

LEGUME INNOVATION LAB FOR COLLABORATIVE RESEARCH ON GRAIN LEGUMES

FY 2016 – 2017 WORKPLAN

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

Lead U.S. Principal Investigator

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Collaborating Scientists

Wayne Loesch, Dept. Horticulture, MSU

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Stanley Nkalubo – NaCRRI, Uganda

Kennedy Muimui – ZARI, Zambia

Karen Cichy, USDA-ARS, East Lansing, MI

I. 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. 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. As a non-traditional agricultural export crop, beans have gained a major dominance in terms of tonnage and monetary value among Uganda's exports. That beans are produced in every district illustrates the dependence on beans as a major food security crop and their importance in farmers' household incomes. The crop is ranked fourth in terms of export volume and eighth in terms of export value. The crop is also the most important source of protein for the Ugandan population providing 45% of the total human dietary protein and plays a significant role in ensuring food security. Beans provide a cheap source of protein to most vulnerable groups such as children below five years, pregnant mothers and AIDS patients. 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 (ALS, ANT, root rots, BCMV) 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 presence of other stresses such as high temperature, root diseases, shallow infertile soils and climate change all contribute to intensify the problem. Improvements in current understanding of the physiology of drought and evapo-transpiration 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 therefore needed. 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. 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. Planned Project Activities for FY 2016-17

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 Andean bean germplasm for the Eastern Africa highlands (Zambia and Uganda), and the U.S.

Collaborators

Jim Steadman, Carlos Urrea, - Nebraska
Stanley Nkalubo - Uganda
Kennedy Muimui – Zambia
Karen Cichy, USDA-ARS, Michigan

Approaches and Methods

1. Seed increase in each country for all available nurseries. Screen the disease nursery to different pathogens in greenhouse in Zambia. The races to be used will be determined from objective 2.
2. Initiate selection for disease resistance in field and under screen house inoculation condition in Zambia.
3. Screen the disease nursery to different pathogens (, ANT, and ALS field conditions in Uganda. The races to be used will be determined from objective 2.
4. Complete screening for rust and CBB in Uganda
5. Screen the disease nursery to CBB in North Platte, NE.
6. Screen a subset of the Andean panel and NIFA root rot lines to terminal drought in Scottsbluff, NE.
7. Complete screening of the drought nursery in Uganda to intermittent drought stress.

8. Screen the drought nursery in Nebraska to terminal drought stress.
9. Evaluate population s generated from crosses between resistance sources for angular leaf spot (ALS), rust, anthracnose, common bacterial blight, virus resistance and drought tolerance with large seeded lines with contrasting colors in Uganda.
10. Use of markers identified in objective 3 to make selections in each country
11. Screen Andean lines for cooking time using a pin drop (Mattson cooker) method.
12. Canning evaluation of climbing sugar beans from Uganda
13. Evaluate Andean elite lines for micronutrient bioavailability in MI and NE.
14. Evaluate three non-destructive, high throughput methods to measure cooking time and seed chemical composition; including reflectance and transmittance NIR and hyperspectral imaging.
15. Implement NIR cooking time prediction models to develop a bench top prototype to non-destructively measure cooking time in dry beans.
16. Cross lines with superior disease resistance to those with shorter cooking time and high mineral bioavailability. Cross with CBB resistant and anthracnose resistant varieties from ADP and other sources.
17. Advance crosses for anthracnose, bruchid (weevil) and virus resistance in Uganda

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.

Collaborators

Jim Steadman, Carlos Urrea - Nebraska
Stanley Nkalubo - Uganda
Kennedy Muimui – Zambia

Approaches and Methods

1. Initiate the collection of isolates of ANT, ALS, CBB, and Rust in different bean production regions of Zambia.
2. Increase seed of the differentials for ANT, ALS and rust in Zambia and Uganda
3. Race characterization of ANT and ALS in Zambia. Rust characterized at UNL.
4. Complete with race characterization for ANT, ALS and Rust in Uganda.
5. Utilize the mobile nursery protocol to determine the effectiveness of rust resistance genes in genotypes in Zambia and Uganda.
6. 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 in Zambia.
7. Increase seed of these selected genotypes for inclusion in the mobile nursery.
8. Choose the most relevant races of ANT, ALS and rust and strains of CBB for screening breeding nurseries in Zambia.
9. Partner with S01.A4 project to characterize isolates of web blight in different host countries to use in search for an improved screening method for resistance. The only current control methods are use of chemicals, so alternative control methods are needed.

10. The project will actively collaborate with MSU and UNL NIFA projects in Zambia and Uganda and with the S01.A4 project to address issues with a variety of pathogens that are not being directly addressed in current workplan.

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.

Collaborators

Jim Steadman, Carlos Urrea, - Nebraska
Stanley Nkalubo - Uganda
Kennedy Muimui – Zambia
Karen Cichy, Michigan
Kelvin Kamfwa, Michigan

Approaches and Methods

1. Conduct greenhouse phenotypic evaluation of two RIL populations for BNF at MSU.
2. Collect DNA from two RIL populations for study of BNF.
3. Genotype two RIL populations using 6K SNP Chip from BeanCAP project.
4. Develop tightly linked SNP markers for major anthracnose resistance genes in collaboration with S01.A4 project that will develop markers for other resistance genes.
5. Sequence information from the bean genome will be used to focus on specific genomic regions where major anthracnose resistance genes have been mapped -MSU.
6. Bean bioinformatic sources such as Bean Genes at UCD will be used as sources to identify new sequence based markers that are located near major resistance genes for mapping in populations segregating for major foliar pathogens.
7. Emphasis will be given to identify agarose based markers that could be implemented in country in addition to using SNP based markers.
8. 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.
9. Conduct sensory evaluation of lines with superior cooking time and mineral bioavailability in Michigan, Uganda, and Zambia.
10. Conduct a field phenotypic evaluation of ADP panel and Portillo x Red Hawk RIL population for drought tolerance in Uganda.

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

Collaborators

Wayne Loescher, Coordinator Obj 4, MSU
Carlos Urrea - Nebraska
David Kramer, Jim Kelly – MSU

Stanley Nkalubo - Uganda
Kennedy Muimui – Zambia
Idupulapati Rao – CIAT

Approaches and Methods:

We will continue to rely extensively on new instrumentation and techniques now available at MSU (at the Center for Advanced Algal and Plant Phenometrics). These allow exposing lines of plants to a set of distinct dynamic environmental conditions that mimic those experienced under realistic field conditions, or allow sophisticated experimental manipulations. These also allow non-destructive and continuing measurements of photosynthetic properties (e.g., gas exchange and chlorophyll fluorescence), growth and plant architecture, and more detailed measurements of photosynthesis. These will contribute to identifying new traits based on relationships between genotype and drought and heat responses.

1. Continue to assemble selected sets of physiologically contrasting genotypes from breeders, both *P. vulgaris* and *P. acutifolius* (e.g., Urrea, Kelly, Porch).
2. Continue conducting phenometric measurements and evaluations of contrasting genotypes. Continue development and testing of new instrumentation for field evaluations of photosynthesis and stress responses (e.g., Loescher, Kramer).
3. Identify physiological differences among genotypes with contrasting responses to high light and high temperature stresses.
4. Extend methodology to include assessments and evaluations of drought stress.

Objective 5: Institutional Capacity Building

MSU Doctoral student, Dennis Katuumura in plant breeding, genetics and biotechnology will conduct field research on culinary aspects of bean lines and genetic population(s) in Michigan and Uganda. MSU Doctoral student, Isaac Dramadri will conduct field research in Uganda on drought screening of the Andean panel and on a mapping population. With the return of Dr. Kelvin Kamfwa to the University of Zambia, expanded collaboration on research related to N-fixation will be continued in Zambia. In addition, short-term trainings for collaborators in host countries will be designed to assist them to undertake the implementation of the project objectives and activities using the latest technologies that are being deployed at MSU and Nebraska. Also training will be provided by in country collaborators to graduate students, technicians on the use of new screening techniques in drought and diseases. Where applicable, extension staff and users (farmers) will be trained on the use of the new technologies developed.

1. Provide short-term training in the areas of bioinformatics, use and management of SNPs for PIs of participating countries (Uganda, Zambia).
2. Provide short term training in the use of various drought and diseases screening methods for PIs of participating countries and institutions personnel (technicians) and where applicable extension staff and users (farmers) in Uganda and Zambia.

III. Contribution of Project to USAID Feed the Future Performance Indicators: The “Performance Indicators – Targets” forms for each country have been completed for the project for FY 2013, 2014, 2015 and 2016 following FTF guidelines. One student is currently in doctoral degree training, and plans exist for short term training for other technicians in the program. The scientific assistance provided to farmers is shared among men and women as both genders are active in bean production in Uganda and Zambia.

Target Outputs

1. The development and release of locally adapted, acceptable, drought and disease resistant bean cultivars for the major production regions in Uganda, Zambia and Michigan.
2. Increased sustainable productivity and profitability of bean production due to increased yield and reduced inputs.
3. Improved grower income and stability of bean production will contribute to better nutrition and health of farm families.
4. Increased awareness and knowledge of genomic and phenomic research methods on drought stress, major foliar diseases, enhanced fixation and nutritional quality will further improve bean productivity, long-term land management, and environmental risk, thus contributing to sustainability of bean production and agricultural communities and improved dietary patterns.
5. Identification of germplasm sources that are of benefit in the improvement of selected bean traits for the U.S. market.
6. Enhanced human resource development, gender equity and improved infrastructure capacity of participating institutions in Uganda and Zambia.

IV. Outputs:

- Training of 6 staff (4 male and 2 female) at ZARI in disease and pest identification
- Seed of different nurseries increased in Zambia
- Angular Leaf Spot Nursery evaluated and source of resistance identified in sites in Zambia
- Common Bacterial Blight Nursery evaluated and source of resistance identified in sites in Zambia
- Anthracnose Nursery evaluated and source of resistance identified in sites in Zambia
- Rust Nursery evaluated and source of resistance identified in sites in Zambia
- Isolates of ANT, ALS, CBB, and Rust collected from different bean production regions of Zambia.
- Initiate crossing of landraces with resistant sources of ALS, ANT, CBB, and Rust in Zambia
- At least five nurseries assembled for drought, ANT, ALS, CBB, and rust
- Drought nursery established, evaluated and contrasting drought tolerant lines identified
- Anthracnose Nursery established, evaluated and source of resistance identified

- Angular Leaf Spot Nursery established, evaluated and source of resistance identified
- Common Bacterial Blight Nursery established, evaluated and source of resistance identified
- Rust Nursery established, evaluated and source of resistance identified
- Seed of different nurseries increased in country
- Isolates of ANT, ALS, CBB, and Rust obtained from different bean production regions of Uganda.
- ANT, ALS and Rust pathotypes/races characterized in Uganda.
- Crosses initiated between Ugandan landraces with tolerant/resistant sources of drought ANT, ALS, CBB, and Rust.
- Progeny screening for different pathogens for resistance (drought, ANT, ALS, CBB and Rust) initiated.
- Training of 8 persons (4 male and female) in breeding data collection and management in Uganda
- Identification of Andean drought tolerant lines from a trial tested in Scottsbluff, NE
- Multi-location evaluation of cooking time and mineral bioavailability in 12 selected Andean lines. Breeding of Andean lines with superior mineral bioavailability, short cooking time and disease resistance.
- Validate high throughput/non-destructive methods for determining cooking time
- Information gathered on farmer/regional preference for fast cooking bean lines as compared to local checks.
- Develop drought screening protocols (using both field and next generation phenometric based techniques) and assemble a drought nursery to be tested across locations in Africa and the US
- Seed multiplication and distribution to participant countries – work through PABRA
- Begin characterization of biophysiological (gas exchange and chlorophyll fluorescence) characteristics associated with drought
- Begin the improvement of both bush and climbing Andean beans introgressing sources of drought and multiple disease resistance
- Enhance country capacity building training 2 PhD students for Africa
- SNP data available to initiate the Association Mapping at least in BNF
- Identified more robust markers for major anthracnose gene(s)

V. Engagement of USAID Field Mission(s). The project PI plans to visit field missions in each country to inform them of the research being undertaken

VI. Partnering and Networking Activities:

- Collaborate with S01.A4 Legume Innovation Lab Project to collaborate on regional nursery and disease screening to improve Mesoamerican beans – Beaver et al.
- Collaborate with BeanCAP project in using SNP Markers developed through that program to map QTL for drought and quality traits.

- NGOs in Uganda 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).
- African Farm Radio Research Initiative (AFRRI) for radio broadcast delivery of new information being implemented by Farm Radio International, and funded by the Bill & Melinda Gates Foundation, to communicate with farmers in remote areas overcoming geographic, economic and literacy barriers.
- Freshpkt-Food Canning Company in Lukasa works with farmers to increase bean production for the canning industry and would be a logical partner for this project.
- Stewards Globe Seed Company has taken up some of the bean varieties from the Bean Program and is engaged in seed production
- The Bean program is working with Farmer Groups in sustainable agriculture by promoting new and improved bean varieties to diversify local diets and improve their nutrition through community seed systems. It is expected that over 200,000 traditional and new bean growers can be reached through this initiative.
- The Bean program in Zambia has strong partnership with a number of NGOs and CBOs who include Self Help Africa, World Vision, Shangila Seed Growers Association, Concern World Wide, IITA Miracle Project, Action Aid to mention but a few. These are partners who are working with communities in disseminating improved technologies.
- In Uganda, funding was secured through AGRA – Alliance for a Green Revolution in Africa and PABRA network. Funding prospects from Kirkhouse Trust in NaCRRI with Annet Namayanja and Pamela Paparu.
- Root rot project Funded by BBSRC (UK): Pathogen Distribution, Characterization and Identification of Resistance Markers Associated with Root Rot Resistance in Common Beans in East and Central Africa –PI – Pamela Paparu, NaCRRI, Uganda.
- Bean value chain project funded by Maendeleo Agricultural Enterprise Fund: Enhancing women smallholder farmers' capacities to produce and market a “sugar bean” in domestic, regional and international markets, “The Sugar bean value chain” - PI Annet Namayanja, NaCRRI, Uganda.

VII. Leveraging of Legume Innovation Lab Resources:

- USDA- NIFA projects: To Develop Common Bean (*Phaseolus vulgaris*) Germplasm with Resistance to the Major Soil Borne Pathogens in Uganda with MSU
- USDA-NIFA: Genetic Approaches to Reducing Fungal and Oomycetes Soilborne Problems of Common Bean in Eastern and Southern Africa with UNL with partners USDA-ARS in Zambia and Mozambique.
- PABRA/SABRN. This project will be in line with the PABRA agenda in Africa and will complement each other and provide opportunity to leverage resources. The choice of Zambia will be an entry point in sharing outputs with other countries as well as link with FTF projects in the region, where Zambia is partnering.
- Agricultural Productivity Program for Southern Africa (APPSA) under the Regional Centre of Leadership-Legumes is set to leverage the project in Zambia with research and capacity building.

- Uganda Ph.D. student in plant breeding, genetics and biotechnology at MSU to work on drought physiology funded through the BHEARD program will work in the project.

VIII. Timeline for Achievement of Milestones of Technical Progress: The "Milestones for Technical Progress" form for the workplan period for FY13, FY14, FY15 and FY16 have been completed for each objective listed in the workplan.

Training/Capacity Building Workplan for FY 2016 – 2017

Degree Training:

First and Other Given Names: Dennis

Last Name: Katuuramu

Citizenship: Ugandan

Gender: M

Training Institution: MSU

Supervising Legume Innovation Lab PI: James D. Kelly

Degree Program for training: Doctorate

Program Areas or Discipline: Plant Breeding, Genetics and Biotechnology

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? Yes

Host Country Institution to Benefit from Training: Makerere University

Thesis Title/ Research Area: Identification of the genomic loci underlying nutritional quality traits in common bean (*Phaseolus vulgaris* L.) seed and participatory evaluation and selection of nutritious beans by farmers in Uganda

Start Date: August 2016

Projected Completion Date: September 2017

Training Status: Active

Type of Legume Innovation Lab Support (full, partial or indirect): Full

Degree Training:

First and Other Given Names: Isaac

Last Name: Dramadri

Citizenship: Uganda

Gender: M

Training Institution: MSU

Supervising Legume Innovation Lab PI: James D. Kelly and Wayne Loescher

Degree Program for training: Doctorate

Program Areas or Discipline: Plant Breeding, Genetics and Biotechnology

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? Yes

Host Country Institution to Benefit from Training: MSU

Thesis Title/ Research Area: Physiological studies on drought tolerance in Andean beans.

Start Date: August 2013 on Legume Innovation Funding

Projected Completion Date: September 2017

Training Status: BHEARD Fellowship from USAID Mission, Kampala.

Type of Legume Innovation Lab Support (full, partial or indirect): Indirect – research support

Short-term Training:

1. Type of training: Drought and Disease Screening methods Description of training activity: To orient staff that will be involved in the day to day data collection and monitoring of drought and disease nurseries so as to get reliable and common parameters
Location: Kabwe Research Centre under ZARI, Kasama, Zambia
Duration: One week (5 working days)
When will it occur: November 2015 – March 2016
Participants/Beneficiaries of Training Activity: Research Technicians and Professionals
Anticipated numbers of Beneficiaries (male and female): 12 (5 females and 7 males)
PI/Collaborator responsible for this training activity: James Kelly/Carlos Urrea / Kennedy Muimui could seek CIAT/PABRA for resource person
List other funding sources that will be sought (if any): PABRA/SABRN support will be sought
Training justification: Having good data collection and evaluation methods is a pre-requisite for good research results. It is important that all those involved will have a common understating and methods of evaluation and data collection
2. Type of training: Application and use of hand held gadgets for field data capture

Description of training activity: Take staff through drought use of data capture gadgets like tablets, photosynQ, GPS, etc. to improve data capture accuracy
Location: National Crops Resources Research Institute, Namulonge, Uganda
Duration 5-7 days
When will it occur: Between October 2016- 2017
Participants/Beneficiaries of Training Activity: Research Assistants and technicians
Anticipated numbers of Beneficiaries (male and female) 12 (7 males and 5 females)
PI/Collaborator responsible for this training activity Stanley Nkalubo/Isaac Dramadri/ Paul Asete/Blessing Odogwu
List other funding sources that will be sought (if any) CIAT/PABRA
Training justification: Data capture in the Uganda bean program is normally manual and labor intensive leading to errors and at times data losses due to the nature in which it is captured and relayed. There have been recent advances in data captured through an example being the use of tablets and smart phones. Our staff need to be exposed to these new advances and we hope that this will lead to more efficient day capture and minimize errors and losses.