0	0	22	0	15	38	26	0	74	0	0	105	0	0
	New	0	0	0	22	0	15	16	0	0	30	0	0	29	0	0
	Continuing	0	0	0	0	0	0	22	16	0	44	0	0	76	0	0
5	4.5.2(12) Number of public-private partnerships formed as a result of CRSP assistance															
	Number by type of partnership (total)	0	0	0	0	0	0	0	14	0	20	0	0	31	0	0
	Agricultural production	0	0	0	0	0	0	0	5	0	10	0	0	15	0	0
	Agricultural post harvest transformation	0	0	0	0	0	0	0	2	0	2	0	0	4	0	0
	Nutrition	0	0	0	0	0	0	0	5	0	4	0	0	6	0	0
	Multi-focus	0	0	0	0	0	0	0	2	0	4	0	0	6	0	0
	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Performance Indicators, continued

6	4.5.2(2) Developmental outcomes:															
	Number of additional hectares under improved technologies or management practices															
	Number under specific technology types (total)	0	0	0	80	0	28	115	0	0	155	0	0	195	0	0
	crop genetics	0	0	0	80	0	28	115	0	0	155	0	0	195	0	0
	animal genetics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	pest management	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	disease management	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	soil-related	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	water management	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	post-harvest handling and storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	processing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	climate mitigation or adaptation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	fishing gear/technique	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	total w/one or more improved technology	0	0	0	80	0	0	115	0	0	155	0	0	195	70	70
	New/Continuing hectares	0	0	0	80	0	32	115	40	0	155	0	0	195	0	0
	New	0	0	0	65	0	17	45	10	0	40	0	0	40	0	0
	Continuing	0	0	0	15	0	15	70	30	0	115	0	0	155	0	0
	Sex of person managing hectare	0	0	0	0	0	0	0	115	0	155	0	0	195	0	0
	Male	0	0	0	0	0	0	0	56	0	82	0	0	98	0	0
	Female	0	0	0	0	0	0	0	59	0	73	0	0	97	0	0
	Association-applied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	4.5.2(39) Number of new technologies or management practices in one of the following phases of development: (Phase I/II/III)	0	0	0	3	0	4	8	1	0	18	0	0	19	11	11
	Phase 1: Number of new technologies or management practices under research as a result of USG assistance	0	0	0	3	0	4	6	0	0	8	0	0	8	6	6
	Phase 2: Number of new technologies or management practices under field testing as a result of USG assistance	0	0	0	0	0	0	2	0	0	4	0	0	3	3	3
	Phase 3: Number of new technologies or management practices made available for transfer as a result of USG assistance	0	0	0	0	0	0	0	1	0	2	0	0	4	2	2
8	4.5.1(24) Numbers of Policies/Regulations/Administrative Procedures in each of the following stages of development as a result of USG assistance in each case: (Stage 1/2/3/4/5)															
	Sector (total)	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
	Inputs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Outputs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Macroeconomic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Agricultural sector-wide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Research, extension, information, and other public service	0	0	0	0	0	0	0	5	0	10	0	0	15	0	0
	Food security/vulnerable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Climate change adaptation or natural resource management (NRM) (ag-related)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Stages of development															
	Stage 1 of 5: Number of policies / regulations / administrative procedures analyzed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Stage 2 of 5: Number of policies / regulations / administrative procedures drafted and presented for public/stakeholder consultation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Stage 3 of 5 : Number of policies / regulations / administrative procedures presented for legislation/decree	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Stage 4 of 5 Number of policies / regulations / administrative procedures prepared with USG assistance passed/approved	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Stage 5 of 5: Number of policies / regulations / administrative procedures passed for which implementation has begun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes:

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

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

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

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