

Global Grain Legume Researchers Meeting

May 12 – 16, 2014, Athens, Greece

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Meeting Agenda

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

2014



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Global Grain Legume Researchers Meeting

Improving Agriculture and Nutrition through Grain Legumes

May 12 – 16, 2014, Radisson Blu Park Hotel, Athens, Greece

Program

Monday, May 12

7:00 – 8:30 am	Registration
8:30 – 8:50 am	Opening Session and Welcome Cynthia Donovan, Deputy Director, Legume Innovation Lab
8:50 – 9:25 am	<i>USAID Feed the Future Strategy and Investments in Grain Legume Research and Institutional Capacity Building</i> Jennifer “Vern” Long, Office of Agriculture, Research and Policy, Bureau for Food Security, USAID
9:25 – 10:15 am	<i>Feed the Future Innovation Lab for Collaborative Research on Grain Legumes: Technical Vision for 2013–2017</i> Irvin Widders, Director, Michigan State University
10:15 – 10:45 am	Break
10:45 – 12:20 pm	Thematic session: Agriculture for Nutrition Session Moderator: Robert Mazur, Iowa State University
12:10 – 12:30 pm	<i>Achieving Concurrent Agricultural Productivity and Nutrition Goals Through Research</i> Patrick Webb, Tufts University, Director, Nutrition Innovation Lab
12:10 – 12:30 pm	<i>Nutrition Sensitive Value Chains: The Potential of Grain Legumes</i> Alan de Brauw, Leader for Research on Nutrition Sensitive Value Chains, CGIAR Agriculture for Nutrition and Health Program, IFPRI, Washington DC
12:00 – 12:20 pm	Panel Discussion
12:20 – 12:30 pm	Meeting Logistics and Expense Reimbursement Celina Wille and Angelica Santos
12:30 – 2:00 pm	Lunch
2:00 – 3:40 pm	Thematic Session. Legume Innovation Lab Projects: Strategic Objective 1.A. Genetic Enhancement of Grain Legume Productivity Moderator: Issa Drabo, INERA, Burkina Faso
2:10 – 2:40 pm	<i>SO1.A1. Genetic Improvement of Middle American Climbing Beans for Efficient Production in the Guatemalan Highlands</i> Juan Osorno, Lead PI, North Dakota State University

2:40 – 3:10 pm	SO1.A3 <i>Improving Genetic Yield Potential of Andean Beans with Increased Resistances to Drought and Major Foliar Diseases and Enhanced Biological Nitrogen Fixation</i> James Kelly, Lead PI, Michigan State University
3:10 – 3:40 pm	SO1.A4 <i>Development and Implementation of Robust Molecular Markers and Genetic Improvement of Common and Tepary Beans to Increase Grain Legume Production in Central America and Haiti</i> James Beaver, Lead PI, University of Puerto Rico
3:40 – 4:00 pm	Break
4:00 – 5:30 pm	Session Moderator: Carlos Urrea, University of Nebraska
4:00 pm	SO1.A5 <i>Genetic Improvement of Cowpea to Overcome Biotic Stress and Drought Constraints to Grain Productivity</i> Phil Roberts, Lead PI, University of California- Riverside
4:30 – 5:30 pm	<i>New Frontiers: Phenotyping for Photosynthetic Traits: A Strategy for Increasing Genetic Yield Potential in Grain Legumes</i> David Kramer, Plant Research Laboratory, Michigan State University
6:30 pm	Welcome Reception Roof of Radisson Blu Hotel, Athens

Tuesday, May 13

8:00 – 9:45 am	Thematic Session. Strategic Objectives: <i>Transforming Legume Value Chains and Improving Nutrition</i> Moderator: Constance A. Gewa, George Mason University
8:15 – 8:45 am	SO2.2 <i>Enhancing Pulse Value Chain Performance through Improved Understanding of Consumer Behavior and Decision Making</i> Vincent Amanor-Boadu, Lead PI, Kansas State University
8:45 – 9:15 am	SO3.1 <i>Legumes and Growth</i> Mark Manary, Lead PI, Washington University School of Medicine in St Louis
9:15 – 9:45 am	SO4.1 <i>Impact Assessment of Dry Grain Pulses CRSP and Legume Innovation Lab Investments in Research, Institutional Capacity Building and Technology Dissemination for Improved Program Effectiveness</i> , Mywish Maredia, Lead PI, Michigan State University
9:45 – 10:15 am	Break
10:15 – 12:15 pm	Thematic Session. Moderator: Johannes Lehmann, Cornell University
10:15 – 11:15 am	<i>New Frontiers: Understanding Factors Influencing Smallholder Farmer Decision Making</i> Joshua Ramisch, University of Ottawa, Canada

11:15 – 11:45 am	SO1.B1. <i>Scalable and Sustainable Biological Solutions for Pest Management of Insect Pests of Cowpea in West Africa</i> Barry Pittendrigh, Lead PI, University of Illinois at Urbana Champaign
11:45 – 12:15 pm	SO2.1. <i>Farmer Decision Making Strategies for Improved Soil Fertility Management in Maize-Bean Production Systems</i> Robert Mazur, Lead PI, Iowa State University
12:15 – 12:15 pm	Preparation of FY 2015 Project Workplans and Budgets by Teams Irv Widders
12:30 – 2:00 pm	Lunch
2:00 – 6:00 pm	Legume Innovation Lab Project Team Meetings: FY 2015 Research Planning Breakout Rooms in Radisson Blu
2:00 – 5:00 pm	Technical Management Advisory Committee (TMAC) Meeting Julia Kornegay, Chair
2:00 – 5:00 pm	Interviews of Legume Innovation Lab PIs and Meeting Speakers Marguerite Halversen, Communications and Promotions Dinner (on one's own)
7:00 – 9:00 pm	Technical Management Advisory Committee (TMAC) Meeting Julia Kornegay, Chair

Wednesday, May 14

8:00 – 11:30 am	Thematic Session. Strategic Partnerships in Research and Capacity Building to Achieve Development Outcomes Session Moderator: Doug Buhler, Senior Associate Dean for Research, College of Agriculture and Natural Resources, Michigan State University
8:10 – 8:50 am	<i>Board of International Food and Agriculture Development (BIFAD) Vision for USAID Innovation Labs and Strategic Partnerships to Achieve Feed the Future Goals</i> Dr. Brady Deaton, President Emeritus, University of Missouri, and Chair of BIFAD
8:50 – 9:20 am	<i>CGIAR Grain Legume Program and Value of Strategic Partnership with Legume Innovation Lab</i> Steve Beebe, CIAT
9:20 – 9:40 am	<i>Achieving Synergies among USAID Investments in Grain Legume Research</i> Tracy Powell, Office of Agriculture Research and Policy, BFS, USAID-Washington
9:40 – 10:00 am	Panel Discussion

10:00 – 10:20 am	Break
10:20 – 10:50 am	Concurrent Breakout Sessions A <ul style="list-style-type: none"> • Pan Africa Bean Research Alliance. Steve Beebe, CIAT • Pulse Health Initiative. Janice Rueda, American Pulse Alliance • USAID Climate Resilient Cowpea Innovation Lab. Tim Close, UCR
10:50 – 11:30 am	Concurrent Breakout Session B <ul style="list-style-type: none"> • McKnight Grain Legume Community of Practice. Charles Riches, MF • CG Agriculture for Nutrition and Health (A4NH). Alan de Brauw, IFPRI • USAID Climate Resilient Bean Innovation Lab. Phil McClean, NDSU
11:30 – 12:30 pm	<i>Plenary Session: Legume Innovation Lab Technical Management Advisory Committee (TMAC): Responsibilities and Activities</i> Julia Kornegay, Chair, NCSU
12:30 pm	Lunch
PM	Personal time for independent activities

Thursday, May 15

8:00 – 10:30 am	Thematic Session: <i>Innovations in Sustainable Seed Systems for Grain Legumes</i> Moderator: Vincent Amanor-Boadu, Kansas State University
8:10 – 8:45 am	<i>Seed Production Systems in Pulse Crops in India: Community-based Perspectives</i> Dr. J.S. Sandhu, Agriculture Commissioner, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India
8:45 – 9:20 am	<i>Integrating Seed Systems for Enhancing Impact: Leverage Points for Action</i> , Louise Sperling, Principle Scientist, CIAT
9:20 – 9:40 am	<i>Bean Technology Dissemination Project Experience with Community Seed Banks in Central America</i> Juan Carlos Rosas, EAP-Zamorano, Honduras, and Luis Flores, Michigan State University
9:40 – 10:00 am	<i>Characteristics of sustainable seed systems for grain legumes</i> Byron Reyes and Mywish Maredia, Michigan State University
10:00 – 10:30 am	Panel/Plenary Discussion
10:30 – 10:50 am	Break
10:50 – 12:30 am	Sessiopn Moderator: Angelica Santos, Administrative Officer, MSU Management Office

10: 50 – 11:15 am	<i>Compliance with USAID Regulations and Policies on Equipment Procurement, Environment Mitigation and Monitoring Plans (EMMPs) and Participant Training</i> Jennifer “Vern” Long, Agreement Officer’s Representative (AOR), USAID
11:15 – 12:00 pm	<i>Legume Innovation Lab Program Implementation Issues</i> <ul style="list-style-type: none"> • Feed the Future Performance Indicators (Cynthia Donovan) • International Travel Approval (Cynthia Donovan) • Project Financial Management and Reporting (Angelica Santos) • Communications and Promotion (Marguerite Halversen)
12:00 – 12:30 pm	Election of three PIs to serve on TMAC (Led by TMAC)
12:30 – 2:00 pm	Lunch
2:00 – 5:00 pm	Project Team Meetings. Coordination of research and capacity building activities both within and among Legume Innovation Projects and with partners
2:00 - 4:00 pm	Roundtable on Sustainable Seed Systems
2:00 – 4:00 pm	Interviews of Legume Innovation Lab PIs and Meeting Speakers Marguerite Halversen)
7:00 – ??? pm	Legume Innovation Lab Banquet at the Radisson Blu Hotel

Friday, May 16

8:00 – 9:00 am	Session Moderator: Phil Miklas, USDA-ARS
8:00 – 9:00 am	<i>Challenges to Strengthening of Grain Legume Value Chains in Developing Countries and Vision for Research on Grain Legumes by the Bill and Melinda Gates Foundation</i> Jeff Ehlers, BMGF
9:00 – 9:45 am	<i>Scaling Up in Agriculture and Nutrition</i> Mywish Maredia and Cynthia Donovan, Michigan State University
9:00 – 10:15 am	<i>International Grain Legume Research Gaps, Challenges and Opportunities</i> Open Forum Facilitator: Phil Roberts, University of California, Riverside
10:15 – 10:45 am	Break
10:45 – 11:15 am	<i>2016 International Year of the Pulses</i> Janice Rueda, American Pulse Association

11:15 – 11:30 am	Discussion of Legume Innovation Lab Response to 2016 International Year of the Pulses Irv Widders
11:30 – 11:15 am	Announcement of Capacity Building Award Recipients TMAC Representative
11:45 – 12:00 pm	Closing Session
12:00 – 2:00 pm	Lunch
2:00 – 4:00 pm	TMAC Meeting in Radisson Blu

Meeting participants depart for home on Friday PM and on Saturday

Project Briefs

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

2014



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

Lead U.S. Principal Investigator and University

Juan M. Osorno, North Dakota State University, Fargo, North Dakota, USA

Host Country (HC) and U.S. Co-PIs

Phil McClean, Dept. of Plant Sciences, North Dakota State University, Fargo, North Dakota, USA

Julio C. Villatoro, ICTA–Guatemala

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Karla Ponciano, ICTA–Guatemala

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Edgardo Carrillo, ICTA–Guatemala

Abstract

With approximately 11 million habitants, Guatemala is mostly a rural country, with 60 percent of the population living on farms and 50 percent of the population indigenous. Maize and beans are the main staple food in most households, with a per capita consumption of 9.4 kg per year. Since few other sources of protein are available, this amount is not sufficient to ensure an acceptable nutritional quality, especially within poor households.

The highlands of Guatemala are a unique bean producing region where intercropping (locally known as *milpa*) is still the main production system, mostly with a maize–bean association. The system uses climbing beans that grow around the corn stalks either concurrently or in a relay system. Unfortunately, on-farm productivity of these climbing beans is approximately one-third of their genetic yield potential, mostly due to the lack of improved cultivars able to withstand biotic and abiotic stresses. This low productivity significantly impacts food security and nutritional quality in the region, especially among women and children. Historically, climbing beans have received less attention and breeding efforts in comparison with the bush-type beans commonly grown in the lowlands, as shown by the significant yield gap between regions. The Legume Innovation Lab is starting a new project focused in the highlands of Guatemala with the goal of developing improved varieties of climbing beans that would increase productivity in the region. In addition, the Guatemalan climbing beans are a unique group of germplasm that has not been studied extensively and could offer new genetic variation for traits of economic importance.

Problem Statement and Justification

Dietary recommendations from the Guatemalan government suggest a 75:25 percent daily ratio of maize:bean for a good nutritional balance between carbohydrates and protein intake; however, collected information suggests that the actual daily maize:bean ratio in rural households is approximately 97:3 percent. As expected, the resultant lack of protein intake has reduced the nutritional quality in many households, significantly affecting children. Severe malnutrition cases and even deaths are reported in rural areas, mostly in the highlands.

Beans are grown on 31 percent of the agricultural land and mostly in the low- to mid-altitude regions (0–1500 masl [meters above sea level]) in a monoculture system. In contrast, intercropping (*milpa*) is the main production system in the highlands, where maize–bean is the most common crop association. The main bean producers are small landowners, largely in the highlands. These farmers plant 66 percent of the total area planted to beans in the country, yet the production is only 53 percent of the total national bean production. In contrast, large landowners (greater than 45 ha) in lowland areas produce 28 percent of the beans on only 18 percent of the area planted to beans.

On-farm productivity of these climbing beans is approximately one-third their genetic yield potential, mostly due to the lack of improved cultivars able to withstand biotic and abiotic stresses. Fungal and bacterial diseases and insect pests are the main cause for yield reductions. In addition, production is made with almost no inputs of fertilizers or other chemicals. Historically, climbing beans worldwide have received less attention and breeding efforts in comparison with the bush-type beans commonly grown in the lowlands, as shown by the significant yield gap between regions. There is an existing collection of approximately 600 accessions of climbing beans collected across all bean production regions in Guatemala. This collection is kept by ICTA and has been characterized morphologically and with few molecular markers (6 SSR primers). In addition, this is a group of germplasm that has not been intensively studied and, therefore, may be an untapped source for new genes for resistance/tolerance to biotic and abiotic stresses that could be useful for the entire breeding community.

Objectives

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

Approaches and Methods

The bean breeding program at ICTA has selected a group of ten accessions from the germplasm collection that offer agronomic traits of interest, such as plant growth type, seed yield, disease resistance, earliness, and seed quality, among others. We will start field testing these ten accessions across ten to twenty locations. At the same time, genetic purification of selected lines will be done. After the first year of field testing, the best two lines will be selected for field testing in growers' fields at three locations. Seed from promising lines will be multiplied and released to the public as a first generation of improved climbing beans while a more formal breeding program is being established. Given the uniqueness of this group of germplasm, it is necessary to ensure we are collecting all the genetic variability within this collection so it can be used in the future in breeding programs. To better understand the organization of the genetic diversity of this group, we will screen the core 300 accessions with the 6k BeanCAP chip and conduct a genetic diversity study of possible genetic relationships among the accessions. In addition, an assessment of variation within the ten selected lines will be made to account for the heterogeneity not only among but also within accessions and, possibly, to extrapolate that information to the rest of accessions. The collection will be also evaluated in the U.S. (greenhouse) for reaction to bean rust, anthracnose, *Ascochyta* leaf blight, bean common mosaic virus, and Mexican weevil. This core 300 collection could be used as a diversity panel that could be used for Genome Wide Association Studies (GWAS).

In addition, this project plans to do a small-scale socioeconomic study that will try to answer some of these questions. The results will help design future strategies to improve bean productivity and consumption in the region. A grower survey will be deployed in the main regions where climbing beans are produced. Results of this survey will be shared not only within the project but with other projects currently working in Guatemala (e.g., Másfrijol) and government agencies. A second phase of this study will evaluate the acceptability of new varieties by growers and in the last two years of the project, an assessment of adoption, dissemination, and impact will be made.

Anticipated Achievements and Outputs

- The development and release of improved climbing beans with better agronomic performance (four years).
- A better understanding of the organization of the genetic diversity within this unique set of germplasm (two years).
- Identification of genomic regions associated with traits of agronomic/economic importance (four years).
- An information database of the current market situation and production needs of climbing beans in the highlands of Guatemala (two years).
- Training of the next generation of plant breeders (four years).
- Establishment of a long-term breeding approach (four years).

Projected Developmental Outcomes

Improved germplasm/varieties of climbing beans are expected to be released after this four-year effort. Disease and pest resistance and greater tolerance to abiotic stress of improved cultivars should increase or produce more stable bean yields in the Guatemalan highlands. Collaboration with other projects will allow the dissemination of this genetic material to other regions, further increasing this project's impact. This project will also produce a new information database of the current market situation and production needs of climbing beans in the highlands of Guatemala

Capacity Building of Partner Host Country Institutions

Two individuals from Guatemala will come to do graduate studies at NDSU (Plant Sciences), with the goal that those individuals will be incorporated into agricultural research back into Guatemala. We foresee research projects focused on the analyses of genetic diversity, genetic resistance to diseases, and production systems, among others. The graduate students will be provided a broad range of training in conventional and molecular plant breeding techniques so that they can assume roles of leadership in bean research programs in the target countries. In addition, an informal workshop will be made at NDSU for some members of the bean breeding program at ICTA during the third year. The goal of this training workshop will be to show the ICTA group how bean production is conducted in North Dakota (the largest bean producing state in the United States) and to provide training on molecular markers and other genomic tools that could help in the breeding process.

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

Lead U.S. Principal Investigator

James D. Kelly, Michigan State University, USA

Collaborating Scientists

Wayne Loescher, Michigan State University, USA

James Steadman, University of Nebraska, USA

Carlos Urrea, University of Nebraska, USA

Karen Cichy, USDA-ARS, East Lansing, Michigan, USA

Eduardo Peralta, INIAP, Ecuador

Stanley Nkalubo, NaCCRI, Uganda

Kennedy Muimui, ZARI, Zambia

Abstract

Common bean (*Phaseolus vulgaris* L.) is the most important grain legume consumed in Ecuador, Uganda, and Zambia. Improved bean genotypes from Ecuador have a potentially significant spinoff in adaptability to upland farming systems in East Africa. Building on international bean germplasm, but particularly on the Ecuador germplasm, an opportunity exists to develop and to deploy improved bean varieties, using a combination of traditional and the latest molecular plant improvement techniques. An improved understanding of plant traits and genotypes with resistance to multiple stresses from abiotic (drought) and biotic (root rot and foliar pathogens) sources will provide unique genetic materials for enhanced plant breeding methods and sources to study plant tolerance mechanisms. Improvements in understanding 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 development of improved bean 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 and lower production costs. The project will use QTL (Quantitative trait loci) analysis and single-nucleotide polymorphism (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 the United States.

Project Problem Statement and Justification

Beans are the second most important food legume crop in Zambia and a major source of income and cheap protein for many Zambians. Most of the bean crop (62 percent) is produced on 60,000 ha in the higher altitudes of northern Zambia. Andean beans are predominant and landraces 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, including 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, reflected in the very low national yields ranging from 300 to 500 kg/ha that result in an 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, since Zambia ranks 164 out of 184 countries on the Human Poverty Index. Ecuador has the only active Andean bean breeding program and past advances made in combining different disease resistances in bush beans need to be transferred to the climbing beans that play a vital role in the farming

system and livelihood of small producers. Improvements in climbing beans can easily be transferred to many African countries that grow similar seed types.

Beans are an important crop in Uganda and are grown on more than 660,000 ha of land and consumed throughout the country. They are a major source of food and income for smallholder farmers, especially women and children. The majority of bean production in Uganda is dependent mainly on the use of inferior landrace varieties that are generally low yielding due to susceptibility to the major biotic and abiotic stresses, which gravely undermine the potential of beans 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; the severity of yield reduction depends on the timing, extent, and duration of the drought. The presence of other stresses, such as high temperature, root diseases, shallow infertile soils, and climate change all intensify the problem. Improvements in current understanding of the physiology of drought and evapotranspiration as well as 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. Targeting specific photosynthetic (Ps) traits using phenometric tools to identify and avoid drought sensitive components of the Ps process should lead to the identification of elite genotypes important for breeding improvement. 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 and 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.

Objectives

1. Integrate traditional and marker-assisted selection (MAS) approaches to combine resistances to economically important foliar diseases, drought, and improved 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 United States.
2. 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.
3. Use 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.
4. Develop phenometric approaches to improving the efficiencies of breeding for abiotic stress tolerance, especially drought.
5. Institutional Capacity Building and Training for doctoral students from Zambia and Uganda, one doctoral and one MS student from the United States—all in Plant Breeding, Genetics and Biotechnology.

Approaches and Methods

We plan to conduct QTL mapping and develop molecular markers associated with drought and disease resistance and improved BNF in the Andean Diversity Panel. The pathogenic variability of isolates of foliar pathogens will be determined and identified sources of resistance to ALS, ANT, CBB, BCMV and bean rust will be identified in Andean germplasm. QTL for nitrogen fixation and related traits will be conducted using genome-wide association analysis in Andean bi-parental mapping populations. We will

rely on new instrumentation and techniques now available at the Center for Advanced Algal and Plant Phenometrics at MSU to improve the efficiencies of breeding for stress tolerance, which will allow nondestructive and continuing measurements of photosynthetic properties (e.g., gas exchange and chlorophyll fluorescence), growth and plant architecture, and more detailed measurements of photosynthesis. These analyses will contribute to identifying new traits based on relationships between genotype and drought response. The acceptability of fast cooking, high mineral content will also be assessed using a pin drop (Mattson cooker) method in bean germplasm in Uganda, Zambia, and Ecuador; bi-parental mapping populations will be developed to identify QTL for cooking time. New discovered QTL will be used in breeding for all traits.

Anticipated Achievements and Outputs

- Established and evaluated (mobile) nurseries for ALS, ANT, CBB, rust, and drought and identified source of resistance in Ecuador, Zambia, and Uganda.
- Collected and characterized isolates of ANT, ALS, CBB, and Rust from different bean production regions of Zambia, Uganda, and Ecuador.
- Initiated crossing of landraces with resistant sources of ALS, ANT, CBB, and Rust in Zambia, Uganda, and Ecuador and conducted progeny screening for different for resistances.
- Identified Andean drought tolerant lines from a trial tested in Scottsbluff, Nebraska.
- Assessed the acceptability of Andean lines with superior mineral bioavailability and short cooking times and initiated crossing for genetic improvement of Andean lines with superior mineral bioavailability, short cooking time, and disease resistance and developed high throughput/ nondestructive methods for determining cooking time.
- Developed drought screening protocols (using both field and next generation phenometric-based techniques) and assembled a drought nursery to be tested in Africa and the United States.
- Characterized biophysiological (gas exchange and chlorophyll fluorescence) characteristics associated with drought resistance.
- Developed improved bush and climbing Andean beans with drought and multiple disease resistance.
- Identified more robust markers for ANT and ALS and identified QTL for enhanced BNF and drought tolerance for use in MAS.

Projected Developmental Outcomes

- New improved bean varieties with disease and drought resistance and shorter cooking times
- Release of a new Andean cranberry bean variety with superior overall performance by MSU and two superior quality Mesoamerican navy and black bean varieties by MSU and UNL.
- Release of two new Andean bean varieties by INIAP, Ecuador, and two varieties by ZARI, Zambia. These varieties would differ in seed types so the specific seed type is not yet identified.
- Relevant pathogens, such as rust, characterized in Ecuador, Uganda, and Zambia.
- The project will interface with scientists working for national programs in Ecuador, Uganda, and Zambia, who are heading up active bean breeding programs in each country. Broadening and strengthening these programs is vital to the long-term sustainability of the agricultural sector in all countries. Having the network to exchange germplasm when dealing with similar biotic and abiotic constraints promotes more rapid advancement and increases the opportunity of finding valuable genetic stocks that may result in future varieties with significant, future local impact.

Contributions to Institutional Capacity Building

Enhanced scientific capacity in Uganda and Zambia through graduate student training and short-term workshop: two PhD students for Africa, one MS student for Ecuador, and training for 16 staff (10 male, 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.

Development and Implementation of Robust Molecular Markers and Genetic Improvement of Common and Tepary Beans to Increase Grain Legume Production in Central America and Haiti (S01.A4)

Lead U.S. and Host Country Principal Investigators, Institutions, and Countries

James Beaver and Consuelo Estévez de Jensen, University of Puerto Rico, Mayagüez, PR, USA

Timothy Porch, USDA/ARS/TARS, Mayaguez, PR, USA

Juan Osorno and Phil McClean – North Dakota State University (NDSU), Fargo, ND, USA

Juan Carlos Rosas, Escuela Agrícola Panamericana (Zamorano), Honduras

Julio Cesar Villatoro, Instituto de Ciencia y Tecnología Agrícola (ICTA), Guatemala

Emmanuel Prophete, National Seed Service, Ministry of Agriculture, Haiti

Project Problem Statement and Justification

During the past 30 years, most of the growth in bean production in Central America and the Caribbean has occurred in the lowlands (< 1000 m), especially in the more humid regions. This project addresses several biotic and abiotic constraints often encountered in the tropical lowlands. The presence of BGYMV (Bean common mosaic necrosis virus) and BCMNV (Bean common mosaic necrosis virus) in the Caribbean, Central America, and southeastern Mexico make the selection for resistance to these viruses priority breeding objectives. Legume Innovation Lab plant breeders have developed and released black bean lines, such as *DPC-40*, *XRAV-40-4*, and *MEN-2201-64ML* that combine resistance to BCMNV and BGYMV. Small red bean breeding lines with the same combination of traits for disease resistance are currently being developed at Zamorano. Greater levels of common bacterial blight (CBB) and web blight (WB) resistance are needed for beans produced in warm and humid lowland regions, such as the Petén in Guatemala. Resistance to these diseases also permits increased production of beans in Central America during the first growing season, when rainfall is more abundant and reliable. This project's plant breeders have developed Middle American and Andean bean breeding lines with different combinations of resistance to diseases (CBB, rust, angular leaf spot ALS, WB, and root rot), pests (bruchids, leafhoppers) and tolerance to edaphic constraints (low N soils, high temperature). This project will use these elite breeding lines as the base for the continued improvement of beans for our target countries.

There are regions and/or growing seasons in Central America and Haiti that are too hot and/or dry to produce common beans. The tepary bean (*P. acutifolius*) is a potential alternative grain legume for these stressful environments. Farmers on the Pacific coast of Central America and some countries of Africa already produce tepary beans on a limited scale. In addition to heat and drought tolerance, there are tepary beans with high levels of resistance to common bacterial blight, bruchids and other important traits. Resistance to BCMV and BGYMV as well as larger seed size and improved agronomic traits would increase the potential adoption of tepary beans. Interspecific crosses with common beans will be used to introgress these traits into tepary beans. This effort represents the first systematic attempt to genetically improve tepary beans.

Bean breeders were early adopters of marker-assisted selection (MAS) to identify lines with desired combinations of traits. This resulted in increased efficiency in the development of improved bean breeding lines. There are, however, molecular markers available for a limited number of traits. Others are only effective in a specific gene pool. Therefore, there is a need to develop new or more robust markers, particularly for traits of economic importance to bean breeding programs in the tropics. Recent advances by the BeanCAP project, led by North Dakota State University, in sequencing the bean genome and the development of an SNP array, will facilitate the mapping and development of molecular markers for traits of economic importance, while breeder friendly indel markers are a broadly applicable technology. The

availability of phenotypic data in appropriate populations is a major factor limiting the development of these markers. This Legume Innovation Lab project will assist this effort through the development of the populations and information needed to identify the more robust markers. Dr. Phil McClean at NDSU will lead the collaborative effort to develop improved molecular markers.

There is an urgent need to strengthen the capacity of bean programs in Central America and the Caribbean to conduct research and to independently develop, release, and disseminate improved cultivars. This project will provide MS and PhD degree training in plant breeding and genetics and conduct informal workshops dealing with research techniques to enable national bean programs to contribute to the genetic improvement of beans for Central America and the Caribbean.

Objectives

1. Genetic improvement of common and tepary beans for Central America and Haiti
2. Develop and implement robust molecular markers for disease resistance genes
3. Strengthen the capacity of bean programs in Central America and the Caribbean to conduct research and to develop, release, and disseminate improved bean cultivars.

Research Approach and Methods

Conventional plant breeding techniques and marker-assisted selection are being used by project scientists to develop common bean cultivars and tepary bean breeding lines with enhanced levels of disease and pest resistance and greater tolerance to abiotic stresses. Regional performance trials are conducted in collaboration with national bean research programs and CIAT. Testing in different Central American and Caribbean countries provides additional information concerning the potential performance of breeding lines and expands the potential impact of the research supported by the Legume Innovation Lab. Interspecific populations will be developed to introgress BGYMV- and BCMNV-resistance from common bean to tepary bean.

The BeanCAP project developed a suite of approximately 3000 indel markers distributed across all common bean chromosomes that are codominant and designed to be functional with a single experimental condition (PCR protocol). The power of these markers is that they are simple to implement and thus completely portable in all laboratories and are amenable to multiplexing with suites of markers. Multiplexing reduces the cost of genotyping an individual line. The release of the common bean whole genome assembled sequence allows for precise localization of each of these markers. We will search the published literature and communicate with breeders, geneticists, and pathologists in other Legume Innovation Lab projects to identify genetic materials with contrasting phenotypes (e.g., resistance and susceptibility for the specific disease). Once the location of the marker is determined, it will then be compared to the indel database to discover 30 indel markers that straddle the physical location of the marker. Those indel markers will be used in PCR amplification to determine which one acts as a definitive marker that is unambiguous in its predictive power. NDSU and USDA/ARS scientists will collaborate to determine the potential use of *P. vulgaris* Indels for tepary genetic analysis and mapping

Anticipated Achievements and Outputs

- Release and dissemination in the lowlands of Central America and the Caribbean of black and small red bean cultivars with BGYMV and BCMV (Bean common mosaic virus) resistance and greater tolerance to low soil fertility.
- Release and dissemination in the lowlands of Central America and the Caribbean black, white, and Andean bean breeding lines with resistance to bruchids, BGYMV, BCMV, and BCMNV.

- Release and dissemination of lowland black and white bean breeding lines with resistance to BGYMV, BCMV, BCMNV, and rust.
- Release of yellow and red mottled bean lines with resistance to BGYMV, BCMNV, and BCMV.
- New bioinformatic-based approach to facilitate marker development.
- Release of tepary bean lines with virus resistance and improved agronomic traits.
- Indel markers for traits of economic importance that will facilitate the selection of bean lines with the desired combination of traits.
- Technical personnel in Central America and the Caribbean with greater capacity to produce reliable and repeatable results from field trials and to develop and release improved cultivars.
- Graduate degree training in plant breeding of students from Central America and the Caribbean

Projected Developmental Outcomes

Several improved (black, small red, red mottled, and yellow) bean germplasm lines and cultivars are expected to be released in Central America and the Caribbean during the next five years. This Legume Innovation Laboratory project will continue, in collaboration with CIAT, to support bean research network activities in Central America and the Caribbean. Collaborative activities such as the regional performance nurseries will help to extend the impact of this project through the release of improved cultivars throughout the region. Disease and pest resistance and greater tolerance to abiotic stress of improved cultivars should increase or produce more stable bean yields in Central America and the Caribbean. The BCMNV resistant Andean bean lines and tepary bean breeding lines developed by this project will be shared with Legume Innovation Lab and Feed the Future projects working in Africa.

The development of robust indel markers for traits of economic importance should improve the efficiency of bean breeding programs. Multiplexing indel markers would permit simultaneous screening for multiple traits. Bean lines having desirable genotypes can be identified in earlier generations. Disease resistance genes can be combined without the need to screen lines with specific isolates or races of pathogens. These indel markers should have worldwide utility.

Contributions to Institutional Capacity Building

- In-service training will be provided at NDSU for Legume Innovation Laboratory scientists to review recent advances in sequencing the bean genome and the utilization of SNP arrays to develop indel markers for traits of economic importance.
- Workshops will be held at Zamorano to train technical personnel concerning bean research techniques with the goal of improving the quality of field research. Topics will include the development and management of field trials, breeding and selection methods, field evaluation techniques, research with *Rhizobium*, participatory plant breeding, production of basic seed stocks, and agroecological techniques.
- Undergraduate students at Zamorano will be provided opportunities to participate in bean research activities related to Legume Innovation Lab project objectives.
- M.S. degree training will be completed at the UPR by Ana Vargas (Nicaragua), Angela Miranda (Guatemala), and Diego Rodriguez (Ecuador).
- Ph.D. degree training at NDSU of two bean researchers from Central America, the Caribbean, or Africa will be initiated. Both students will be trained in the use of conventional and molecular techniques.

Genetic Improvement of Cowpea to Overcome Biotic Stress and Drought Constraints to Grain Productivity (SO1.A5)

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Abstract

Cowpea is a highly nutritious grain legume crop vitally important to food security in sub-Saharan Africa, especially for women and children, where it complements cereals in the diet. However, in the Sudano–Sahel region of West Africa, typical smallholder farmer cowpea yields are only 10 to 20 percent of known yield potential. Biotic stresses caused by insect pests and diseases caused by pathogens, parasitic plants and nematodes, and abiotic stresses from drought and low-fertility soils are primary constraints to cowpea grain production.

This project focuses on cowpea breeding with emphasis on insect tolerance and resistance traits, combined where feasible with drought tolerance and disease resistance traits. More specifically, tolerance or resistance to aphids, flower thrips, and pod-sucking bugs is being pursued through trait discovery and molecular-driven breeding selection to generate improved cowpea varieties. Field and lab-based phenotyping in Burkina Faso, Ghana, and Senegal will be matched with SNP marker high-throughput genotyping to identify and select for target QTL in the cowpea genome. Advanced breeding lines are being tested regionally across the host countries to broaden their release potential. In addition, several near-release advanced lines will be performance tested for full release decisions in Burkina Faso and Senegal, capitalizing on previous USAID CRSP investment. In California, cowpea dry grain novel market classes of breeding lines will be advanced together with leveraged funding in support of the U.S. dry bean industry. Primary capacity building in each of the host countries will be achieved by graduate degree training in cowpea breeding and genetics coupled with short-term annual training of NARS scientists in molecular breeding.

Problem Statement/Justification

In the Sudano–Sahel region of West Africa, typical smallholder farmer cowpea yields are only 10 to 20 percent of known yield potential. Biotic stresses caused by insect pests and diseases caused by pathogens, parasitic plants, and nematodes and abiotic stresses from drought and low-fertility soils are primary constraints to cowpea grain production. By targeting insect tolerance and combining, where feasible, with drought tolerance associated traits, we have a realistic opportunity to increase cowpea productivity. To be widely adopted, new cowpea varieties must have features desired by consumers as well as farmers, including grain appearance, cooking qualities, and processing characteristics. Breeding targets include large white grains with rough seed-coat, preferred throughout West Africa and amenable to direct dry milling; they can be marketed over a wide area, buffering supply and pricing in the region. Cowpea varieties with large white grain and resistance to pests would increase marketing opportunities in both

West Africa and the United States. Large rough brown seed type is also in high demand, especially in large urban centers in Nigeria. Current, premium rough-brown cultivars like *Ife Brown* are susceptible to pests and diseases and require genetic improvement. Our project targets West Africa cowpea production in FTF focus countries Ghana and Senegal, and also Burkina Faso, which offers regional importance from an agroecological perspective for cowpea yield gain.

The project aims to 1. discover insect tolerance and resistance QTL for cowpea breeding application; 2. increase the productivity of African and US cowpea producers through the development of improved varieties that possess resistance or tolerance to the major insect stresses combined with drought tolerance or disease resistance impacting cowpea production; 3. expand farmer marketing opportunities by breeding improved cowpea varieties with desirable grain characteristics; and 4. provide training and capacity building in modern cowpea breeding to African researchers.

The project employs genomics and modern breeding methods to improve cowpea for yield-limiting constraints, emphasizing insect tolerance and resistance. Significant gain can be made by targeting the major insect threats that occur at early (aphids), mid-flowering and pod-set (flower thrips), and later pod-filling (pod-sucking bugs) stages of the cowpea season. Some promising leads on resistance and tolerance donors and initial QTL identity have been made to provide good starting points in the project. High throughput SNP genotyping platforms, high density consensus cowpea genetic maps, plus numerous discovered QTL for important biotic stress resistance and abiotic drought and heat tolerance traits are now available. Several early generation populations carrying various target traits provide a valuable starting point for breeding advancement. We have been working closely with the CGIAR–GCP Integrated Breeding Platform program development using our cowpea data as a test user case; these technological advances are being applied to the project work.

Objectives

1. Discover QTL for insect resistance and apply in molecular breeding for target regions in West Africa and the United States.
2. Complete release and validation of advanced cowpea lines developed under the Pulse CRSP in Burkina Faso, Senegal, and United States.
3. Increase capacity of NARS in Burkina Faso, Ghana, and Senegal to serve the cowpea sector.

Research Approach and Methods

We have developed the necessary tools to exploit molecular breeding for cowpea, including genetic SNP markers; high density SNP-based genetic maps, including consensus maps; a high-throughput SNP genotyping platform for cowpea; QTL for many major biotic and abiotic stress resistance and tolerance traits; and accompanying software programs. These tools enable selection of multiple traits simultaneously across the genome. Under three subobjectives on aphid, flower thrips, and pod-sucking bug resistance, the approach is to discover and validate QTL underlying the target insect tolerance/resistance traits, then apply the QTL knowledge to breeding population development and advancement. The KASP SNP platform has 1,022 mapped SNPs providing excellent coverage across the cowpea genome. Breeding parents and progenies (individuals or bulked families) will be phenotyped and genotyped for QTL discovery or trait selection. Genotyping data will be used for both foreground (trait) and background selection. Three backcrossing populations per partner will be developed to combine insect tolerance and drought plus other traits carried by the chosen parents. Intercrossing of advanced backcross line will provide further opportunity to combine additional traits. Molecular profiling of insect populations in the target countries will be made to index biotype variation.

We are capitalizing on the previous Pulse CRSP breeding effort by completing the release requirements of advanced lines now in the final stages of performance testing. In Senegal, three prerelease large white grain type cowpeas and in Burkina Faso, 20 prerelease CRSP advanced lines require final on-farm multilocation performance testing. They will also offer the opportunity for tracking along the impact pathway as new releases entering the seed multiplication and distribution process in each country. Gender considerations have been incorporated into the trait selection process regarding grain types preferred by women farmers, processors of value-added products, and consumers. A second component of this objective is to use our SNP marker genotyping capability to advance the backcrossing of the BT gene insertion for *Maruca*-resistance into preferred varieties using breeding populations in Burkina Faso and Ghana. The genome-wide SNP data will be used to measure the percent recovery of the recurrent parent background to expedite the backcrossing selection process.

Anticipated Achievements and Outputs

- Biotype definition of aphid populations in response to aphid resistance genes in cowpea will produce new knowledge important to insect resistance breeding. Similar approaches will be made for flower thrips and pod bug insect populations.
- QTL governing cowpea tolerance and resistance to aphids, flower thrips, and pod-sucking bugs will be discovered and validated, providing new breeder resources (mapped QTL tagged with SNP markers and new understanding for their successful application).
- Improved cowpea varieties and advanced breeding populations of consumer preferred market types with resistance to biotic stresses and drought tolerance will be produced by recurrent backcrossing to introgress specific traits into preferred varieties, and recurrent selection to develop next generation varieties.
- Variety releases will be made from existing CRSP-developed cowpea advanced lines in Burkina Faso and Senegal.

Projected Developmental Outcomes

Higher yielding cowpea varieties will increase the nutritional status of diets for women and children in sub-Saharan Africa. Higher yielding, market-preferred cowpea varieties will generate additional family income to support improved living conditions and child educational opportunities. New knowledge of insect tolerance and resistance traits in cowpea will benefit grain legume breeding programs beyond the project host countries. Short- and long-term training will increase the likelihood of next generation cowpea breeders applying modern breeding in sub-Saharan Africa.

Contributions to Institutional Capacity Building

A combination of short-term and long-term training activities is being conducted to develop capacity in modern cowpea breeding in the NARS of Burkina Faso (INERA), Ghana (SARI), and Senegal (ISRA). The QTL discovery and molecular breeding activities provide an excellent training framework for both new and senior breeders in cutting-edge molecular breeding approaches. Training includes both short-term visits by HC breeders to UC Riverside, breeding workshops coupled to LIL and related project annual meetings, and long-term degree training to develop a new generation of cowpea breeders. Graduate students (two already enrolled) are being trained directly at UC Riverside in cowpea genetics, pathology, and molecular breeding, and also by mentoring those working on cowpea breeding dissertation projects at WACCI, Ghana, and other African Universities.

IPM-omics: Scalable and Sustainable Biological Solutions for Pest Management of Insect Pests of Cowpea in Africa (S01.B1)

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Abstract

Cowpea is an important protein source for tens of millions of West Africans living on less than \$2 a day. The major biotic constraint on cowpea crops in West Africa is an insect pest complex. Pesticides and/or transgenics will not provide the long-term solutions needed to bring these pest populations below the economic thresholds needed by cowpea farmers. The only remaining logical strategy: Integrated Pest Management (IPM) involving a pipeline of diverse pest control solutions. Our program is focused on the development and deployment of scalable pest control solutions involving a combination of traditional pest control and deployment strategies and cutting-edge technologies, including genomics and GIS to help direct the most effective deployment of these approaches. Testing and deploying cutting-edge information communication and technology (ICT) tools is also a part of the scaling of these solutions.

Our program, *IPM-omics*, involves defining the pest problems, bringing forward appropriate solutions through a biocontrol/biopesticide pipeline, and scaling these solutions through multipronged strategies that will include farmer field flora, ICT approaches, women's cooperatives, and partnerships with small-scale industries. We have and will continue to develop online interfaces that make our outcomes easily available to other groups that can benefit from the materials; we will continue to develop approaches so that we can share solutions with outside groups that can help in the scaling and sustainability of these solutions. We will develop, deploy, and test training/technology packages/programs that will be passed-off to groups (e.g., NGOs, national/international agencies), and we will determine the potential for impact of this approach.

Problem Statement and Justification

Insect pests of cowpeas dramatically reduce yields for cowpea farmers in West Africa, many of whom live on less than \$2 per day. Arguably, the greatest biotic constraints on cowpea (*Vigna unguiculata* [L.] Walp.) production are insect pests. The major pests of cowpea in the field in northern Nigeria, Niger, and Burkina Faso include the legume pod borer (*Maruca vitrata* Fabricius); the coreid pod-bugs (*Clavigralla tomentosicollis* Stal and *Anoplocnemis curvipes* [F.]); the groundnut aphid (*Aphis craccivora* Koch); and thrips (*Megalurothrips sjostedti* Trybom). Foundational work has been initiated to understand these insect pests in the areas where we propose to work to develop and deploy solutions. This foundational work has positioned us well to have a better understanding of pest biology and population structure (due to molecular tools), which will help direct current and future pest control strategies.

Although biocontrol agents, transgenic plants, and traditional plant breeding for insect-resistant varieties are all potentially effective methods for controlling pests of cowpeas, a continued refinement of our

understanding of pest populations is needed to integrate these—and other—pest control options into an overall integrative pest management plan to maximize cowpea production in the field. IPM refers to a pest control strategy in which a variety of complementary approaches are used to minimize the negative effects of pests on a given crop or cropping system. As we develop, refine, and deploy IPM strategies, we must understand the important life-history parameters of these pest insects in relationship to their environment.

Scalable IPM solutions are going to be highly necessary to increase yields, which are dramatically affected by pest populations. From the last cycle of the CRSP program, we observed that a logical set of combined IPM strategies could increase yield of cowpeas by more than 100 percent (e.g., neem plus *M. vitrata*-specific virus spray controls). We also have developed and released biocontrol agents that can be released across more areas of West African and establish themselves in the field to suppress insect populations over the long-term; this approach is highly cost-effective, sustainable, farm-sized, and gender neutral. Over the next four years, we will research, develop, implement, and determine the impacts of an IPM-omics program for cowpea in West Africa. We will continue to research and develop scalable solutions, with the potential for larger-scale impact with donor community buy-in.

Objectives

1. Define the pest problems on cowpea in Ghana, Burkina Faso, Niger, and Benin
2. Discover, document, and set the stage for scaling of appropriate IPM solutions
3. Scaling of solutions
4. Capacity Building Research Approach and Methods

Research Approach and Methods

Objective 1. We have and will continue to use a mixture of field studies and molecular tools to define the pest population on cowpea across multiple ecological zones in Ghana, Burkina Faso, Niger, and Benin.

Objective 2. We have and will continue to bring forward ecologically sound and highly cost-effective pest control strategies for the pests of cowpea. This will involve the continued development of appropriate solutions through host plant resistance traits, a biocontrol/biopesticide pipeline, and other IPM solutions that involve local educational programs.

Objective 3. We will research and deploy tangible outputs for the scaling of our IPM solutions. This includes, but is not limited to, releasing of biocontrol agents that can establish in the environment (and control the pest populations), testing the potential for cottage industries for biopesticide production, and, finally, creating scalable educational tools for IPM.

Objective 4. We will continue to capacity build through diverse educational programs that range from graduate student and technician training to ICT technologies that help local institutions increase their impact.

Anticipated Achievements and Outputs

1. In the past phase of this program our approach of combining field and molecular data gave us important insights into the movement patterns of *M. vitrata*; the results from this work are now driving recommendations for pest management strategies for this species. In the next phase of this project, we expect to develop similar insights and recommendations for other pest species that attack cowpea in the field.

2. Our program has both developed novel pest control strategies for the control of the pests of cowpeas (e.g., neem plus a virus that kills *M. vitrata* larvae) and emerging new biocontrol agents that will be highly useful in minimizing pest populations on cowpeas.
3. We expect to develop, based on our research outputs, the most cost-effective strategies for biocontrol agent release. Additionally, we also expect to determine the potential for local biopesticide production through women's cooperatives, from both a technical and market prospective.
4. We will train new MS and PhD students with a focus on IPM for cowpeas and the population genomics of the pests of cowpeas, cross-train technicians and scientists in our network, and develop scalable ICT solutions for the educational component of our IPM program.

Projected Developmental Outcomes

We expect to have a greater understanding of the pest problems of cowpeas to facilitate the cost-effective development and deployment of IPM solutions for cowpea farmers in Ghana, Burkina Faso, Niger, and Benin. It is expected that many of these strategies will have the potential to double the yield of cowpea crops in the field.

Contributions to Institutional Capacity Building

Our program will continue to train the next generation of scientists in Ghana, Burkina Faso, Niger, and Benin who will focus on issues associated with pest problems in cowpea through the training of undergraduate, master's, and PhD students. We will also promote the cross-training of scientists and technicians across the four host-country programs and with U.S. scientists to build a network capable of understanding pest problems on cowpea in West Africa and to develop the sharing of solutions. We will continue to develop, to test, and to deploy novel ICT programs in local languages, alongside and in conjunction with farmer field flora, in order to take our pest control innovations into the hands of cowpea farmers. Finally, our ICT infrastructure will allow us the capacity to share these pest control approaches directly with other government and nongovernment organizations as well as international organizations involved in the dissemination of pest control solutions.

Farmer Decision Making Strategies for Improved Soil Fertility Management in Maize–Bean Production Systems (S02.1)

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Abstract

Poor and declining soil fertility is the primary constraint to common bean productivity among smallholder farmers in Africa, affecting cropping systems, food security, nutrition, incomes, and livelihoods.

Adoption of improved crop management practices, particularly regarding soil fertility, has been modest.

Our *central premise* is that addressing soil-related constraints requires understanding farmers' current practices and enhancing their capabilities in diagnosing and finding solutions to yield constraints.

Problem Statement/Justification

Smallholder farmers in Africa—women and men—manage complex, multifunctional maize–bean cropping systems in diverse landscapes and agroecosystems. Common beans serve multiple important roles in their cropping systems, food security, nutrition, incomes, and livelihood resilience. They register low yields and experience pervasive poverty and food insecurity. Low productivity is due to poor soil fertility, limited access to improved seed varieties, excess water during plant growth, insects, and diseases. Typical yields of 200 to 500 kg ha⁻¹ are significantly less than the 2000 kg ha⁻¹ often obtained in researcher-managed fields. Poor and declining soil fertility is considered the primary constraint to common bean productivity, responsible for 30 percent of the yield gap. Grain legume research programs identify and develop improved technologies and management practices that can substantially increase yields. However, adoption of improved crop management practices, particularly for soil fertility, has been modest for beans.

This research project is based on two premises: 1. sustainable intensification of agriculture production requires improved soil fertility management in which legumes are an integral part of cropping systems and 2. addressing soil-related constraints requires not simply increasing access to fertilizers or use of other soil amendments, but—fundamentally—enhancing smallholder farmers' capabilities in diagnosing and finding solutions to important yield constraints.

Project activities are taking place in key bean production regions in two important Feed the Future (FTF) focus countries: Uganda, where maize and beans are promoted through FTF projects in 62 districts, and Mozambique, where Feed the Future priority provinces are Nampula and Zambézia; beans are a priority crop). Increasing bean productivity can help reduce poverty and improve nutrition. In Uganda, beans are

the most important legume crop, and fifth crop overall. In Mozambique, beans are a cash crop for 35 percent of producing households; the country is the largest informal exporter of maize and beans in southern Africa (50 percent share of regional exports in both). Poor soil fertility has been identified as a major factor in reduced bean yields, and both countries have weak extension systems and rural institutions, so that access to crop technologies, inputs, and credit is limited primarily to informal systems.

Objectives

1. Characterize farmers' motivations, current knowledge and practices, problem diagnoses and solutions, and livelihood and risk management strategies.
2. Develop and refine models about farmers' decision making.
3. Develop and validate appropriate diagnostic and decision support aids.
4. Develop and assess the effectiveness of innovative approaches for dissemination of information and decision support aids, training, and follow-up technical support.
5. Enhance institutional research capacity relative to grain legumes.

Research Approach and Methods

This project seeks to develop tools (methods and procedures) that will enable smallholder farmers with varying levels of education to better diagnose soil-related production constraints and make improved site-specific crop system management decisions that contribute to higher productivity (including grain legumes) in the short-term as well as improvements in soil fertility in the long-term. It will also assess the effectiveness of innovative communication approaches and technologies to engage farmers with diverse characteristics and other key stakeholders in widespread dissemination and adoption of diagnostic and decision support aids in different agroecological contexts. Core research activities are:

- Participatory rural appraisal and baseline surveys for activity planning, taking into account critical social, economic, and cultural factors that impact decision making and the adoption of new strategies and technologies, and for monitoring changes over time
- Farmer innovator and scientific analyses of soil-related constraints
- Participatory, on-farm studies using identified possible solutions
- Participatory, gender equitable development and validation of diagnostic and decision support aids
- Development and pilot-testing of innovative sociotechnical approaches for communication, dissemination, and scaling up

Anticipated Achievements and Outputs

- Characterization of smallholder bean farmers' agricultural motivations, current knowledge and practices, problem diagnoses, and livelihood and risk management strategies (by 2015)
- Models of farmer decision-making strategies that reflect influences of social, cultural, economic, institutional, and contextual factors developed and refined (by 2016)
- Innovative diagnostic aids using observable characteristics that enable farmers to make site-specific management decisions developed and validated (by 2016)
- Process for identifying alternative strategies and management practices for improving cropping system productivity and soil fertility developed (by 2017)
- Effective and efficient methods and media for information dissemination to intermediate and end users developed and assessed (by 2017)
- Capacity building through applied, research-based training conducted (2013 onwards)
- Research results published in peer-reviewed literature and other key outlets (2015 onwards)

Projected Developmental Outcomes

Improved management capabilities will have four important short- and long-term benefits:

1. Empowering farmers (especially women) to take an active role in identifying problems and solutions in bean production
2. Improving household income through the sale of increased bean production
3. Providing higher volume of beans for traders along the value chain within the country and in cross-border trade
4. Ensuring greater availability of nutritious beans and less dramatic seasonal price fluctuations for net consumers (other rural households and urban consumers).

The project will contribute directly to achieving four of the six Feed the Future focal areas: inclusive agriculture sector growth, gender integration, climate-smart development, and research and capacity building.

Contributions to Institutional Capacity Building

This multidisciplinary research project enables soil scientists and social scientists in Uganda and Mozambique to strengthen their skills in key areas, including systems approaches to crop and soil fertility improvement that take into account social, cultural, economic, institutional, and contextual factors that shape farmers' decision making. Development and application of diagnostic and decision support aids, combined with research on communication for dissemination/scaling up impact, will be useful in many future research projects in these countries. Interinstitutional training activities include short-term training at Iowa State and Hawai'i for technical staff and junior and senior researchers; long-term training at Makerere University (two master's students in soil science and one in extension and innovation studies), Iowa State University (master's student in sustainable agriculture and sociology, and (master's student in communication) and the University of Hawai'i (one PhD student in tropical plant and soil sciences).

Enhancing Value Chain Performance Through Improved Understanding of Consumer Behavior and Decision Making (SO2.2)

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CGIAR/Pan-African Bean Research Network

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Grain Legume Association Ltd., Malawi

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Abstract

Despite their high nutritional profile and knowledge about their nutritional benefits, grain legumes are not high on the food hierarchy in Malawi, Tanzania, and Zambia. The challenge confronting producers and their supply chains is how to enhance their competitiveness in their local markets and get the necessary policy support from their government to sustain it. This project seeks to make two critical contributions to this challenge. First, it seeks to develop a clearer appreciation of the factors influencing grain legume consumption in the three countries to provide empirical direction for market and policy development. Second, it seeks to provide training and capacity building support for the industry's stakeholders to seize identified opportunities and address existing and emerging challenges. When this project succeeds, it will contribute to creating value in the grain legume value chain by helping stakeholders along the value chain utilize an improved understanding of consumer choice decisions in their own decision-making processes.

The project has three integrated dimensions: 1. An empirical foundation for understanding factors and their influence on food choices; 2. application of the empirical results in crafting policies and facilitating knowledge and skill development in managing value chains; and 3. developing and delivering outreach programs to help both private and public stakeholders improve the performance of grain legume value chains. These activities contribute to supporting strategies and initiatives that enhance the well-being of smallholder producers. This project, therefore, provides innovative and unique pathways that bring producers, including smallholder producers, and public and private stakeholders together to help achieve the underlying objectives of the Feed the Future initiative.

Problem Statement/Justification

We know very little about the factors that shape demand for grain legumes in Eastern and Southern Africa. As a result, industry stakeholders, from small and large holder producers through aggregators,

exporters, wholesalers, and retailers to policy makers have been unable to develop knowledge-based strategies to influence the demand for grain legumes. Addressing this knowledge gap across the supply chain would improve stakeholder decision making and enhance operational performance by helping them identify and develop effective business models that contribute to the sustainability of their competitiveness.

Because food consumption is determined by both social and economic factors, it is hypothesized that improving the appreciation of the stakeholders of the legume supply chains in Eastern and Southern Africa on how consumers make food choice decisions and where legumes fit into those choices would help develop a more effective strategy to enhance their performance and profitability. For example, it could enhance the breeding strategies of research institutions and seed developing companies and help public policy makers direct policies that support sustained improvement in consumption.

This project, therefore, seeks to develop new understanding of the factors influencing consumers' food choice decisions in Malawi, Tanzania, and Zambia, and then use this understanding to facilitate improvements in grain legume value chains. The project has three integrated dimensions. First, it develops an empirical foundation of understanding the factors and the extent that these factors influence food choices. This will be the first empirical evaluation of factors and their complex interactions influencing consumer choice of grain legumes in Eastern and Southern Africa. Second, the research employs these insights to engage industry stakeholders (government, private businesses, nongovernmental organizations, producers, traders, processors, etc.) and public institutions (research institutes, universities, extension, etc.) in a search for value creation and value expansion opportunities as well as solutions to challenges preventing value chain effectiveness. The third dimension involves using the foregoing information to carefully develop and deliver outreach programs aimed at enhancing strategy development, management and decision-making, and other skills of industry stakeholders. In the end, the project provides innovative and unique pathways that bring smallholder producers and other stakeholders into *specific* alliances to help smallholder producers improve their economic well-being.

Objectives

Our overall objective is to facilitate the development and execution of private and public sector strategies that enhance growth in the grain legume industry. The specific objectives are:

1. Identify and analyze the factors shaping bean/cowpea consumption and their relative positions in consumers' food rankings in the selected countries.
2. Conduct situation analyses for bean/cowpea production and marketing/distribution systems with a view to identifying the nature and extent of the gaps in their value chains.
3. Implement formal and informal capacity building initiatives to address identified gaps and to support value chain management capacity across the grain legume industry in the focus countries.

Research Approach and Methods

We collect primary data using a survey approach that uses a two-stage sampling technique in the three focus countries. The first stage is the sampling of enumeration areas in the three largest cities in each country and the second stage involves the selection of households in each enumeration area. There are two parts to the survey process. The first part gathers socioeconomic information about the participants and the second part uses the DCE approach to elicit respondents' food preferences. We also employ econometric analyses to evaluate the data to identify the factors that influence choices and preferences. We use secondary data to evaluate the production and marketing situation of grain legume products in the

focus countries. Finally, we use dynamic curriculum development and multiple engagement processes to facilitate the training and outreach efforts to build decision-making and operational capacity across the grain legume industry in the focus countries.

Anticipated Achievements and Outputs

The primary anticipated achievement from this effort is the enhanced capacity of grain legume stakeholders in the focus countries through research-based decision-making. This improvement in decision making should lead to higher performance across the whole supply and value chains. The principal outputs contributing to these achievements are a number of research reports addressing the first two objectives and curricula on value chain development and management training programs resulting from the research. Additionally, the project anticipates producing a number of MS-level graduates and Master of Agribusiness graduates to improve the professional analytical and decision-making capacity environment in the focus countries.

Projected Development Outcomes

1. Better information to facilitate product development for target markets, thereby improving commercialization success
2. Enhanced productivity along the value chain, leading to improved value creation at each stage
3. Sustainable collaborative initiatives that produce superior business models that are inclusive for smallholder participants across the industry

Contributions to Institutional Capacity Building

The capacity building initiatives defined in this project are designed to facilitate stakeholders' ability to think critically about their options before choosing and assess the economic outcomes of their alternatives before acting. Systematically developing short courses to fill identified and emerging skills and knowledge gaps contributes to this focused capacity building initiative. By using multiple pedagogical approaches and delivery mechanisms, we are able to reach a broader segment of the industry. Because the industry's challenges are symptomatic of the sector and generally apply to most small- and medium-sized businesses, we believe the benefits of our capacity building efforts in the host countries private and public institutions would reach beyond the primary targets of this project.

Legumes and Growth (SO3.1)

Lead U.S. Principal Investigator (PI) and affiliated U.S. University

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Abstract

Because millions of children die annually due to undernutrition and hundreds of millions more are stunted, interventions that decrease the burden of childhood malnutrition are urgently needed. Environmental enteropathy (EE), a pervasive chronic subclinical inflammatory condition among children that arises when complementary foods are introduced, places them at high risk for stunting, malabsorption, and poor oral vaccine efficacy.

Two randomized, controlled clinical trials to determine if common beans or cowpeas improve growth, ameliorate EE, and alter the intestinal microbiome during this high-risk period are proposed. The first study involves 6–11-month-old children who will receive common beans, cowpeas, or standard local complementary foods for six months. Anthropometry will be compared among the three groups. EE will be assessed using a urine dual-sugar absorption test and by quantifying human intestinal mRNA for inflammatory messages and the intestinal microbiota characterized by deep sequencing of fecal DNA to enumerate the host microbial populations and their metabolic capacity. The second randomized, controlled trial will enroll 12–35-month-old children and follow them for twelve months; each subject will receive dietary interventions, either legume-based or control. Anthropometric, host inflammatory, and gut microbiota analyses will be conducted similar to the first study. By amalgamating the power of the clinical trial and advanced biological analyses, we will elucidate the potential of legumes to have a major impact on child health in sub-Saharan Africa.

Project Statement and Justification

Approximately 45 percent of all deaths worldwide among children under the age of five (i.e., 3.1 million deaths annually), are directly or indirectly related to undernutrition. Additionally, stunting permanently affects an additional 165 million children worldwide and reduces the affected individual's physical, immunological, and cognitive capacity throughout his or her lifetime. Stunting is estimated to account for 21 percent of all disability adjusted life years (DALYs) in children. Both stunting and wasting are causally related to the dietary intake and gut health in children younger than three years of age.

In developing, impoverished settings, a nearly ubiquitous gut inflammatory condition known as environmental enteropathy (EE) often develops within the first three years of life, a high-risk period marked also by the transitions from exclusive breastfeeding to mixed feeding with complementary foods to the complete reliance on adult foods for sustenance early in life. While subclinical, EE predisposes children to more clinically manifest forms of malnutrition: wasting and stunting. Given the significant contribution of malnutrition to childhood morbidity and mortality, meaningful progress on reducing EE is needed to establish a lasting foundation for progress against global hunger.

In traditional sub-Saharan African societies, complementary foods are dominated by monotonous, protein-poor, and micronutrient-poor starches such as maize, cassava, and sorghum. Alternative, yet

culturally acceptable, complementary foods that can provide a better and more palatable balance of nutrients may promote a decrease in EE and improved growth. Legumes provide just such an opportunity, since their protein content is significantly higher than cereals and they are rich in dietary fiber, starch, minerals, vitamins, and antioxidants. Common beans and cowpeas, for example, have three- to four-fold more protein per gram than corn. The zinc content in legumes is also relatively high and might further decrease the progression of EE, as has been demonstrated recently in a prospective randomized trial. Legumes make an excellent complementary food for children weaning from exclusive breastfeeding and with appropriate preparation are quite digestible and well tolerated. Successful legume–maize blends have, in fact, already been developed in the past and demonstrated favorable acceptability profiles in children younger than one year of age; they were also nutritionally sound as a weaning supplement. Cowpea is also attractive for study, as it grows well in the African context, is culturally accepted, and is a hardy, drought-tolerant, crop. Cowpea also has significant anti-inflammatory effects, mediated by specific phenolic profiles and antioxidant activity.

Human and animal studies of the effect of legumes on the intestinal microbiome are limited. A recent study comparing the gut microbiota in children from rural Burkina Faso who consumed a diet rich in legumes with European children showed a relative lack of potentially pathogenic Enterobacteriaceae in the African children, conceivably protecting these children from severe gut inflammation and bacterial translocation.

Since EE is a chronic inflammatory condition, interventions with anti-inflammatory effects might also improve gut health. A growing body of evidence suggests that a diet enriched in legumes decreases inflammation markers correlated to illnesses with inflammatory component,s such as colorectal cancer and cardiovascular disease. Legumes could therefore serve as a complementary food in this high-risk population, with key measurable endpoints and biomarkers, including markers of EE and growth parameters.

Objectives

1. Evaluate changes in childhood anthropometry (height-for-age and weight-for-height z scores), biomarkers of EE (lactulose:ramnose and a panel of human mRNA messages correlated with EE) and the characteristics of the microbiome (population taxonomy from phyla to genus, and the collective metabolic capacity expressed as Kyoto Encyclopedia of Genes and Genomes (KEGG) categories) after inclusion of either cowpeas or common beans as an integral component of complementary feeding for 6–11-month-old rural Malawian children.
2. Evaluate changes in child growth (height-for-age and weight-for-height z scores), biomarkers of EE (lactulose:ramnose and a panel of human mRNA messages correlated with EE) and the characteristics of the microbiome (population taxonomy from phyla to genus, and the collective metabolic capacity expressed as Kyoto Encyclopedia of Genes and Genomes, KEGG, categories) after adding either cowpeas or common beans to the diet of 12–35-month-old rural Malawian children.
3. Analyze changes in the developing intestinal microbiome among both age cohorts and all three intervention cohorts (cowpeas, common beans, standard feeding) to inform an understanding of the role of the microbiota in early childhood growth and gut health.

Approaches and Methods

This project will conduct two randomized, controlled clinical trials to investigate the effect of legume consumption on infant and toddler growth and gut health; assessment will be conducted every three

months. Both trials are prompted by the overarching hypothesis that children provided with a legume supplement will have greater linear growth and an improvement in biomarkers of EE compared to those who receive standard food supplements.

Each study will randomize infants and toddlers at high risk for EE and stunting to a sustained intervention of cowpea, common bean, or standard maize supplements and assess the outcomes of interest every 3 months. The outcomes will include anthropometric measurements, clinical symptoms, biomarkers of EE and gut inflammation, and population characteristics of the microbiota. To detect a difference in change in length of 1.1 cm, which corresponds to a change in height-for-age Z score (HAZ) of 0.45 units at 12 months of age, 79 children are needed in each group.

The first trial will evaluate changes in childhood anthropometry (height-for-age and weight-for-height z scores), biomarkers of EE (lactulose:rhamnose and a panel of human mRNA messages correlated with EE) and the characteristics of the microbiome (population taxonomy from phyla to genus, and the collective metabolic capacity expressed as Kyoto Encyclopedia of Genes and Genomes (KEGG) categories) after inclusion of either cowpeas or common beans as an integral component of complementary feeding for 6-11-month-old rural Malawian children.

The second trial will evaluate changes in child growth (height-for-age and weight-for-height z scores), biomarkers of EE (lactulose:rhamnose and a panel of human mRNA messages correlated with EE) and the characteristics of the microbiome (population taxonomy from phyla to genus, and the collective metabolic capacity expressed as Kyoto Encyclopedia of Genes and Genomes, KEGG, categories) after adding either cowpeas or common beans to the diet of 12-35 month-old rural Malawian children.

Anticipated Achievements and Outputs

- Development of legume recipes for specific aims with LUANAR colleagues
- Acceptability testing of legume recipes in infants and children
- Continuous enrollment, randomization, intervention delivery, and specimen collection in Mitondo for both groups of children
- Specimen processing and data analysis
- Manuscript preparation and submission
- Evaluation of future directions and implications of findings with key local and international stakeholders

Projected Developmental Outcomes

An understanding of whether children provided with a grain legume supplement will have greater linear growth and an improvement in biomarkers of EE compared to those who receive standard food supplements.

Contributions to Institutional Capacity Building

The studies will also facilitate the training of two doctoral-candidate nutrition students from the University of Malawi and two food science master's-level students from University of Malawi–Bunda College of Agriculture.

Impact Assessment of Legume Innovation Lab’s investments in Research, Institutional Capacity Building and Technology Dissemination for Improved Program Effectiveness (SO4.1)

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US and HC PIs/collaborators of other Legume Innovation Lab Projects

Abstract

Building on the momentum and experience gained over the last three years, this project proposes to contribute towards rigorous, evidence-based ex ante (i.e., potential) and ex post (i.e., realized) assessments of outputs, outcomes, and impacts of research with the goal of assisting the Legume Innovation Lab program and its Management Office (MO) achieve two important goals—accountability and learning. Greater accountability (and strategic validation) is a prerequisite for continued financial support from USAID, and better learning is crucial for improving the effectiveness of development projects and ensuring that the lessons from experience—both positive and negative—are heeded. Integrating this culture of impact assessment in publicly funded programs such as the Legume Innovation Lab will ultimately help increase the overall impact of such investments. The project team proposes to provide technical leadership in the design, analysis, and collection of baseline and end line data to conduct ex ante and ex post impact assessment of the Legume Innovation Lab’s investments in research, institutional capacity building, and technology dissemination in Africa, Latin America, and the United States. It also proposes to conduct systematic analysis of existing data or field studies to address strategic research questions on the role of grain legumes in household food security, nutrition, and income.

Project Statement and Justification

Impact assessment is essential for evaluating publicly funded research programs and planning future research. Organizations that implement these programs should be accountable for showing results, demonstrating impacts, and assessing the cost-effectiveness of their implementation strategies. It is therefore essential to document outputs, outcomes, and impacts of public investments in research for development (R4D) activities.

Building on the momentum and experience gained over the last three years, the proposed research will contribute towards evidence-based rigorous ex ante and ex post assessments of outputs, outcomes, and impacts, with the goal of assisting the Legume Innovation Lab program and its Management Office (MO) achieve two accountability and learning. Greater accountability (and strategic validation) is a prerequisite for continued financial support from USAID and better learning is crucial for improving the effectiveness of development projects and ensuring that the lessons from experience—both positive and negative—are heeded. Integrating this culture of impact assessment in publicly funded programs such as the Legume Innovation Lab will ultimately help increase the overall impact of such investments.

Objectives

1. Provide technical leadership in the design, collection, and analysis of data for strategic input and impact evaluation
2. Conduct ex ante (i.e., potential) and ex post (i.e., realized) impact assessment of the Legume Innovation Lab’s investments in research, institutional capacity building, and technology dissemination in Africa, Latin America, and the United States

3. Build institutional capacity and develop human resources in the area of impact assessment research

Approaches and Methods

Towards objective 1, the approach consists of collaborating with other research project PIs to assess the feasibility of integrating data collection and impact evaluation strategies as part of their Legume Innovation Lab project design. One of the main tasks for this project is to review the workplans and to have a discussion with project PIs to assess the following:

1. Existing data sets that can inform the baseline and help in the analysis of impact attribution
2. The possibility of collecting relevant data using project budgets or supplemental resources
3. The possibility of writing joint proposals to leverage resources from other sources

For specific research project components and pilot sites where it makes sense to collect baseline data and follow-up monitoring and impact evaluation data—and for which adequate resources are available—the Impact Assessment team provides technical leadership in the form of human resources and professional expertise in data collection (e.g., sample design, impact evaluation design, designing data collection instruments, training enumerators, data entry templates, etc.) and analysis. Likely candidates for such joint ventures in baseline assessment and/or impact assessment studies over the next 4.5 year period include:

- A socioeconomic baseline study on the constraints and opportunities for research to contribute to increased productivity of climbing beans in Guatemala
- A study on the market potential of biopesticides in Benin
- A baseline assessment to measure potential impact of bruchid resistant varieties in Tanzania
- Before and after surveys of farmers to be impacted by the dissemination of diagnostic and decision tools/outputs in Uganda and Mozambique

Under objective 2, this project plans to 1. assess the realized (ex post) impact of the Legume Innovation Lab (and its predecessor CRSP programs) investment in technologies/outputs where there is evidence of adoption, and 2. enhance future impacts by engaging in innovative and evidence-based research that will serve as an input in making strategic research priority decisions by the Legume Innovation Lab program and in developing strategies for technology dissemination for maximum impact. The following list of candidate research foci provides examples of types of research studies and activities to be undertaken under this objective.

- Impact of biocontrol IPM strategy in Burkina Faso using the differences-in-difference analytical approach
- Impact of the adoption of improved bean or cowpea varieties in one of the partner countries
- Assessment of factors that contribute to the success and sustainability of seed systems for grain legumes. Under this broad theme, field research will be conducted to address such matters as: 1. the willingness of smallholder farmers to pay for quality seed over grain, 2. factors important for the sustainability of seed systems, 3. alternative models that incorporate sustainability factors (community based seed systems, role of private sectors with vested interest in functionality of seed system, etc.)

- Systematic analysis of existing datasets in FTF and Legume Innovation Lab focus countries to develop profiles of potential research clients and beneficiaries, and to understand the constraints and potential impact of the adoption of new technologies by grain legume growers

In addition to this potential list of studies, the project team will also respond to analytical needs and demand from the Management Office and USAID for special assessments and evaluations that can be accomplished with available resources and data.

Anticipated Achievements and Outputs

1. Completion of at least two theses or dissertation papers on impact assessment research
2. At least six *Impact Briefs* that can be more widely disseminated to convey the impact stories of USAID's investments in the Legume Innovation Lab (and its predecessor, the Dry Grain Pulses CRSP)
3. At least five manuscripts for publication in academic journals and presentations at professional meetings

Contributions to Institutional Capacity Building

The project team will conduct educational sessions at project planning meetings and/or Global PI meetings to build capacity across the Legume Innovation Lab in developing and using impact pathways, theories of change, and collecting/reporting on performance indicators data. Such impact assessment training workshops or seminars will help the Legume Innovation Lab researchers (both from the United States and host countries) become familiarized with the operational aspect of impact assessment and help inculcate the culture of impact evaluation.

A short course (three to five days) on novel methods to assess the impact of agricultural projects will be developed and offered to NARS partners. This course will focus on teaching theoretical concepts and demonstrating practical applications of these concepts to economists, faculty, and students from local universities and research centers, including the use of statistical software. Where appropriate, this will be a joint activity in collaboration with NARS partners and CGIAR centers (e.g., CIAT, IITA) and opportunities to leverage resources to cover the local cost of organizing the short course and supporting the participants will be jointly explored.

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Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

2014



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Technical Application

Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

2014



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**Feed the Future
Food Security Innovation Lab:
Collaborative Research on Grain Legumes**

Technical Application

Program Extension (February 1, 2013 – September 29, 2017)

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Technical Applications

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EXECUTIVE SUMMARY

Technical Application for the Feed the Future Food Security Innovation Lab: Collaborative Research on Grain Legumes

The Technical Application presents Michigan State University's technical and administrative vision for the Feed the Future Food Security Innovation Lab: Collaborative Research on Grain Legumes (Legume Innovation Lab), previously branded the Dry Grain Pulses Collaborative Research Support Program (Pulse CRSP), for the proposed 56-month extension period of February 1, 2013, through September 29, 2017. If approved, this document will be incorporated into an amendment to USAID's contract to Michigan State University for the management of the Feed the Future Innovation Lab: Collaborative Research on Grain Legumes (Cooperative Agreement no. EDH-A-00-07-00005-00).

The Technical Application proposes an innovative and vibrant research, technology dissemination, and capacity building strategy for grain legumes that:

- Builds upon the technical advances in grain legume research and capacity building achieved during the 2007–2012 award period;
- Exploits opportunities to make substantial new technological gains while contributing to USAID's Feed the Future Global Food Security Research Strategy of "enhancing grain legume productivity and the nutritional quality of diets";
- Focuses efforts on priority technical constraints and challenges facing legume value chains, utilizing the innovative research approaches afforded by modern science and the capacities of U.S. universities;
- Integrates program strengthening measures in response to lessons learned over the past five years and recommendations from the Pulse CRSP's Technical Management Advisory Committee (TMAC) and the External Evaluation Team (EET) commissioned by USAID;
- Reflects expanded partnerships and coordination of activities with the CGIAR through the CRP3.5 on Grain Legumes and Africa RISING in areas where the Legume Innovation Lab has comparative strength and ongoing collaborative efforts;
- Enables the Legume Innovation Lab to provide continued international leadership in grain legume research and capacity building in synergy with other USAID investments at the international (BHEARD, HESN, Peanut Innovation Lab), regional, and country levels as well as with other U.S. government programs (USDA/ARS, BeanCAP, and NIFA); and
- Positions the Legume Innovation Lab to better contribute to the achievement of FTF agricultural development strategies of country and regional USAID Missions and to provide development assistance through the Associate Award mechanism.

The research program of the Legume Innovation Lab will focus on four Strategic Objectives (SOs) during the five-year extension (2013–2017). These SOs are consistent with the Global Themes of the previous five-year Pulse CRSP award (2007–2012) but reflect a better programmatic alignment with USAID's Feed the Future Global Food Security Research Strategy.

Strategic Objective 1. Advancing the Productivity Frontier: *To substantively and sustainably increase grain legume productivity by improving adaptation to diverse agroecologies and reducing smallholder farmer vulnerability to climate change, with special consideration for the livelihoods of women*

SO1.A: *To substantively enhance the genetic yield potential of grain legumes by exploiting new research tools afforded by genomics and molecular breeding approaches (e.g., MAS), with a focus on improving resistances to economically important abiotic and biotic constraints that limit yield in the agroecological regions where legumes are commonly grown in Africa and Latin America*

SO1.B: *To sustainably reduce the yield gap for selected grain legume crops produced by smallholder, resource-poor farmers in strategic cropping systems*

Strategic Objective 2. Transforming Grain Legume Systems and Value Chains: *To transform grain legume-based systems through improved smallholder production management decision making and more effectual governance management of grain legume value chains by stakeholders, including smallholder farmers and consumers*

Strategic Objective 3. Enhancing Nutrition: *To improve the nutritional quality of diets and to enhance the nutritional and health status of the poor, especially women and young children, through the consumption of edible grain legume-based foods*

Strategic Objective 4. Improving Outcomes of Research and Capacity Building: *To improve outcomes of legume research and capacity building projects and to assess impacts to improve decision making regarding future investments*

A portfolio that includes ten multi-institutional research projects and one impact assessment project are proposed under these SOs for the FY2013–2017 funding period. Seven of these projects are extensions of Pulse CRSP Phase II and III projects but with significant refocusing, the addition of new collaborating scientists and partner institutions, and innovations in research approaches to make substantial gains toward achieving outcome goals and benefiting legume value chains in FTF focus countries. Three projects will be new, selected through the issuance of an RFP and peer review of proposals. Table 1 presents the titles for all eleven projects (with abbreviated titles) under the respective SOs with tentative funding levels for each. Table 2 identifies the proposed U.S. and Host Country institutions to be partnering in each project.

Table 1. Legume Innovation Lab Projects per Strategic Objective, with Tentative Funding

SOs and Related Projects		Tentative funding level	Abbreviated project name
SO1: Advancing the Productivity Frontier for Grain Legumes: A. Substantively Enhancing Genetic Yield Potential; B. Sustainably Reducing the Yield Gap			
SO1.A1	Genetic enhancement of photosynthesis and assimilate transport to reproductive structures (pods and seed) in grain legumes for increased productivity and reduced vulnerability to climate change	1,700,000	Photosynthetic enhancement
SO1.A2	New roots for grain legumes: Improving grain legume productivity in stressful soils through genetic improvement of root structure and function	1,000,000	New roots for legumes
SO1.A3	Improving genetic yield potential of Andean bean types with increased resistances to drought and major foliar diseases and enhanced symbiotic nitrogen fixation	2,000,000	Andean bean breeding
SO1.A4	Improving genetic yield potential of Mesoamerican bean types with enhanced adaptation to low fertility soils (N and P) and resistances to root pests	2,000,000	Mesoamerican bean breeding
SO1.A5	Genetic improvement of cowpea to overcome drought and biotic constraints to grain productivity	2,000,000	Cowpea breeding
SO1.B1	IPM-omics: Scalable and sustainable biological solutions for pest management of insect pests in cowpea in Africa	2,000,000	IPM-omics
SO2: Transforming Grain Legume Systems and Value Chains			
SO2.1	Farmer decision-making strategies for improved soil fertility management in maize–bean production systems	1,500,000	Farmer decision-making
SO2.2	Enhancing legume value chain performance through improved understanding of consumer behavior and decision making	1,000,000	Legume value chains
SO3: Enhancing Nutrition			
SO3.1	Understanding the role of edible grain legume consumption in distinct diets on gut health and human nutrition	1,300,000	Nutrition: gut health
SO3.2	Improving the nutrition and health of infants and women through the inclusion of edible grain legumes in diets and by obtaining insights into dietary decision making by the poor	2,500,000	Nutrition: infants and diets
SO4: Improving Outcomes of Research and Capacity Building			
SO4.1	Impact Assessment of Legume Innovation Lab investments in research, institutional capacity building, and technology dissemination for improved program effectiveness	900,000	Impact assessment

Table 2. Grain Legume Strategic Objectives, Sub-awarded Projects, and U.S. and HC Partner Institutions

SOs and Related Projects	U.S. Institutions	HC and Partner Institutions
SO1: Advancing the Productivity Frontier for Grain Legumes: A. Sustainably Enhancing Genetic Yield Potential; B. Sustainably Reducing the Yield Gap		
SO1.A-1: Photosynthetic enhancement	TBD via RFP	TBD- Recommend institutions in Ethiopia, Uganda, Tanzania, Mozambique, Zambia, Ghana, Burkina Faso, Senegal
SO1.A-2: New roots for legumes	PSU, USDA/ARS, NDSU,	EAP-Zamorano, Honduras; IIAM, Mozambique; Bunda College, Malawi.
SO1.A-3: Andean bean breeding	MSU; USDA/ARS; U. Nebraska	NARO-Uganda; Zambia Agriculture Research Institute (ZARI), Zambia; INIAP, Ecuador.
SO1.A-4: Mesoamerican bean breeding	UPR, USDA/ARS, NDSU,	EAP-Zamorano, Honduras; ICTA, Guatemala; NSS, Haiti; SUA, Tanzania
SO1.A-5: Cowpea breeding	UC- Riverside	ISRA, Senegal; INERA, Burkina Faso; TBD, Ghana
SO1.B-1: IPM-omics	UIUC; Northwestern U.; ISU	INERA, Burkina Faso; INRAN, Niger; SARI, Ghana; CRI, Ghana; IITA, Benin
SO2: Transforming Grain Legume Systems and Value Chains		
SO2.1: Farmers decision-making	ISU; UH, Manoa; UIUC;	Makerere Univ., Uganda; NaCRRI, Uganda; VEDCO, Uganda; IIAM, Mozambique
SO2.2: Legume value chains	KSU	Univ. of Zambia, Zambia; Univ of Malawi, Malawi; Sokoine University of Agr., Tanzania
SO3: Enhancing Nutrition		
SO3.1: Nutrition: gut health	TBD via RFP	TBD via RFP (Recommend institutions in Ghana, Senegal, Burkina Faso, Uganda, Tanzania, Mozambique and/or Zambia)
SO3.2: Nutrition: infants and diets	TBD via RFP	TBD via RFP (Recommend institutions in Ghana, Senegal, Burkina Faso, Uganda, Tanzania, Mozambique and/or Zambia)
SO4: Improving Outcomes of Research and Capacity Building		
SO4.1: Impact assessment	MSU	West Africa, East and Southern Africa, and Central America

The Legume Innovation Lab's technical approach for FY 2013–2017 contributes to USAID's Feed the Future goals and research strategy for grain legumes by:

- Contributing directly to the FTF themes of (1) Advancing the Productivity Frontier, (2) Transforming Key Production Systems, and (3) Enhancing Nutrition and Food Safety;
- Assuming a leadership role within the international grain legume research community through engagement of leading scientists at U.S. universities and institutional partners in selected FTF focus countries, and coordination with CGIAR legume scientists through CRP3.5;
- Focusing on priority FTF focus countries and cropping systems (the West African Sudano–Sahelian systems; the Eastern and Southern African maize-based systems, and the maize-bean cropping system in Central America);
- Supporting USAID's whole-of-government approach through coordination with FTF USDA/ARS and USDA/NIFA investments in grain legume research;
- Enhancing capacity of strategic national and international agriculture research institutions address critical staffing needs so as to be able to respond to future challenges of the grain legume sectors;
- Advancing gender equity through research, technology dissemination, and capacity building activities that directly benefit women;
- Achieving broad quantifiable, sustainable impacts from outputs of Legume Innovation Lab research as evidenced by widespread technology adoption and benefits to stakeholders of legume value chains—from smallholder farmers to consumers of grain legumes; and
- Supporting USAID country and regional mission FTF strategic value chains and agriculture sector development priorities.

The FY 2013–2017 Legume Innovation Lab will be a strategic partner with the CGIAR in the implementation of the Consortium Research Program (CRP) on Grain Legumes (3.5). This partnering relationship will be manifest through both reciprocal administrative appointments to principal research oversight/advisory committees of each and through the coordination of legume research by both programs. The obvious result will be synergies from USAID investments in legume research as evidenced by:

- joint collaboration between CGIAR and Legume Innovation Lab U.S. university scientists and host country collaborators toward common research objectives,
- complementary activities that support the achievement of CRP3.5 product lines, and
- beneficial Legume Innovation Lab-led research initiatives that address strategic objectives for legume but that reflect technical gaps in CRP3.5.

The Technical Application also presents responses by the Pulse CRSP Management Office at Michigan State University to the excellent recommendations presented by the USAID-commissioned External Evaluation Team in its August 2012 report. Detailed responses by the Management Office to the EET's recommendations are included in an Appendix to the Technical Application. The Management Office at Michigan State University expresses its appreciation to the EET members: Drs. Julia Kornegay, Julian Adams, Bahram Arjmandi, Michael Gruzak and Steven Long, for their professional dedication and effort in completing a quality review that shows insight into the challenges facing the international grain legume sector and an understanding of the Pulse CRSP's research and capacity building achievements from FY 2007–2012.

The Cost Application presents a total budget of \$24,500,000 to support the Legume Innovation Lab for the 56-month extension period (February 1, 2013– September 29, 2017). The primary budgetary commitment (estimated at \$19,825,000) will be to 11 subcontracted research, technology dissemination, and capacity building projects for achievement of the SOs. Special budget lines are also included to support competitive supplemental institutional capacity building awards for research institutions in FTF focus countries, a joint scholarship program with CRP3.5 for the graduate training of young professionals from the CGIAR, and centralized data collection and synthesis for Innovation Labs. As presented in Figure 1, approximately 60 percent of the subcontractual obligations will support SO1 (Enhancing Productivity), 14 percent for SO2 (Transforming Production Systems), 21 percent for SO3 (Enhancing Nutrition), and 5 percent for SO4 (Impact Assessment). Funding resource allocations to regions and related cropping systems (Figure 2) are 55 percent to Eastern and Southern Africa (maize–legume cropping systems); 32 percent to West Africa (Sudano–Sahelian cropping systems), and 13 percent to Central America and Haiti (maize–bean systems).

Figure 1. Resource Allocation by Strategic Objective

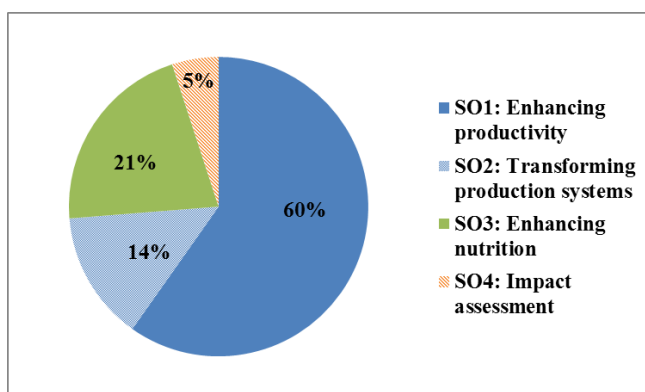
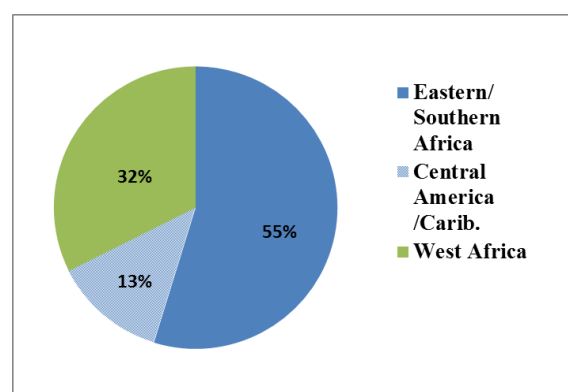


Figure 2. Resource Allocation by Region



Program implementation activities and Management Office operations will require the balance of the funding obligation from USAID. In accord with EET recommendations, the Legume Innovation Lab is proposing to sponsor and to organize three major global grain legume research meetings jointly with diverse international institutions (including CRP3.5) and other R&D programs (e.g., McKnight, N2Africa) along with USAID regional and country Missions and legume stakeholder groups. These meeting expenses, along with CRSP technical performance assessment and advisory functions of the Technical Management Advisory Committee, will be supported with Program Implementation funds. The Legume Innovation Lab Management Office will also strengthen key functions, including USAID Mission engagement and support for FTF programming, impact assessment at all levels, and program communications and promotions.

Abbreviations and Acronyms

AGRA	Alliance for a Green Revolution in Africa
AOR	Agreement Officer's Representative, USAID
APLU	Association of Public and Land-grant Universities
ARS	Agricultural Research Service (USDA)
BCMNV	Bean Common Mosaic Necrosis Virus
BCMV	Bean Common Mosaic Virus
BIC	Bean Improvement Cooperative
BIFAD	Board of International Food and Agriculture Development
BGYMV	Bean Golden Yellow Mosaic Virus
BHEARD	Borlaug Higher Education Agricultural Research and Development Program
BNF	Biological Nitrogen Fixation
BREAD	National Science Foundation Basic Research to Enable Agriculture Development
<i>Bt</i>	<i>Bacillus thuringiensis</i>
CAP	USDA Coordinated Agricultural Projects
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture)
CRI	Crops Research Institute (Kumasi, Ghana)
CRP	Consortium Research Program (of the CGIAR)
CRSP	Collaborative Research Support Program
CSSA	Crop Science Society of America
CSIR	Council for Scientific and Industrial Research (Ghana)
EAP	Escuela Agrícola Panamericana-Zamorano (Honduras)
ECABREN	Eastern and Central African Bean Research Network
EET	External Evaluation Team (commissioned by USAID)
Fe	Iron
FTE	Full-time Equivalent
FTF	Feed the Future
FSP	Food Security Program (USAID award to MSU)

GCP	Generation Challenge Programme
GPS	Global Positioning Systems
HC	Host Country
IARC	International Agriculture Research Center (of the CGIAR)
ICARDA	International Center for Agricultural Research in the Dry Areas
ICB	Institutional Capacity Building
ICM	Integrated Crop Management
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICTA	Instituto de Ciencia y Tecnologia Agrícolas (Guatemala)
IFT	Institute of Food Technologists
IIAM	Instituto de Investigação Agrária de Moçambique (Mozambique)
IITA	International Institute of Tropical Agriculture
INERA	Institut de l'Environnement et de Recherches Agricoles (Burkina Faso)
INIAP	Instituto Nacional Autónomo de Investigaciones Agropecuarios (Ecuador)
INRAN	Institut National de la Recherche Agronomique du Niger (Niger)
INTA	Instituto Nacional de Tecnologías Agrícolas (Nicaragua)
IPM-omics	Integrated Pest Management Omics
ISRA	Institut Sénégalais de Recherches Agricoles (Senegal)
K	Potassium
KIST	Kigali Institute of Science and Technology (Rwanda)
KSU	Kansas State University
MAS	Marker-Assisted Selection
ME	Management Entity for the Dry Grain Pulses CRSP (Michigan State University)
MO	Management Office of the Dry Grain Pulses CRSP
MSU	Michigan State University
N	Nitrogen
N2Africa	Nitrogen to Africa, a research project putting nitrogen fixation to work for smallholder farmers growing legume crops in Africa
NaCRRI	National Crops Resources Research Institute (Uganda)
NARS	National Agriculture Research System(s)
NGOs	Nongovernmental Organizations
NIFA	National Institute of Food and Agriculture (USDA)

NSS	National Seed Service (Haiti)
P	Phosphorus
PCCMCA	Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos y Animales
PI	Principle Investigator
PICS	Purdue Improved Cowpea Storage
PL	Product Line
PSU	Pennsylvania State University
QTL	Quantitative trait loci
RFP	Request for Proposals
SABREN	Southern African Bean Research Network
SARI	Savannah Agriculture Research Institute (Tamale, Ghana)
SNF	Symbiotic Nitrogen Fixation
SNP	Single Nucleotide Polymorphism
SO	Strategic Objective
SOW	Scope of Work
SUA	Sokoine University of Agriculture (Tanzania)
TBD	to be determined
TL	Tropical Legumes (Programs of the CGIAR)
TMAC	Technical Management Advisory Committee
USDA	United States Department of Agriculture
VEDCO	Volunteer Efforts for Development Concerns (Uganda)
ZARI	Zambian Agriculture Research Institute (Zambia)
UCR	University of California, Riverside
UNZA	University of Zambia
UPR	University of Puerto Rico
Zn	Zinc

TECHNICAL APPLICATION
for the
Feed the Future Food Security Innovation Lab:
Collaborative Research on Grain Legumes (2013–2017)

Introduction

This document presents a technical and an administrative vision for the *Feed the Future Food Security Innovation Lab: Collaborative Research on Grain Legumes (Legume Innovation Lab)*, previously branded the Dry Grain Pulses Collaborative Research Support Program (Pulse CRSP), for the proposed four and a half-year extension period of April 1, 2013, through September 29, 2017. If approved by the Office of Agriculture Research and Policy, Bureau of Food Security, U.S. Agency for International Development (USAID), this document will be incorporated into an amendment to USAID’s contract to Michigan State University (MSU) for the management of the Feed the Future Food Security Innovation Lab: Collaborative Research on Grain Legumes (Cooperative Agreement no. EDH-A-00-07-00005-00).

The technical and administrative approaches for the Legume Innovation Lab being proposed for the next 4.5 years testify to the program’s stature within the international grain legume research community as well as the Management Office’s (MO’s) technical leadership in grain legume research, human resource development, and the dissemination of technologies to improve the livelihoods of smallholder, resource-poor grain legume farmers in developing countries. Moreover, the portfolio of projects demonstrates the MO’s commitment to assisting the Bureau of Food Security in achieving its global agricultural development mandate as defined in the Feed the Future (FTF) Global Food Security Research Strategy.

To develop the technical approach, the Management Office held two research priority-setting workshops, consulted with numerous grain legume scientists, met with CGIAR research program heads, and consulted with the Pulse CRSP Technical Management Advisory Committee (TMAC).

- [Enhancing pulse productivity on problem soils by smallholder farmers: Challenges and opportunities](#), Penn State University, August 2011.
- [Enhancing the Nutritional Quality of Diets through Pulses in Developing Countries](#), Michigan State University, December 2011.

The workshops commissioned by the Pulse CRSP in 2011 significantly informed the Management Office’s thinking on future research priorities for grain legumes. With cosponsorship and participation by three IARCs (CIAT, IITA, ICRISAT), multiple federal agencies (USAID, USDA/ARS, USDA/NIFA), and several international agriculture research programs (N2Africa, McKnight Foundation, etc.), the following workshops brought together respected scientists from around the world, both external and internal to the CRSP community, with relevant multidisciplinary expertise to discuss and recommend research priorities for grain legumes. Executive summaries of these workshops are available on the [Pulse CRSP’s webpage](http://pulsecrsp.msu.edu/pulsecrsp/workshops_2011) (pulsecrsp.msu.edu/pulsecrsp/workshops_2011).

The MO took to heart the challenges set forth in USAID’s Feed the Future Research Strategy of achieving “grain legume productivity gains” for greater “diversification of production systems” and “enhanced dietary diversity with nutrient-dense foods” when establishing the Strategic Objectives for the next five years. Section C in the technical approach specifically outlines the Legume Innovation Lab’s alignment and support for the diverse array of directives in FTF’s Research Strategy and engagement with USAID’s priority focus countries and regions (cropping systems).

During the current award period (2007–12), the Pulse CRSP (to be branded Legume Innovation Lab from 2013 forward) Management Office made a concerted effort to reach out to the CGIAR grain legume research community to strengthen research linkages and collaboration with program scientists (U.S. university and host country NARS scientists), which resulted in the selection of the Pulse CRSP as a strategic partner in the new Consortium Research Program (CRP) 3.5 on Grain Legumes. The MO is therefore proposing a technical approach for the Legume Innovation Lab (FY 2013–2017) that exploits the comparative research capacities and expertise of U.S. universities to address a research agenda for grain legumes with the CGIAR in a complementary and coordinated manner.

In summary, the MO is proposing a vibrant technical and administrative approach for grain legumes from April 1, 2013, through September 29, 2017, to achieve priority Legume Innovation Lab objectives:

- To build upon the technical advances in legume research and capacity building achieved during the current award period (2007–2012),
- To exploit opportunities to make substantial new technological gains while contributing to USAID’s Feed the Future Research Strategy of “enhancing grain legume productivity and nutritional quality of diets,”
- To focus efforts on priority technical constraints and challenges facing grain legume value chains, utilizing the innovative research approaches afforded by modern science and the capacities of U.S. universities,
- To integrate program-strengthening measures in response to lessons learned over the past five years and recommendations from the Pulse CRSP’s Technical Management Advisory Committee and the External Evaluation Team (EET) commissioned by USAID,
- To strengthen partnerships, complementarity, and coordination of research activities with the CGIAR through CRP3.5 Grain Legumes and other FTF research projects (i.e., USDA/ARS and NIFA, etc.) in areas where the Legume Innovation Lab has comparative strength and ongoing efforts, and
- To position the Legume Innovation Lab to better link and contribute to the achievement of FTF agricultural development strategies of country and regional USAID Missions and to provide development assistance through the Associate Award mechanism.

Technical Approach

Emerging Global Challenges And Opportunities for the Legume Innovation Lab

The food and nutritional security situation of the world has changed dramatically since the Dry Grain Pulses CRSP was initiated in 2007:

- Food shortages have occurred with increasing frequency in regions of the world affected by unfavorable weather events and shifts in agricultural systems.
- Grain prices (maize, rice, legumes) in world markets have risen significantly, resulting in staples becoming unaffordable to the poor and thus accentuating food and nutritional insecurity.
- The incidence of malnourishment, especially among infants and childbearing women, persists at unacceptably high levels, complicated by both under- and over-nutrition among rural and urban poor populations.

With the world's population increasing from 7 billion in 2011 to more than 9 billion by 2050, many regions of the world will face unprecedented challenges in food and nutritional security. The projected 70 percent increase in food demand must mostly be produced without a concomitant increase in per capita arable land. The situation will be exacerbated by projected episodic climate change events (e.g., drought or excess rainfall, high temperatures) causing regular grain shortages that will distort the global markets for staple commodities. Global grain legume markets have already evidenced vulnerability and market price fluctuations in response to drought in key production areas over the past several years.

Accompanying population growth are projected increases in under-nutrition by more than 40 million per year. Protein and essential micronutrients are especially important for the growth and general health of infants and young children. Overcoming malnutrition is further complicated by poor food dietary choices and the lack of access to quality potable water, which results in concurrent under- and over-nutrition. This dual under-/over-nutrition condition is being observed at alarming rates by nutritionists worldwide, presenting formidable health consequences for persons of all ages and increased societal burdens for health care management and costs, which challenge developing countries.

Legumes are increasingly recognized by government policy makers, agricultural scientists, and international development experts as a strategic component in a comprehensive response to the pending global food and nutritional security crisis. The importance of edible grain legumes lies not only in their value as an affordable, nutrient-dense staple that can improve dietary quality but also in their multifunctional benefits to poor households, including:

- a staple food critical for household food and nutritional security,
- a food that promotes gut health, critical for the effective absorption of nutrients from all dietary foods,
- a cash crop with potential for generating needed household income,
- a commodity that uniquely benefits smallholder farmers, especially women, and
- a group of crops that contributes to agriculture system productivity, resilience, and sustainability.

The overarching global program goal of the Legume Innovation Lab's technical approach for FY 2013–2017 will be to substantively increase grain legume productivity through sustainable intensification of

smallholder farm systems to increase the availability of affordable grain in domestic markets, increase consumption of legumes by the poor, and improve nutrition and nutritional security in developing countries.

Strategic Objectives For The Legume Innovation Lab 2013–2017

The research program of the Legume Innovation Lab will focus on four Strategic Objectives (SOs) during the 4.5-year extension (2013–2017) consistent with the Global Themes of the current award (2007–2012) but will reflect a better programmatic alignment with USAID’s Feed the Future Global Food Security Research Strategy. Tables 1 and 2 outline these strategic objectives and the projects associated with each of them; tentative funding levels for each project are also listed.

Strategic Objective 1. Advancing the Productivity Frontier for Grain Legumes: To sustainably and substantively increase grain legume productivity by improving plant adaptation to diverse agroecologies and reducing smallholder farmer vulnerability to climate change, with special consideration for the livelihoods of women

The global production of grain legumes is inadequate to meet current and projected demands for food for the growing world population. Enhancing grain legume productivity presents certain formidable challenges because the average yields of edible grain legumes in many regions of the world are unacceptably low, frequently less than 25 percent of genetic yield potential (400–800 kg/ha versus 1800–3200 kg/ha). Long-term trends in grain legume productivity do not provide much hope that yields will increase in the near future without the deployment of game-changing technologies or the intensification of production management practices utilizing inputs.

Because smallholder farmers in developing countries are frequently resource-constrained, the purchase of costly inputs, such as fertilizers and pesticides, is not an option. Moreover, farmers must have confidence in the efficacy of the input(s) before pursuing credit to purchase them. High vulnerability to risk, especially when the purpose for growing grain legumes is to provide household food, becomes a major disincentive for resource-poor farmers.

The development of grain legume varieties with increased genetic yield potential is a sustainable strategy that clearly benefits farmers regardless of scale and access to resources. Because grain legumes are self-pollinating and can be used from one generation to another for planting, genetic traits in a new variety conferring higher productivity potential and resistances to abiotic and biotic stresses would benefit farmers over the long term.

The genomics revolution has recently transformed the genetic improvement of crops and made feasible the effective use of biological diversity to improve agricultural systems in new and innovative ways. Sequencing the genome of legume species allows for the identification of quantitative trait loci (QTLs) for specific morphological, biochemical, and physiological traits associated with grain yield and adaptation to stress. With genetic markers for important traits, a breeder can more efficiently and effectively incorporate and combine genes to achieve breeding objectives.

Table 2. Legume Innovation Lab Projects per Strategic Objective, with Tentative Funding

SOs and Related Projects		Tentative funding level	Abbreviated project name
SO1: Advancing the Productivity Frontier for Grain Legumes: A. Substantively Enhancing Genetic Yield Potential; B. Sustainably Reducing the Yield Gap			
SO1.A1	Genetic enhancement of photosynthesis and assimilate transport to reproductive structures (pods and seed) in grain legumes for increased productivity and reduced vulnerability to climate change	1,700,000	Photosynthetic enhancement
SO1.A2	New roots for grain legumes: Improving grain legume productivity in stressful soils through genetic improvement of root structure and function	1,000,000	New roots for legumes
SO1.A3	Improving genetic yield potential of Andean bean types with increased resistances to drought and major foliar diseases and enhanced symbiotic nitrogen fixation	2,000,000	Andean bean breeding
SO1.A4	Improving genetic yield potential of Mesoamerican bean types with enhanced adaptation to low fertility soils (N and P) and resistances to root pests	2,000,000	Mesoamerican bean breeding
SO1.A5	Genetic improvement of cowpea to overcome drought and biotic constraints to grain productivity	2,000,000	Cowpea breeding
SO1.B1	IPM-omics: Scalable and sustainable biological solutions for pest management of insect pests in cowpea in Africa	2,000,000	IPM-omics
SO2: Transforming Grain Legume Systems and Value Chains			
SO2.1	Farmer decision-making strategies for improved soil fertility management in maize–bean production systems	1,500,000	Farmer decision-making
SO2.2	Enhancing legume value chain performance through improved understanding of consumer behavior and decision making	1,000,000	Legume value chains
SO3: Enhancing Nutrition			
SO3.1	Understanding the role of edible grain legume consumption in distinct diets on gut health and human nutrition	1,300,000	Nutrition: gut health
SO3.2	Improving the nutrition and health of infants and women through the inclusion of edible grain legumes in diets and by obtaining insights into dietary decision making by the poor	2,500,000	Nutrition: infants and diets
SO4: Improving Outcomes of Research and Capacity Building			
SO4.1	Impact assessment of Legume Innovation Lab investments in research, institutional capacity building, and technology dissemination for improved program effectiveness	900,000	Impact assessment

Table 2. Grain Legume Strategic Objectives, Sub-awarded Projects, and U.S. and HC Partner Institutions

SOs and Related Projects	U.S. Institutions	HC and Partner Institutions
SO1: Advancing the Productivity Frontier for Grain Legumes: A. Sustainably Enhancing Genetic Yield Potential; B. Sustainably Reducing the Yield Gap		
SO1.A-1: Photosynthetic enhancement	TBD via RFP	TBD- Recommend institutions in Ethiopia, Uganda, Tanzania, Mozambique, Zambia, Ghana, Burkina Faso, Senegal
SO1.A-2: New roots for legumes	PSU, USDA/ARS, NDSU,	EAP-Zamorano, Honduras; IIAM, Mozambique; Bunda College, Malawi.
SO1.A-3: Andean bean breeding	MSU; USDA/ARS; U. Nebraska	NARO-Uganda; Zambia Agriculture Research Institute (ZARI), Zambia; INIAP, Ecuador.
SO1.A-4: Mesoamerican bean breeding	UPR, USDA/ARS, NDSU,	EAP-Zamorano, Honduras; ICTA, Guatemala; NSS, Haiti; SUA, Tanzania
SO1.A-5: Cowpea breeding	UC- Riverside	ISRA, Senegal; INERA, Burkina Faso; TBD, Ghana
SO1.B-1: IPM-omics	UIUC; Northwestern U.; ISU	INERA, Burkina Faso; INRAN, Niger; SARI, Ghana; CRI, Ghana; IITA, Benin
SO2: Transforming Grain Legume Systems and Value Chains		
SO2.1: Farmers decision-making	ISU; UH, Manoa; UIUC;	Makerere Univ., Uganda; NaCRRI, Uganda; VEDCO, Uganda; IIAM, Mozambique
SO2.2: Legume value chains	KSU	Univ. of Zambia, Zambia; Univ of Malawi, Malawi; Sokoine University of Agr., Tanzania
SO3: Enhancing Nutrition		
SO3.1: Nutrition: gut health	TBD via RFP	TBD via RFP (Recommend institutions in Ghana, Senegal, Burkina Faso, Uganda, Tanzania, Mozambique and/or Zambia)
SO3.2: Nutrition: infants and diets	TBD via RFP	TBD via RFP (Recommend institutions in Ghana, Senegal, Burkina Faso, Uganda, Tanzania, Mozambique and/or Zambia)
SO4: Improving Outcomes of Research and Capacity Building		
SO4.1: Impact assessment	MSU	West Africa, East and Southern Africa, and Central America

Strategic Objective 1 (SO-1) provides a research framework for exploiting new genomics tools (e.g., affordable high-resolution SNP genotyping, high-density gene maps, SNP markers, phenotyping of germplasm collections, etc.) for both *Phaseolus vulgaris* (common bean) and *Vigna unguiculata* (cowpea), including markers identified through BeanCAP and TL-1 (CGIAR-GCP), to achieve substantial gains in genetic yield potential that will enable smallholder farmer households to become nutritionally secure while concurrently creating income generation opportunities.

A concomitant strategy must be pursued to reduce the yield gap in legume production, that is, the difference between genetic yield potential and actual grain yields achieved by farmers. The success record of agronomic scientists in reducing the yield gap in grain legumes on smallholder, resource-poor farms in developing countries has been dismal. Formidable challenges to increasing yields through integrated crop management are attributable to high variability in soil fertility and water availability across a production landscape, the inability of farmers to effectively diagnose abiotic, edaphic, and biotic constraints to grain legume productivity, and limited access by farmers to information and productivity-enhancing technologies and inputs. The Legume Innovation Lab will seek to address these constraints to productivity where modern science affords opportunities to provide sustainable and appropriate solutions to smallholder farmers (e.g., the biological control of pests in cowpea).

Two strategic sub-objectives are therefore proposed under SO1, as noted in Table 1:

SO1.A: To substantively enhance the genetic yield potential of common bean and cowpea by exploiting new research tools afforded by genomics and molecular breeding approaches (MAS), with a focus on improving resistances to economically important abiotic and biotic constraints that limit yield in strategic cropping systems in Africa and Latin America where grain legumes are extensively grown.

The Legume Innovation Lab asserts that the greatest potential for genetic yield enhancement lies in identifying physiological traits underpinning and regulating vegetative and reproductive growth and development. These include traits associated with photosynthesis (carbon fixation), nutrient and water acquisition from the soil, and assimilate and nutrient transport from vegetative to reproductive structures (pods and seeds). To ensure that newly identified traits are robust and will result in higher plant productivity over diverse seasons and agroecologies, Legume Innovation Lab research will seek to identify traits that are expressed and enhance legume grain yield when subjected to such climate change factors as drought, high temperatures, and low soil fertility. Genes for these and other traits will be bred into improved varieties of common bean and cowpea with high yield potential appropriate for smallholder farmer production conditions.

SO1.B: To sustainably reduce the yield gap for selected grain legume crops by smallholder, resource-poor farmers in strategic cropping systems

The Legume Innovation Lab will focus on sustainably reducing the yield gap in cowpea for the Sudano-Saharan region of West Africa. Pod-sucking insect pests are considered the principal constraint to cowpea grain yields in this region. Unfortunately, breeding for genetic resistance to pod-sucking insect pests has not shown promise due to the lack of robust resistance genes in *Vigna unguiculata* and related species. Transgenic *Bt* cowpea lines will not likely become available for commercial planting throughout the Sahel for 5 to 10 years; moreover, the *Maruca* pod borer (*Maruca vitrata*) is only one of

the numerous pod-sucking insect pests that can cause 50 to 90 percent losses in grain yields during a growing season.

As a result of progress made in the identification of biological controls (e.g., insect pest viruses, parasitoids, beneficial insects) for many economically significant cowpea insect pests through collaborative research among IITA, the Pulse CRSP, and the NARS partners in Burkina Faso, Benin, Niger, Ghana, and Nigeria over the past five years, future efforts will be directed toward the development of a comprehensive and sustainable toolkit of Integrated Pest Management (IPM) technologies and management practices and their deployment for the benefit of resource-poor, smallholder cowpea farmers in the region. Genomics and innovative communications tools developed by Pulse CRSP scientists will also enhance the effectiveness of this initiative.

Strategic Objective 2. Transforming Grain Legume Systems and Value Chains: *To transform grain legume-based systems through improved smallholder production management decision making and more effectual governance management of legume value chains by stakeholders, including smallholder farmers and consumers*

Transformation of smallholder, legume-based productions systems and value chains, as advocated under Feed the Future, requires greater clarity of system functions and fundamental changes in system management, if the FTF goals of sustainable productivity enhancement and increased consumption for improved nutrition are to be achieved. Unlike many other crops, grain legumes provide a wide range of multifunctional benefits to smallholder farmers and their families. The Legume Innovation Lab MO, however, believes that a dual research approach that addresses both the supply and demand sides of the legume value chain continuum is necessary to achieve this SO.

On the farm-level supply side, soil infertility due to low native fertility, soil degradation, and persistent soil problems (pH extremes, heavy metal toxicities, micronutrient deficiency, etc.) are limiting legume productivity worldwide. The challenge to addressing soil constraints—considered the primary factor contributing to the yield-gap in grain legumes—is not simply a problem of access to fertilizers but a fundamental inability of smallholder farmers to diagnose their soil, to identify factors that may be limiting crop productivity, and to choose cropping system management practices that will lead to sustainable improvements in soil fertility and health and, ultimately, long-term improvements in productivity.

The approach proposed by the Legume Innovation Lab is based on the premise that sustainable and productive agriculture systems require soil fertility management that relies considerably on using legumes in the cropping system (rotation, intercropping, relay cropping). To address SO-2, the Legume Innovation Lab will develop tools to enable smallholder farmers to better diagnose their soils and make more effectual integrated production system management decisions to improve soil fertility long term.

Farm investment decisions are often conditioned by market opportunities and incentives. For grain legume value chains to function effectively in developing countries, stronger vertical and horizontal relationships must be instituted among subsector participants to reduce transaction costs and to increase performance and, ultimately, incomes. Building the governance capacity of the grain legume trade is essential for improving value chain performance and ensuring remunerative farm-gate prices for grain

legumes to smallholder farmers. A demand-side knowledge gap, however, exists in eastern and southern Africa about how consumers rank legumes in their food preferences and dietary decision making. Research is needed to better understand the preferences of urban and rural consumers, the findings of which will enable stakeholders of grain legume value chains to scope for supply chain business opportunities, exploit market opportunities, and formulate recommendations to policy makers to incentivize grain legume consumption and utilization by consumers, resulting in improved nutritional outcomes.

Strategic Objective 3. Enhancing Nutrition: *To improve the nutritional quality of diets and to enhance the nutritional and health status of the poor, especially women and young children*

Theme 3 of the Feed the Future Research Strategy, Enhancing Nutrition, focuses on increasing both access to nutrient-dense foods, such as edible grain legumes, and regular consumption of diverse, quality foods for improved human health. The research strategy recognizes the vitally important relationships between what a person eats, the individual's ability to absorb and utilize nutrients from the foods consumed, and the influence of interacting health and environmental factors (e.g., water quality).

Nutritional indicators established under Feed the Future emphasize improving the plight of more than 200 million children under the age of five who suffer from chronic or acute malnutrition. Under-nutrition during the early formative period (the first 1000 days) has long-term consequences. Stunting, impaired cognitive development, and weakened immune systems limit the potential of children to develop and lead productive and healthy lives. These nutritional indicators and the prevalence of underweight women also indicate that under-nutrition among women of childbearing age can have negative effects on pregnancy outcomes and infant health.

Enhancing dietary quality through greater consumption of grain legumes is an effective approach to improving human nutrition and health. The benefits afforded by regularly eating beans are not only attributable to their affordability and high nutrient composition (quality protein, complex carbohydrates, fiber, essential fatty acids, vitamins, etc.) but equally to their role in supporting gut health and function. When grain legumes are consumed regularly, research indicates that healthy intestinal microbial communities are supported, leading to less inflammation of the colon and the improved absorption of essential nutrients from ingested foods. Thus, legumes improve the nutritional value of diets among the poor, including cereal-based traditional diets.

Despite the fact that grain legume crops are grown widely throughout Africa, Asia, and Latin America, especially by smallholder farmers for household food security, consumption of legumes by infants and children is low. A study of bean consumption in five African countries indicated that only 30 to 40 percent of infants (six to 23 months) consume legume-based foods. Although access to grain legumes by the poor plays a role, dieticians contend that lack of knowledge of the nutritional importance of grain legumes in the diets of young children influences food selection and dietary decisions by mothers.

Knowledge gaps exist; the physiological role(s) of grain legumes in diets and its interactions with other foods need to be better understood if legumes are to achieve their envisioned impact on the nutritional and health status of the poor, especially young children and women (SO3) as established under Feed the Future. Research is needed to generate nutritional and dietary information to justify the promotion of

grain legume consumption by children, to inform policy makers of the nutritional and health-promoting value of grain legumes, and to develop appropriate interventions (e.g., education programs, nutritional rehabilitation, price subsidies, food supplementation, etc.) to overcome the child and maternal malnutrition prevalent among the poor.

Potential nutritional research questions for future Legume Innovation Lab projects (2013–2017) include:

- What is the nutritional adequacy of traditional diets containing edible grain legumes and their potential to support the healthy growth and development of children and women of childbearing age (pre- and post-pregnancy) in poor rural and urban environments in Africa and Latin America?
- Can consumption of grain legume-based foods by infants between six and 24 months contribute to nutritional and health improvements? Do nutritional synergies exist when consumed with breast milk? What is the nutritional/health value of grain legumes in the diets of children three to five years of age?
- What is the physiological role(s) of grain legume-based foods in contributing to good nutrition as related to gut health and function?
- Can grain legumes in the diets of infants contribute to a healthy gut microbiome, to strengthened immune systems, and to healthy child growth and development in resource-poor households?
- How important are differences in the varieties of edible grain legumes and the methods of food preparation in enhancing overall dietary quality?
- What factors influence dietary decisions as related to edible grain legume consumption and on feeding legume-based foods to infants?
- What educational interventions might be effective in increasing grain legume consumption to reduce the prevalence of malnutrition among various target populations?

Strategic Objective 4. Improving Outcomes of Research and Capacity Building: *To improve outcomes of Pulse CRSP/Legume Innovation Lab research and capacity building projects and to assess impacts to improve decision making regarding future investments*

Impact assessment must be viewed as a strategic activity that informs the prioritization of program activities as well as the design and implementation of Legume Innovation Lab projects to ensure that outputs from research and institutional capacity building investments achieve the intended development outcomes. This view requires programmatic introspection and evaluation, learning lessons from past programmatic decisions and development experiences, and the evaluation of factors that contribute to performance and ultimate impact by previously funded projects. Impact assessment is also forward thinking: understanding current socioeconomic, political, and agroecological conditions and projecting the potential for technologies and policies to benefit stakeholders of grain legume value chains through ex-ante assessments.

Strategic Objective 4 will be achieved through a variety of approaches and activities. Under the leadership of Dr. Mywish Maredea, Michigan State University, this component will provide the following services to USAID and the Management Office to improve outcomes during 2013–2017.

- Advise program directors on projected future research outputs, technologies, and practices with high potential for benefit to and adoption by end-users.

- Assist the MO on appropriate indicators to monitor project technical progress and performance in achieving developmental outcomes and in developing approaches to systematize the collection of needed data for indicator reporting to USAID under Feed the Future.
- Work with PIs of subcontracted projects to define clear outputs from research and capacity building activities, develop impact pathway strategies, determine to whom and when outputs will be handed-over to other public and private sector entities for follow-up translational research and technology dissemination, and identify appropriate baseline data that should be collected for future assessment of adoption by end-users.
- Assess post-adoption impacts of Bean/Cowpea and Pulse CRSP technologies for analysis of return on investments in research, program promotion, and reporting purposes to USAID.

Legume Innovation Lab Research Project Portfolio, 2013–2017

Salient Features of the Legume Innovation Lab’s Research Program

The global research program proposed for the next five years builds on the technical advances achieved by the Dry Grain Pulse CRSP, while redirecting and focusing future research efforts on priority areas with high promise for significant technological gains and the potential for widespread impacts on legume value chains in developing countries. Salient features of the Legume Innovation Lab program for FY 2013–2017 include:

A Focused, Coherent Research Program with Fewer Strategic Objectives and Projects

The proposed program includes just four Strategic Objectives for 10 research projects and one impact assessment project. This represents a reduction of three projects from the 2007–2012 period. The goal of the Legume Innovation Lab research portfolio is to make strategic research investments in a few priority areas where innovations in research technologies afford opportunities to make unprecedented gains or to overcome recalcitrant challenges in increasing productivity.

A Balance of Continuing and New Projects

Consistent with USAID’s extension request, the Legume Innovation Lab proposes that seven of the 10 subcontracted projects in the 2013–17 portfolio involve ongoing research from the past five-year award, while three projects be newly competed with different objectives. The Technical Management Advisory Committee recommended that certain projects be continued based on their record of high performance, potential for future and additional technical gains, and the alignment of their technical foci with Feed the Future priorities. For these projects, the MO will mandate that lead PIs of continuing projects incorporate the following changes into the projects:

1. Focus research and training activities on a few objectives with high potential for impact,
2. Focus activities on priority legume-based cropping systems and countries/regions aligned with FTF priorities, and
3. Include additional U.S. and/or HC collaborators with critical expertise and the capacity necessary to address the new research objectives resulting from project refocusing.

Strengthened Project Teams

The MO has taken advantage of this transition opportunity to strengthen teams for all projects, both continuing and to-be-competed projects, by requiring that lead PIs do the following when setting up projects:

- Engage a new generation of U.S. and HC scientists who are early or midcareer to bring in more contemporary research skills and to ensure longer-term commitments to Legume Innovation Lab research objectives (beyond 2017). (This action supports the EET's recommendation that new early and mid-career scientists be brought into continuing projects, especially in MSU-1, UPR-1, and UCR-1.)
- Engage multidisciplinary teams of scientists in Legume Innovation Lab projects, especially socioeconomists, to ensure that such issues as gender equity, the appropriateness of technologies, and the potential need for policy changes are considered. Socioeconomists can also assist in ex-ante demand assessments and in collecting quality baseline data to quantify future impacts of CRSP technologies.
- Select strategic host country institutions and scientists with advanced research capacities that are committed (1) to collaborating with Legume Innovation Lab PIs and partners (CGIAR scientists) to achieve SOs and (2) to achieving widespread development outcomes that benefit smallholder grain legume farmers beyond country borders for regional impact.

Innovation

Innovations in research and capacity building approaches and output targets will be incorporated into Legume Innovation Lab projects for 2013–2017 to accelerate progress toward SOs, to overcome complex wicked challenges (e.g., enhancing legume productivity, reducing the incidence of malnutrition), and to equip host country scientists to effectively utilize cutting-edge research tools afforded by the genomics and communications technology revolutions.

Examples of such innovations include:

- Phenometrics for identifying new physiological and biochemical traits to enhance photosynthesis and assimilate transport to reproductive structures, and to improve the effectiveness of the plant to acquire water and nutrients from the soil under agroecological conditions typical of smallholder, resource-poor farms
- Identification of Single Nucleotide Polymorphism (SNP) markers for QTLs of important physiological traits utilizing association mapping
- Introgression of genes for drought tolerance and disease resistances from other legume species (e.g., *Phaseolus accutifolius*, *P. coccineus*)
- Development of dynamic, virtual, interactive internet-based maps of insect pest population changes and crop damage in West Africa
- Development of decision tools for low-literate farmers to improve IPM and sustainable integrated soil fertility management of legume-based cropping systems
- Identification of appropriate governance structures to improve legume value chain functions and to increase market access for smallholder grain legume farmers
- Increased understanding of the role of grain legumes in diets for gut microbiome health and function (nutrient absorption) to enable the development of more effective education

and food interventions to improve nutrition for infants and children, and women of childbearing age.

Proposed Research and Capacity Building Projects for 2013–2017

Building upon the technical advances of the Pulse CRSP program during the past five years, the Legume Innovation Lab proposes the following portfolio of subcontracted research, technology dissemination, and capacity building projects for the 4.5-year extension. A brief abstract will be presented for each project with more detailed prospectuses of continuing projects included in Appendix II. For new projects to be openly competed, a justification is presented for the proposed research area. For the purpose of distinguishing future projects (2013–17) from those under the current award period, a new coding system will be used based on Strategic Objectives (SOs) and contributing projects (numbers), as seen in Tables 1 and 2 and detailed, below.

Strategic Objective 1.A: Advancing the Productivity Frontier for Grain Legumes— Substantively Enhancing Genetic Yield Potential

SO1.A1: Genetic enhancement of photosynthesis and assimilate transport to reproductive structures (pods and seed) in grain legumes for increased productivity and reduced vulnerability to climate change (New Project)

PIs and Institutions To be determined (TBD) through the issuance of an RFP

Research Objectives

- To identify new physiological and biochemical traits that play a role in the function and regulation of photosynthesis and assimilate transport to reproductive structures (pods and seeds) in common bean and cowpea and to assess their adaptation to dynamic environments associated with climate change (low water availability, high day/night temperatures)
- To phenotype germplasm collections, including those of related species (e.g., *Phaseolus accutifolius*), for physiological traits associated with high photosynthetic activity under low soil moisture and high temperature regimes
- To identify Quantitative Trait Loci and Single Nucleotide Polymorphism markers for important photosynthetic traits utilizing association mapping in common bean and cowpea
- To build phenotyping capacity for physiological traits that are linked to grain legume breeding programs in developing country institutions in Africa

Focus Countries/Region Eastern or Southern Africa (Ethiopia, Uganda, Mozambique, Tanzania, Zambia)

Justification

Scientists project that the impact of climate change on agricultural productivity in the coming decades will be dramatic. Associated with global warming will be increased incidences of drought or excess rainfall, both of which have adverse effects on crop productivity, especially of grain legumes, which have not benefited to the same extent as cereals (e.g., maize, wheat, and rice) from advances in genomics and transgenes to enhance tolerance to abiotic stresses.

To achieve high yields of grain legumes, the physiological mechanisms controlling the fixation of atmospheric carbon (photosynthesis and the efficient translocation of assimilates into reproductive structures [pods and seeds]), as influenced by stressful environments, must be better understood. Moreover, the genes controlling important physiological traits need to be identified and bred into improved varieties of grain legumes to achieve productivity gains.

The urgency to deal effectively with the challenges imposed by climate change is great. It is imperative that efforts begin now to identify new genes for traits contributing to high yield potential and to use genomics to identify markers and to introgress appropriate gene combinations to create improved varieties of grain legumes for smallholder farmers already affected by climate change.

Status New four-year project to be openly competed through the issuance of an RFP

SO1.A2: *New roots for grain legumes: Improving grain legume productivity in stressful soils through genetic improvement of root structure and function*

PIs and Institutions J. Lynch (lead) and K. Brown, Penn State University; P. Miklas, USDA/ARS; P. McClean, North Dakota State University; J.C. Rosas, EAP-Zamorano, Honduras; C. Josua, M. Miguel, IIAM, Mozambique; J. Bokosi, Bunda College, Malawi.

Research Objectives

- Discover novel root traits (architectural, anatomical, physiological) important for enhanced P, N, and water acquisition by grain legumes (primarily *Phaseolus vulgaris*, *P. acutifolius*, *P. coccineus*, and *Vigna unguiculata*)
- Phenotype core germplasm collections and diversity panels of grain legumes to identify QTLs and markers for improved root traits
- Identify major genes controlling root traits determined to be most useful
- Gain new understanding of how specific root traits contribute to abiotic stress tolerance in target agroecologies of Eastern Africa and Central America
- Improved capacity developed in Mozambique and Malawi to genetically improve common bean by enhancing tolerance to abiotic and edaphic stress factors

Focus Countries/Region: Mozambique, Malawi, and Honduras

Status: Continuation of Phase II PSU-1 project with additional partners

SO1.A3: *Improving genetic yield potential of Andean bean types with increased resistances to drought and major foliar diseases and enhanced symbiotic nitrogen fixation (SNF)*

PIs and Institutions J. Kelly (lead), Michigan State University; K. Cichy, USDA/ARS; C. Urea and J. Steadman, University of Nebraska; Uganda Collaborator TBD; K. Muimui, Zambia Agriculture Research Institute; Eduardo Peralta, INIAP, Ecuador, and H. Vasathakaalam, KIST, Rwanda

Research Objectives

- Characterize the pathogenic and genetic variability of isolates of root and foliar pathogens collected in Zambia and Ecuador and identify sources of resistance to angular leaf spot, anthracnose, common bacterial blight, bean common mosaic virus (BCMV), and bean rust present in Andean *Phaseolus vulgaris* germplasm

- Identify QTLs for drought tolerance, disease resistances, and SNF using single nucleotide polymorphism (SNP)-based genome mapping
- Increase understanding of physiological and morphological mechanisms associated with drought tolerance and enhanced SNF
- Integrate traditional and molecular-assisted selection approaches to combine resistances to economically important foliar diseases and drought, improved SNF, and desired culinary and nutritional traits (e.g., reduced cooking time, high Fe) into a range of large-seeded, high yielding Andean bean varieties of both bush and climbing bean archetypes for the Eastern Africa highlands (Uganda, Zambia), Ecuador, and the United States
- Build human resources for NARS with skills in molecular breeding for drought and disease resistances

Focus Countries/Region: Eastern and Southern Africa highlands (Uganda, Zambia) and Ecuador (Note: INIAP-Ecuador continues as a partner because it affords access to critical disease resistance genes and Andean common bean germplasm that will be of great benefit to breeding programs in Eastern and Southern Africa and the United States.)

Status: Continuation of Phase II MSU-1 project with additional partners

SO1.A4: Improving genetic yield potential of Mesoamerican bean types with enhanced adaptation to low fertility soils (N and P) and resistances to root pests

PIs and Institutions: J. Beaver (lead) and C. Estevez, University of Puerto Rico; T. Porch, USDA/ARS; J. Osorno and P. McClean, North Dakota State University; J.C. Rosas, EAP-Zamorano, Honduras; J.C. Villatoro, ICTA, Guatemala; E. Prophete, NSS, Haiti; and P. Kusolwa and S. Nchimbi-Msolla, SUA, Tanzania.

Research Objectives

- Identify common bean germplasm with increased resistances to root rots and adaptation to low N and P soils
- Develop SNP-based molecular markers for disease (BGYMV, BCMV, and BCMNV, rust) and insect (bruchid) resistance genes
- Breed, using traditional and marker-assisted approaches, improved common bean cultivars of Mesoamerican market classes (small blacks, reds, red mottled, yellow, and white) with high yield potential and combined durable resistances to economically important abiotic and biotic stress factors, and desired culinary and nutritional traits for Central America, the Caribbean, and Eastern Africa
- Enhance the capacity of technical personnel associated with Central American NARS bean programs in principles of plant breeding, the conduct of field trails, germplasm assessment, and in data analyses.
- Train MSc and PhD level plant breeders apt in the use of molecular genetic tools for Eastern Africa, Central America, and the Haiti

Focus Countries/Region: Central America (Honduras, Guatemala), Caribbean (Haiti), and Eastern Africa (Tanzania)

Status: Continuation of Phase II UPR-1 project with additional partners

SO1.A5: Genetic improvement of cowpea to overcome drought and biotic constraints to grain productivity

PIs and Institutions: P. Roberts (lead), T. Close and B. L. Huynh, University of California, Riverside; N. Cisse, ISRA, Senegal; I. Drabo, J.B. Tignegre, INERA, Burkina Faso; HC PI TBD, Ghana.

Research Objectives

- Discover new QTLs and molecular markers for drought, insect, and disease resistances in cowpea
- Develop and use molecular breeding approaches (e.g., MAS) to improve pest resistance and drought tolerance in cowpea for the Sudano–Sahelian region of West Africa and the United States
- Breed improved cowpea varieties with desired agronomic traits (drought tolerance, and *Macrophomina*, *Striga*, and insect resistances), high grain yield potential, and consumer-preferred culinary and grain market traits
- Strengthen cowpea seed production and delivery systems for improved cowpea varieties in Burkina Faso, Senegal, and Ghana

Focus Countries/Region: West Africa (Burkina Faso, Senegal, and Ghana)

Status: Continuation of Phase II UCR-1 project with a new collaborator in Ghana

Strategic Objective 1.B: Advancing the Productivity Frontier—Sustainably Reducing the Yield Gap

SO1.B1: IPM-omics: Scalable and sustainable biological solutions for pest management of insect pests in cowpea in Africa

PIs and Institutions: B. Pittendrigh (lead) and J. Bello-Bravo, University of Illinois, Urbana–Champaign; M. Shumate, Northwestern University; B. Coates, Iowa State University; M. Tamo, IITA-Benin; C. Dabire-Binso and M. Ba, INERA, Burkina Faso; I. Baoua, INRAN-Niger; S. Asante, SARI, Ghana; H. Braimah, CRI, Ghana.

Research Objectives

- To formulate and to validate a comprehensive, sustainable, integrated IPM strategy for cowpea insect pests using diverse control strategies
- To develop and to deploy biocontrol agents and biopesticides in the Sudano–Sahelian region to substantially reduce insect pest problems to a level that will significantly increase yields of cowpeas
- To develop educational tools for low-literate farmers in local languages to assist pest management decision making
- To develop dynamic virtual interactive, internet-based maps of pest problems in the Sudano–Sahelian regions of West Africa and information on biological agents to control cowpea insect pests
- To prepare training modules for local entrepreneurs, targeting women and unemployed youth, to create start-up businesses producing biological pest control products

Focus Countries/Region: West Africa (Burkina Faso, Ghana, Niger, and Benin)

Status: Continuation of Phase II UIUC-1 project with new collaborators in Ghana

Strategic Objective 2: Transforming Grain Legume Systems and Value Chains

SO2.1: Farmer decision-making strategies for improved soil fertility management in maize–bean production systems

PIs and Institutions: R. Mazur (lead), E. Abbott, and E. Luvaga, Iowa State University; R. Yost, University of Hawaii, Manoa; J. B. Bravo, University of Illinois; M. Tenywa, Makerere University, Uganda; TBD, National Crops Resources Research Institute, Uganda; N. Rapando, VEDCO, Uganda; Ricardo Maria, Alda Tomo, Carlos Filimone, and Sostino Mocumbi, Mozambique Agriculture Research Institute (IIAM), Mozambique.

Research Objectives

- Understand and enhance smallholder farmer knowledge of soil fertility management and ability to diagnose soil fertility problems, especially by women farmers.
- Develop and modify models for farmer decision making that take into account critical social, cultural, economic, institutional, and contextual factors influencing soil fertility management
- Develop and validate diagnostic and decision tools for improved integrated soil fertility and cropping system management appropriate for low-literate smallholder farmers
- Determine the effectiveness and efficiency of different methods and media for information dissemination, training, and support to stimulate widespread implementation of improved soil fertility management technologies and practices

Focus Countries/Region: Uganda, Mozambique (Eastern and Southern Africa)

Status: Continuation of Phase II ISU-1 project with new collaborators and a focus on management decision making

SO2.2: Enhancing legume value chain performance through improved understanding of consumer behavior and decision making

PIs and Institutions: V. Amanor-Boadu (lead), Kansas State University; G. Tembo, University of Zambia; L. Mapemba, University of Malawi; F. Kilima, Sokoine University of Agriculture, Tanzania

Research Objectives

- Evaluate the historical, social, and economic factors, including policies, that contribute to shaping consumption of beans and cowpeas in Eastern/ and Southern Africa
- Determine the distinguishing characteristics of urban food consumers in the region
- Develop a hierarchy of consumer food preference profiles and determine the factors that influence consumption of beans and cowpeas
- Develop appropriate business strategies to facilitate improved value chain performance
- Develop public policy recommendations to guide governments and nongovernmental agencies in leveraging beans and cowpeas to enhance nutrition, increase income, and alleviate poverty among smallholder producers, especially women and their families
- Develop innovative educational and outreach programs to enhance the capacity of consumers, producers, breeders, traders, processors, and policy makers to make decisions regarding grain legumes

Focus Countries/Region: Zambia, Malawi, and Tanzania (Eastern and Southern Africa)

Status: Continuation of Phase III KSU-1 project with additional host country partners
Strategic Objective 3: Enhancing Nutrition

SO3.1: Understanding the role of edible grain legume consumption in distinct diets on gut health and human nutrition (New Project)

PIs and Institutions: To be determined through issuance of an RFP

Proposed Research Objectives

- Elucidate the physiological roles of legume-based foods in digestive system function (e.g., mucosal transport, gut microbiota temporal stability, nutrient absorption), gut health (e.g., colon mucosa health, reduced inflammation, bacterial colonization of the epithelium, etc.), and immune system strength.
- Evaluate differences among grain legumes (species and grain types) in terms of their effects on digestive system function/health and metabolomics
- Determine dose-responses of legume-based foods in combination with cereals (typical in traditional diets) in terms of affecting the bioindicators of intestinal function and health, metabolomics, and the nutritional status of children
- Identify foods complementary to grain legumes for improving dietary nutritional quality and digestive function, especially for young children
- Assess methods of legume-based food preparation on nutritional value and contribution to nutritious and health-promoting diets for the poor

Focus Countries/Region: FTF focus countries in Eastern and Southern Africa and/or in West Africa

Justification:

Infants and young children growing up in poverty in developing countries are confronted by numerous lifestyle challenges that affect their nutritional status, growth, cognitive development, and health. These challenges include limited access to diverse, nutrient-dense foods, the poor nutritional quality of cereal-based diets, lack of access to potable water, poor hygiene, and a heavy disease burden.

Emerging research suggests that regular consumption of edible grain legumes may have positive effects on gut health, including improved gut microbiota stability, a healthier functioning mucosa, reduced intestinal track inflammation, strengthened immune systems, and improved growth. In-depth studies are needed, however, to better understand the important roles that legume-based foods might play in diets and digestive system function and how they affect human nutrition directly and indirectly.

A healthy digestive system is critical for obtaining the maximum potential nutritional benefit from ingested foods. Individuals suffering from gut inflammation, gut bacterial flora instability, chronic diarrhea, and/or poorly functioning colon mucosa cannot effectively acquire essential nutrients from the foods they eat. Thus, poor gut health and function will only exacerbate a malnourished condition and prevent a child or adult from benefitting from dietary improvements or nutritional interventions.

That grain legumes are not only nutrient dense but also conducive to good gut health provides a compelling justification for research to validate and to elucidate the physiological and biochemical basis of their role in diets. This information is especially important for addressing malnutrition problems among infants and children in developing countries where traditional diets are inherently poor in protein and essential nutrients. The knowledge generated from these studies will help government officials develop more effective food and nutritional policies and food and health organizations implement more effective community nutrition education and food intervention programs that include grain legumes.

Status: Project to be openly competed through the issuance of a RFP

SO3.2: Improving the nutrition and health of infants and women through the inclusion of edible grain legumes in diets and by obtaining insights into dietary decision making by the poor (New Project)

PIs and Institutions: To be determined through issuance of an RFP

Proposed Research Objectives

- To improve the nutrition of infants during the first 1000 days of life and to reduce the incidence of child stunting due to undernutrition through increased consumption of edible grain legume-based foods
- To better understand the nutrient and energy needs of infants and children that can be met by eating specific grain legumes at different ages and stages of development
- To improve pregnancy outcomes and lactation through inclusion of edible grain legumes in the diets of adolescent females of child-bearing age
- To better understand food choices and dietary decision making among urban and rural household food providers and their implications for the nutritional status and health of family members, especially among poor households
- To develop strategies to provide nutrition education information effectively to food providers in poor urban and rural households in priority countries and regions of Africa where grain legumes are commonly grown and consumed
- To formulate policy recommendations to promote enabling environments conducive to improved grain legume consumption for enhanced nutrition outcomes among young children and women in poor households

Focus Countries/Region: FTF focus countries in Eastern and Southern Africa, West Africa, and Central America

Justification

Edible grain legumes (such as common bean, cowpea, chickpea, lentils) are nutrient-dense foods that are widely considered an important component of a nutritious and health-promoting diet by dietitians and health professionals.

The newly released dietary guidance provided in the 2012 “MyPlate” states that beans and related grain legumes should be included in both the “Grains and Protein” and the “Fruit and Vegetables” categories because legumes not only constitute excellent sources of protein and complex carbohydrates but also provide essential vitamins (folic acid, etc.), minerals (K, Fe, Zn, etc.), and dietary fiber. Dr. Joanne Slavin, member of an Institute of Food Technologies (IFT)

expert panel and the U.S. government committee that wrote the “MyPlate” dietary guidelines, recently remarked (at the 2012 IFT Wellness Conference) that “most people do not eat enough beans in their diets” to achieve the desired health benefits.

Unfortunately little attention is being given to grain legumes as a potential candidate food for improving infant (during the first 1000 days) and child (2–5 years) nutrition. Much of the focus is currently on animal-based foods and soybean products. From a nutrition standpoint, animal-based foods are clearly superior to grain legumes for these age groups. However, a cost-benefit analysis raises questions about the desirability of promoting meat-based diets in poorer societies because of limited access. A more rational strategy would be to promote increased consumption of plant-based, nutrient-dense foods (such as edible grain legumes) because of their high nutritional value, benefits to digestive system health, and their lower water and carbon footprints.

Nutritionists identify edible grain legumes as possessing many common attributes (high protein content and dietary fiber), while recognizing that each species is compositionally unique. In recent years, soybean products have overshadowed grain legumes in nutritional intervention programs for children because of their superior amino-acid profile and high calorie content—to the disregard of data that indicates that anti-nutritional factors (e.g., phytates, oligosaccharides, etc.) may actually be worse in soybean than in other grain legumes, including certain types of common bean.

Because edible grain legumes are staple foods in traditional diets in many regions of the developing world, clear taste and food choice preferences exist for edible grain legumes over soybean. This reality presents an opportunity to promote the consumption of edible legume-based food products, which are locally available, to address infant and child undernutrition. To develop effective infant/child nutrition education programs and food-based nutritional interventions involving young children (6 months to 3 years) and young women of child bearing age, feeding studies are desperately needed to provide convincing data to health professionals and physicians on the nutritional value of eating more legume-based foods.

Knowledge gaps also exist in understanding food preferences and factors that influence dietary composition choices by food providers in poor rural and urban households where malnutrition is prevalent. Research is also needed to assess food environments in developing countries relative to legume-based foods to fully understand food consumption trends and diets of the poor. Such information is vital to designing effective nutrition-education programs and promoting enabling environments to mobilize political and private sector resources to improve the nutrition of young children and women.

Status: Project to be selected through the issuance of an RFP and peer-review of proposals

Strategic Objective 4: Improving Outcomes of Research and Capacity Building

SO4.1: Impact assessment of Legume Innovation Lab investments in research, institutional capacity building, and technology dissemination for improved program effectiveness

PIs and Institutions: M. Maredia (lead) and E. Crawford, Michigan State University

Project Objectives

- Advise the Legume Innovation Lab Management Office on research priority setting, performance assessment, and on strategies for technology dissemination for maximum impact.
- Assist each subcontracted Legume Innovation Lab project team at the onset and on an ongoing basis with the aim of
 - defining impact pathways for project outputs
 - integrating data collection and impact evaluation strategies into project design
 - advising and assisting in data collection methodology and analysis
 - identifying appropriate outputs, outcomes, and impacts for reporting purposes.
- Conduct ex ante and ex post impact assessment of the Legume Innovation Lab and the Dry Grain Pulses CRSP investments in research, institutional capacity building, and technology dissemination, respectively, in Africa, Latin America, and the United States.

Focus Countries/Region: West Africa, Eastern and Southern Africa, and Central America

Status: Continuation of Phase III MSU-4 project

Strategic Technical Alignment with Feed The Future in 2013–2017

The proposed Legume Innovation Lab technical approach for the 4.5-year extension period has been refocused to align technically with and be supportive of USAID's Feed the Future Global Food Security Research Strategy. In addition, the Management Office has sought to incorporate USAID's guidance regarding a globally focused, innovative, and coordinated research and capacity building program on grain legumes with the CGIAR. The following outlines the Legume Innovation Lab's future programmatic contributions to Feed the Future.

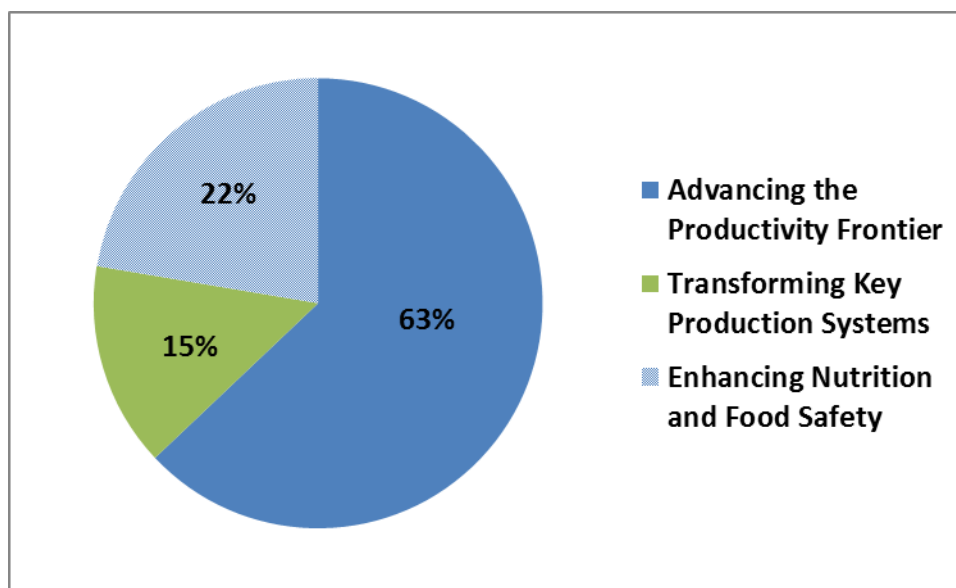
1. Technical Research Alignment

The proposed Strategic Objectives of the Legume Innovation Lab directly support FTF's Research Themes of (1) Advancing the Productivity Frontier, (2) Transforming Key Production Systems, and (3) Enhancing Nutrition and Food Safety through Agriculture. The greatest portion of the Legume Innovation Lab's investments will be in support of enhancing grain legume productivity (60 percent), with 14 percent directed to transforming production systems and 21 percent to enhancing nutrition (Figure 1). How future Legume Innovation Lab research projects align with research priorities set forth in USAID's FTF Research Strategy are presented in Table 3.

2. Leadership in the Global Development Community

USAID's Pulse CRSP (to become Legume Innovation Lab) has emerged as an international leader in common bean and cowpea research and capacity building. Looking to the next 4.5 years, the Legume Innovation Lab will proactively continue to exert global leadership through

Figure 1. Resource Allocation by FTF Research Themes



innovation and cutting-edge approaches to research made possible through mobilization of internationally recognized scientists and laboratories at U.S. universities. In many ways, these U.S. scientists are the envy of the world and clearly the comparative strength of the Legume Innovation Lab. By constituting teams of scientists with the appropriate mix of disciplinary expertise from U.S. universities in partnership with scientists from the USDA/ARS, National Agriculture Research Systems (NARS), host country agricultural universities, the CGIAR and NGOs, Legume Innovation Lab projects offer promise of overcoming the constraints facing grain legume production and value chains.

In the 4.5-year extension of the Legume Innovation Lab, the following leading U.S. bean and cowpea scientists and universities will be actively engaged internationally in collaborative research and contributing to USAID's FTF program.

Genetics and Breeding

Michigan State University: Drs. James and Karen Cichy (USDA/ARS)

North Dakota State University: Drs. Juan Osorno and Phillip McClean

University of California, Riverside: Drs. Phil Roberts and Timothy Close

University of Nebraska: Dr. Carlos Urea

University of Puerto Rico: Drs. James Beaver and Timothy Porch (USDA/ARS)

Washington State University: Dr. Phillip Miklas (USDA/ARS)

Plant Physiology

Pennsylvania State University: Drs. Jonathan Lynch and Kathleen Brown

Table 3. Alignment of Legume Innovation Lab Projects with FTF Research Strategy

Legume Innovation Lab Alignment with FTF Research Strategy	
Priority of FTF Research Strategy	Legume Innovation Lab Projects contributing to priority
Reducing risks from pests and diseases in grain legumes (p. 23)	SO1.B1 IPM-omics SO1.A3 Andean bean breeding SO1.A4 Mesoamerican bean breeding
Crop resistance to heat, drought, salinity, and flood (p. 23)	SO1.A1 Photosynthetic enhancement SO1.A2 New roots for legumes SO1.A3 Andean bean breeding SO1.A5 Cowpea breeding
Improved resource use efficiency of crops (p. 24)	SO1.A3 Andean bean breeding
Enhanced symbiotic nitrogen fixation (SNF) (p. 24)	SO1.A4 Mesoamerican bean breeding
Research priorities assessment and evaluation (p. 27)	SO4.1 Impact assessment
Southern and Eastern Africa maize-based systems (p. 30)	SO2.1 Farmer decision-making
West African Sudano-Sahelian Systems/Insect-resistant cowpea (p. 30)	SO1.A5 Cowpea breeding SO1.B1 IPM-omics
Grain legume productivity gains (p. 33)	SO1.A1 Photosynthetic enhancement SO1.A2 New roots for legumes SO1.A3 Andean bean breeding SO1.A4 Mesoamerican bean breeding SO1.A5 Cowpea breeding SO1.B1 IPM-omics
Numbers indicate page citation in the Feed the Future Global Food Security Research Strategy, U.S. Government, May 2011. http://www.feedthefuture.gov/sites/default/files/resource/files/FTF_research_strategy.pdf	

Entomology, Pathology and Microbiology

University of Illinois: Dr. Barry Pittendrigh

University of Nebraska: Dr. James Steadman

University of Puerto Rico: Dr. Consuelo Estevez

Northwestern University: Dr. Michelle Shumate

Soil Fertility Management

University of Hawaii, Manoa: Dr. Russell Yost

Rural Sociology and Extension Education

Iowa State University: Drs. Robert Mazur, Eric Abbot, and Ebby Luvaga

University of Illinois: Dr. Julia Bello Bravo

Agriculture Economics: Value Chains and Impact Assessment

Kansas State University: Dr. Vincent Amanor-Boadu

Michigan State University: Drs. Mywish Maredia and Eric Crawford

Other new laboratories and expertise in nutrition and physiological genetics will be brought into the program when the three new Legume Innovation Lab projects are competed and awarded. The Legume Innovation Lab will continue to exert leadership and influence by pursuing partnerships and promoting open scientific exchange through collaborations with the international grain legume research community. For the next five years, the Legume Innovation Lab will strengthen its collaboration with the CGIAR through *CRP3.5 Grain Legumes* as well as through the Africa Rising Sustainable Cropping Systems Intensification program in the Sudano-Saharan Region of West Africa and the maize-based systems of Southern and Eastern Africa (focus on seed systems, IPM, value chains).

The Legume Innovation Lab will seek to promote greater networking among host country grain legume scientists, especially NARS scientists, since they are afforded fewer opportunities to interact and collaborate with the greater international research community. In Central America, the Lab will continue to support the Central American Bean Research Network under the leadership of Dr. Juan Carlos Rosas, Escuela Agrícola Panamericana-Zamorano, Honduras. In Southern and Eastern Africa, Legume Innovation Lab PIs will continue to collaborate and interact with the Southern Africa Bean Research Network (SABREN) and the Eastern and Central Africa Bean Research Network (ECABREN), respectively.

The Legume Innovation Lab plans to seize a leadership opportunity by organizing a Pan-Africa Grain Legume Research Conference in partnership with NARS and CGIAR centers during 2015 or 2016. Such a conference is desperately needed to bring together the broader grain legume research community in the African continent. All too frequently, legume research and development projects in Sub-Saharan Africa (e.g., GCP, TL1&2, McKnight Foundation Legume Program in both West and Southeastern Africa, PICS, N2AFRICA, AGRA, and Value-Added Bean Technologies) create programmatic silos. The Legume Innovation Lab believes that tremendous mutual benefits can be gained by fostering scientific interaction, the sharing of data and experiences between legume researchers working on distinct legume species and agroecologies, and by improving the coordination of research.

The Legume Innovation Lab plans to continue to cosponsor the World Cowpea Conference with IITA and provide support for cowpea scientists in developing countries (with special priority given to graduate students) to attend and present papers on supported research activities.

3. Strategic Alignment and Coordination with other FTF Investments in Legume Research and Capacity Building

In support of FTF's goal of "changing how we work," the Legume Innovation Lab will support FTF's "whole of government" approach. To this end, the proposed portfolio of Legume Innovation Lab projects will engage three prominent USDA/ARS common bean geneticists (Timothy Porch, Puerto Rico; Karen Cichy, Michigan; Phillip Miklas, Washington) in three distinct projects. Since these three scientists are already receiving FTF funds through USDA/ARS, their participation in Legume Innovation Lab projects will ensure direct research linkages to international grain legume research initiatives and collaboration with host country scientists. This beneficial partnership with USDA/ARS scientists should result in synergies and accelerated advances toward strategic objectives.

The Legume Innovation Lab is also working to coordinate with various FTF initiatives in capacity building and tools for technology development and diffusion. With scholarship programs, including Borlaug Higher Education for Agricultural Research and Development (BHEARD), the MO is working with PIs and USAID Missions to identify excellent candidates for degree training and to highlight research opportunities with host country partners. With the new Higher Education Solutions Networks, especially the Global Center for Food Systems Research based at MSU, the MO is exploring opportunities for linkages on key issues, such as legume value chain development in urban areas.

The majority of U.S. university principal investigators (PIs) participating in the Legume Innovation Lab also leverage substantial funding and grants from public and private sources (NIFA, NSF, etc.) to support their respective ongoing grain legume research programs and to enhance their international engagements. To the extent possible, the MO of the Legume Innovation Lab will interact with PIs to ensure that project research objectives for FY2013–2017 are complementary to FTF investments in grain legumes and in capacity building. Opportunities are already identified with the following programs:

Common Bean Coordinated Agriculture Project (BeanCAP). PIs participating in BeanCAP include J. Kelly, J. Osorno, C. Urrea, K. Cichy, T. Porch, P. Miklas, and P. McClean, the project coordinator.

USDA NIFA. PIs J. Kelly at MSU and J. Steadman at U. Nebraska received the following NIFA awards:

- Developing and delivering common bean germplasm with resistance to the major soil borne pathogens in Eastern Africa (MSU)
- Genetic approaches to reducing fungal and Oomycete soil-borne problems of the common bean breeds in Eastern and Southern Africa (U. Nebraska)

NSF Basic Research to Enable Agriculture Development (BREAD). PI J. Lynch received a BREAD award

The Legume Innovation Lab MO is making a concerted effort to coordinate program research and other research initiatives linked to the CGIAR. Examples include:

- Tropical Legumes I and the Generation Challenge Program “Improving tropical legume productivity for marginal environments in Sub-Saharan Africa and Asia.” PIs P. Roberts and T. Close, UC, Riverside, are involved in both
- Tropical Legumes II. I. Widders (director) interacts regularly with Dr. Emmanuel Monyo, principal coordinator, through CRP3.5
- McKnight Foundation Legume Program in Southern and Eastern Africa

4. Concentrated Effort on FTF Focus Countries and Priority Cropping Systems in Africa and Latin America

The Legume Innovation Lab will focus its research and capacity building efforts on sustainably intensifying legume-based productions systems and value chains in three USAID-priority regions under Feed the Future, including (1) the Sudano–Sahel cereal–legume system of West Africa, (2) the maize–legume system of Southern and Eastern Africa, and (3) the maize–bean hillside system of Central America. An estimated 55 percent of Legume Innovation Lab funds will benefit the Eastern and Southern Africa regions, while 32 percent and 13 percent will be invested in projects that benefit West Africa and Central America, respectively.

The Legume Innovation Lab has strategically selected institutional partners with predominant research capacity in needed competency areas in each of these regions with the clear expectation that outputs generated will have system-wide and regional impacts. This therefore requires a commitment from our host country institutional partners to contribute to a broader effort that extends beyond national borders, and requires networking and effective collaboration with diverse institutional partners.

Table 4 identifies the host countries, partner institutions, and active Legume Innovation Lab projects in the three priority regions. It should be noted that additional institutional partners will be added in these countries when the three new projects are awarded.

During the extension period, the Legume Innovation Lab will continue to require that all subcontracted projects invest a minimum of 30 percent of direct funds in combined degree and short-term training. Emphasis will be placed on responding to identified human resource needs of partner HC institutions (NARS, agricultural universities, NGOs, etc.) and strengthening women’s roles and capacity in these institutions. PIs will be encouraged to explore innovative approaches to training that result in enhanced educational and cost effectiveness, including distance learning programs (e.g., KSU’s master’s program in Business Management), sandwich degree programs, training in research methods for technical support staff, and short-term research visits by HC scientists in U.S. university laboratories.

The Legume Innovation Lab MO also realizes that English language instruction is required to successfully recruit and provide access to U.S. graduate programs for students from non-English speaking countries, since graduate schools are now rigidly enforcing TOEFL and GRE requirements for admission. Since the Legume Innovation Lab is committed to training young

professionals from Francophone (Senegal, Burkina Faso, Niger), and Lusophone (Mozambique) countries, the Legume Innovation Lab is revising its policy to allow support for up to one year of English language instruction for trainee candidates for graduate study.

Building on the overwhelmingly positive experience during 2007–2012, the Legume Innovation Lab will increase its investment in competitively awarded institutional capacity building by host country institutions to \$1 million over the 4.5-year period. These funds support short-term training/workshops, research equipment purchases, short-term research sabbaticals, research networking activities, etc. that are proposed by HC scientists. Typically, awards average between \$10,000 and \$30,000 each and must be spent within a fiscal year. Since funds for institutional capacity building are over and above the 30 percent-and training commitments by projects and the monies are always advanced to the HC institution, they directly benefit HC institutions in tangible ways.

New to the Legume Innovation Lab will be the establishment of a jointly funded scholarship fund with the CGIAR. These scholarships are targeted for promising young HC professionals interested in grain legume research to pursue MS or PhD programs with Legume Innovation Lab PIs at U.S. universities. Proposed requirements of the program include:

- Nomination of HC trainee candidates by a CGIAR scientist or center
- Commitment to focus thesis research on a priority constraint for grain legumes or a technological output associated with a product line in CRP3.5
- Commitment to conduct a component of the research project in residence at a CGIAR center
- Membership by a CGIAR scientist on the trainee's graduate guidance committee

The Legume Innovation Lab commits \$500,000 in financial support for this new scholarship fund, with the expectation that CRP3.5 will provide matching funds. Recipients of these scholarships will be jointly selected by representatives from the CRP and the Legume Innovation Lab. The expectation is that this initiative will not only enhance the human resource capacity of the CGIAR in strategic areas but also contribute to strengthened collaborative relationships between Legume Innovation Lab and CGIAR scientists.

Finally, the Legume Innovation Lab will seek to use its funding for institutional capacity building to leverage the academic formation of a new generation of HC grain legume scientists. The troublesome reality is that a generation of critical HC grain legume scientists (including breeders, agronomists, entomologists, and economists) are approaching retirement age, many of whom are Legume Innovation Lab PIs with leadership roles in their national legume research programs. Since two to five years are required for completion of graduate degree programs, an urgent imperative of the Legume Innovation Lab is to invest (starting in FY 2013) in preparing young professionals to fill the research positions to be vacated through retirements. To the extent possible, the MO will insist that partner institutions consider future research staffing needs (as affected by pending retirements) and seek to identify qualified persons for Legume Innovation Lab training in these areas. Since gender equity must also be an institutional priority, a concerted effort must be made to recruit and award Legume Innovation Lab assistantships to qualified women from focus countries.

Table 4. Regional Cropping Systems and Host Country Partner Institutions in Legume Innovation Lab.

FTF Regions and Countries	HC and Partner Institutions
West Africa (Sudano-Sahelian cropping system)	
Burkina Faso	Institut de l'Environnement et de Recherches Agricoles (INERA)
Ghana	Council for Scientific and Industrial Research (CSIR) Savannah Agricultural Research Institute (SARI) Crops Research Institute - Kumasi (CRI)
Niger	Institut National de la Recherche Agronomique du Niger (INRAN)
Senegal	Institut Sénégalais de Recherches Agricoles (ISRA)
Southern and East Africa (maize-legume cropping system)	
Tanzania	Sokoine University of Agriculture (SUA)
Malawi	University of Malawi; Bunda College (Lilongwe University of Agriculture and Natural Resources LUANAR)
Mozambique	Instituto de Investigação Agraria (IIAM)
Uganda	Makerere University National Agricultural Crops Resources Research Institute (NaCCRI) Centre for Volunteer Efforts for Development Concerns (VEDCO)
Zambia	University of Zambia (UNZA) Zambian Agricultural Research Institute (ZARI)
Central America (hillside maize-bean cropping system)	
Guatemala	Instituto de Ciencia y Tecnología Agrícolas (ICTA)
Haiti	National Seed Service (NSS)
Honduras	Escuela Agrícola Panamericana - Zamorano (EAP)

5. Advancing Gender Equity

As the FTF Research Strategy indicates, women play a multiplicity of roles including “producers, entrepreneurs, scientists, extension agents, and consumers” (USAID 2011, p. 4). The Legume Innovation Lab recognizes the multiplicity of these roles and the importance of creating opportunities for women to improve their ability to be effective and successful. The Legume Innovation Lab will therefore mainstream gender considerations in all aspects of its program implementation, monitoring, and evaluation. This includes efforts at capacity building efforts of women within agricultural research, gender sensitive technology development and extension, communications tools that are designed to address needs of women, and nutrition research to ensure women’s capacity to use legumes in a diversified diet.

To improve the welfare of women over the longer term, the Legume Innovation Lab will continue to emphasize human resource development as a priority in its projects. PIs of subcontracted projects will recruit highly qualified women for graduate degree programs and technical positions in research projects. Short-term training activities will be designed around engaging women at all levels, including training roles. To ensure accountability, PIs will be required to establish gender-based performance indicator targets and report on actuals achieved at year’s end. The expectation is that the Legume Innovation Lab will continue to improve over FY 2013–2017 on both its degree and short-term training of women for the 2007–2012 period—59 percent and 48 percent respectively.

Investing in research on technologies that benefit women farmers is a priority of the Legume Innovation Lab in support of FTF. Since women are the principal producers of grain legumes in Africa and regions of Latin America, with SO1 and SO2 we will focus on technologies that enhance women’s productivity and abilities to sustainably manage a legume crop and provide nutrient-dense food for their families in the face of uncertain rainfall patterns. Improved varieties of bean and cowpea with greater tolerance to drought and high temperatures as well as adaptation to low fertility soils should be particularly beneficial to women. Women are more likely to have limited access to resources to purchase inputs such as fertilizers. Combined with improved varieties, enhanced understanding of women farmers’ knowledge, motivation, and use of practices to improve soil fertility will enable the development of soil diagnostic tools and decision aids to assist women farmers in making better management decisions regarding legume crops in their farming systems.

Communication instruments and decision tools developed under SO1.B.1 and SO2 can also improve women’s access to information and their ability to make effective management decisions. Video animations on IPM practices, recorded in local languages for low-literate farmers, can be transmitted to cell phones using Bluetooth technology, affording potential to reach large populations of low literate smallholder farmers with timely, low-cost, and effective information on controlling insect pests in cowpea. Easy to use soil fertility diagnostic tools will also contribute to women farmers’ achievement of productivity gains.

The Legume Innovation Lab believes that research targeting women is the most effective strategy to address malnutrition among the poor in developing countries, regardless of whether the benefits are to productivity or in the dietary choices that women make for their families. SO2 includes

evaluation of consumption of legumes in selected countries with a view to enhancing value chain performance, including gender analysis of demand. Under SO3, knowledge on the contributions of legume-based foods to the nutrition and health of infants (6 to 24 months) and young children will aid women in meeting the nutritional requirements of their families. Factors influencing the dietary decisions of both the rural and urban poor will also be elucidated and, thus, facilitate the development of effective educational and nutritional interventions to address malnutrition in communities.

Following FTF guidelines on performance monitoring, the Legume Innovation Lab will include gender sensitive approaches as can be seen in the Performance Monitoring Plan and selected FTF Indicators as well as in the proposed Impact Assessment Strategy.

6. Support of USAID Country and Regional Mission Feed the Future Strategic Value Chains and Development Priorities

Under Feed the Future, USAID Missions have a mandate to raise agricultural productivity and reduce malnutrition; in selected FTF focus countries, grain legumes have been identified as a strategic commodity line for investment. The Legume Innovation Lab and its collaborating U.S. and host country partner institutions are in a position to make critical contributions to enhancing productivity by smallholder farmers, overcoming malnutrition among young children and mothers, and to strengthening the human resource and research capacity of national institutions. During the extension period, the MO will commit resources to informing Missions in FTF focus countries and elsewhere of Legume Innovation Lab capacities and technologies and their potential to contribute to Mission program objectives. The Legume Innovation Lab's directors and PIs will also engage USAID Mission staff regarding country technology needs, priorities for institutional capacity building, and the implementation of projects to achieve maximum impact in accord with FTF country priorities.

The Legume Innovation Lab MO is highly interested in pursuing Associate Awards from USAID Missions, especially for services and activities requiring Legume Innovation Lab expertise, the dissemination of research outputs (technologies, management practices, and knowledge) with high potential for widespread impacts, and human resource and institutional capacity building. The MO and CRSP subcontractors have strong working partnerships with diverse public and private institutions in both FTF countries and the United States that can be mobilized to address a Mission's specific development objectives. An Associate Award is a simple, noncompetitive mechanism by which a Mission can contract with the Legume Innovation Lab for services by specific partners. The Legume Innovation Lab is in an excellent position to identify local partners and to design technology transfer approaches that can be turned over to local partners, whether through an Associate Award or another mechanism.

In accord with USAID's FTF Research Strategy, the Legume Innovation Lab's research objectives will contribute both to long-term knowledge and technology generation and to human resource development. The MO recognizes, however, that Mission objectives are focused on achieving local impact within a short time frame. As evidenced by the performance of the Bean Technology Dissemination associate award in Honduras, Guatemala, Nicaragua, and Haiti, the Legume Innovation Lab has the capacity, jointly with developing country partners, to disseminate validated

technologies on a large scale to beneficiaries (120,000 smallholder farmers in three years). Examples of grain legume productivity-enhancing technologies that would be ready to go include seed of improved varieties of cowpea and common bean with high yield potential, tolerance to drought, and resistances to economically important diseases; IPM practices and biological controls for pod-sucking insects in cowpea; and nutritionally complete extruded bean or cowpea-based foods for nutritional interventions among young children.

The Legume Innovation Lab and its HC partners also have local linkages to diverse public and private sector institutions and programs that could significantly assist Mission and their subcontractors in extending the outputs of science to benefit stakeholders of grain legume value chains, including consumers, in FTF focus countries. With our HC partners, we are in an excellent position to identify local institutions for USAID Way Forward local contracting as well assist in identifying excellent candidates for USAID training programs, such as the Borlaug Higher Education for Agricultural Research and Development (BHEARD)

The Legume Innovation Lab proposes multiple strategies to engage the USAID Missions.

- a) Contacts by Legume Innovation Lab PIs (both U.S. and HC) with Mission Agriculture and Economic Growth staff to inform of validated technologies and knowledge available for dissemination in support of country FTF strategic objectives and to introduce national partners that could be a valued resource for implementation of FTF programs.
- b) Communications instruments targeted to USAID Missions, including an enhanced Legume Innovation Lab website (currently, www.pulsecrsp.msu.edu/), publications (newsletters, project briefs, white papers), and innovative media such as blogs and videos highlighting Legume Innovation Lab in-country activities, achievements, and topics of potential interest relative to FTF priorities (climate change, sustainability of cropping systems, under- and over-nutrition among children in poverty, etc.).
- c) Direct engagement by Legume Innovation Lab Deputy Director Dr. Cynthia Donovan with FTF Missions to ensure a line of communication with key staff to keep the MO informed of Mission development priorities and programs, and to facilitate links to resources within the Legume Innovation Lab that might be of interest and benefit to the Mission. Where appropriate, the MO will work with Missions to develop Scopes of Work for activities to be subcontracted to the Legume Innovation Lab through the associate award mechanism or subcontracts with current Mission partners.

Strategic Partnership in CRP 3.5 Grain Legumes

The Legume Innovation Lab will be a Strategic Partner with the CGIAR in the implementation of the Consortium Research Program of the CGIAR on Grain Legumes (CRP3.5). This relationship will be formalized by reciprocal appointments of representatives from each program to the principal research oversight committee of the other. In the case of the Legume Innovation Lab, the director of CRP3.5 or a designee will be a standing member of the Technical Management Advisory Committee. Dr. Irvin Widders has already participated in CRP3.5 planning meetings and been invited to serve on the CRP3.5 Research Advisory Committee.

This partnering relationship will be manifest in three ways:

1. joint collaboration between CGIAR and Legume Innovation Lab U.S. university scientists and host country collaborators toward common research objectives,
2. complementary activities that support achievement of CRP3.5 product lines, and
3. beneficial research initiatives by the Legume Innovation Lab that address strategic objectives for grain legumes that represent technical gaps in CR3.5.

The Legume Innovation Lab affords a mechanism by which the CGIAR can access scientific expertise and cutting-edge research technologies (e.g., biochemical analytical services, gene sequencing capacity, instrumentation and facilities for controlled physiological research, computer-based modeling, bioinformatics, and innovations in communications technology, etc.) from world renowned laboratories at U.S. universities. Through collaboration in research to advance Product Lines for grain legumes (CRP3.5), in which Legume Innovation Lab PIs have clearly defined roles, the CGIAR can gain the commitment and services of U.S. and HC scientists without investing in additional staff. The ultimate result is that USAID benefits from clear synergies from its investments in grain legume research. Table 5 outlines the relationship between CRP3.5 Product Lines (PL), as presented in the August 15, 2012, proposal to the CGIAR, and Legume Innovation Lab's SOs and associated projects on common bean and cowpea for FY 2013–2017.

The international research community of U.S. and HC scientists that participate in the Legume Innovation Lab will benefit from the partnership with the CRP through:

- Access to germplasm and ideotypes of common bean and cowpea with desired traits for use in breeding local varieties appropriate for specific agroecologies and markets, and
- Opportunity to share knowledge and experiences important for successful deployment of genetic-based technologies (identified as Strategic Components in CRP3.5), including demand analysis, seed technology delivery, and marketing.

Response to CRSP Evaluations

1. USAID: Commissioned External Evaluation Team Report and Recommendations

The Management Office of the Legume Innovation Lab commends the USAID-commissioned External Evaluation Team (EET) for its thorough and comprehensive evaluation of the Dry Grain Pulses CRSP's technical and administrative performance during the initial five-year award period, as outlined in the Scope of Work. In the preparation of this Technical and Cost Application for the five-year extension, the MO has sought to address all the recommendations to strengthen the program as presented in the EET's Report of August 2012. A detailed response to the EET's recommendations was prepared by the MO and is included in Appendix I of this Technical Application.

The MO extends its sincere appreciation to the External Evaluation Team of Drs. Julia Kornegay, Julian Adams, Bahram Arjmandi, Michael Gruzak, and Steven Long for their professional dedication and countless hours of effort, under constraints of both time and financial resources, to complete a quality report that reflects insight into the grain legume sector and an understanding of its research activities. Recommendations in the EET's report were of value to the MO in making decisions on project extensions and program implementation and administration for the next five years.

2. BIFAD-commissioned Review of CRSP Model Report and Recommendations

The proposed technical approach for the five-year extension of the Legume Innovation Lab conforms best to Model 2 under Recommendation 5 of the Report. Legume Innovation Lab SOs focus on the “demand drive themes” identified in the Feed the Future Research Strategy and will contribute to the strengthening of a priority value chain for poverty alleviation and food and nutritional security (grain legumes). Moreover, Legume Innovation Lab research will result in specific outputs (technologies, IPM practices, decision tools, nutrition information) that support USAID Mission programming to achieve FTF development objectives and macro-level indicators.

The Legume Innovation Lab also supports Recommendation 6 by increasing its investments during the 4.5-year extension in institutional capacity building of not only host country universities but also the National Agriculture Research Systems and the international grain legume research community (CGIAR centers). In addition to designating a minimum of 30 percent of direct project funding for degree and short-term training, the Legume Innovation Lab will competitively award \$1 million to partner host country institutions for capacity building and commit \$500,000 to establish a joint scholarship fund with CRP3.5 for PhD and MSc training of CGIAR-appointed young professionals working on grain legumes.

Finally, the Legume Innovation Lab Technical Application presents compelling evidence of the program’s commitment to “leveraging impact of CRSP investments” (Recommendation 8) by coordinating research activities with USDA ARS and NIFA programs on grain legumes (even to the extent of including ARS scientists as PIs in projects) and establishing a “strategic partnership with the CRP3.5 on Grain Legumes.”

Table 5. CRP3.5 Product Lines and the Legume Innovation Lab's SOs

Strategic Partnership: CRP3.5 Grain Legume and Legume Innovation Lab	
1. Opportunities for Research Collaboration between Legume Innovation Lab projects and CRP3.5 Product Lines (PL)	
CRP3.5 PL	Legume Innovation Lab
PL 1. Drought and low phosphorus tolerant common bean, cowpea, and soybean (CRP3.5)	SO1.A2 New roots for legumes SO1.A4 Mesoamerican bean breeding SO1.A5 Cowpea breeding
PL 4. High nitrogen-fixing chickpea, common bean, fava bean, and soybean (CRP3.5)	SO1.A3 Andean bean breeding
PL 5. Insect-smart chickpea, cowpea, and pigeonpea production systems (CRP3.5)	SO1.B1 IPM-omics
2. Complementary Research by the Legume Innovation Lab	
SO1.A1 Photosynthetic enhancement (genetic enhancement for physiological traits) SO1.A3 Andean bean breeding (resistances to major foliar diseases) SO1.A4 Mesoamerican bean breeding (adaptation to low N and resistances to root pests) SO1.A5 Cowpea breeding (resistances to insect and Striga)	
3. Beneficial Independent Research of the Legume Innovation Lab	
SO2.1 Farmer decision-making SO2.2 Legume value chains SO3.1 Nutrition: gut health SO3.2 Nutrition: infants and diets SO4.1 Impact assessment	

Administrative Approach

A. Management Office

Michigan State University and the College of Agriculture and Natural Resources remain committed to performing the Management Entity functions of the Feed the Future Food Security Innovation Lab: Collaborative Research on Grain Legumes (Legume Innovation Lab) and to hosting the program's Management Office (MO) for the five-year extension period of FY 2013–2017. As a land grant university with a vision for global partnerships in education and research, MSU's leadership continues to support the Legume Innovation Lab's global mission and strategic objectives. As evidenced in the External Evaluation Report of the Dry Grain Pulses CRSP, the MO has been able "to provide outstanding technical leadership and administrative support to achieve the objectives of the program." For the next 4.5 years, the MO will strengthen capacities in critical areas (e.g., mission engagement and support, communications and promotion, event planning and arrangements, CGIAR partnerships) while maintaining capacity in essential areas (technical leadership, contracting and financial management, impact assessment). These services will be provided with an emphasis on quality, expediency, and cost-effectiveness. The MO budget (see Cost Application), which includes program administrative and implementation costs, will be maintained at approximately 20 percent of total funds obligated to the Legume Innovation Lab. MSU will provide approximately 22 percent cost-share of all MO expenses, which will certainly stretch USAID's support for such key activities as impact assessment, program communications, and Global Grain Legume Research Meetings.

To support program growth and the expanded roles of the Management Office, as recommended by USAID, the EET, BIFAD, and the Technical Management Advisory Committee, the following staffing changes and innovative new functions are being proposed by the Legume Innovation Lab for the coming four and one-half years.

1. Staffing of MO for 2013–2017

Director (0.9 FTE)

Dr. Irvin Widders, an MSU professor and plant physiologist, will continue as director, responsible for providing both technical and administrative leadership to the Legume Innovation Lab and representing the Legume Innovation Lab in interactions with partner institutions and international grain legume research and development communities and programs (e.g., CRP3.5, AFRICA RISING). To ensure continued and significant improvement in the livelihoods of smallholder grain legume farmers in developing countries, Dr. Widders will initiate and develop an international dialog with diverse partners to advocate for development strategies to increase international investment in grain legume research and capacity building, particularly in regard to needed knowledge and technologies.

Deputy Director (0.75 FTE)

Dr. Cynthia Donovan, an Agricultural Economist with extensive agricultural development experience in Africa and Latin America, will serve as the deputy director for FY 2013–17. In addition to providing complementary expertise and assisting the director with management of the program, she will assume principal responsibility for (1) strengthening the Legume Innovation Lab's engagement with USAID regional and country Missions in support of FTF development

strategies and programming and (2) enhancing Legume Innovation Lab communications with international stakeholders and partners. The deputy director will explore opportunities for USAID associate awards and grants with international foundations to realize the potential of Legume Innovation Lab-generated knowledge and technologies to achieve development impacts in accord with USAID FTF priorities.

Administrative Officer (1.0 FTE)

Mr. Ben Hassankhani will continue to assume administrative program responsibility for postaward contractual management with USAID; for establishing and overseeing compliance of subcontracts with partner U.S. institutions (including Technical Project Descriptions, Budgets and Annual Workplans, and Performance Indicators with lead U.S. universities of projects); and for managing the financial aspects of the program. In the administration of associate awards and in select cases where a lead institution lacks administrative capacity, the administrative officer would assume responsibility for managing sub-subcontracts (fixed price) with partner host country institutions.

Communications and Promotions Specialist (0.75 FTE)

Dr. Marguerite Halversen, a professional writer and communications specialist, will assume an increased role in providing leadership for the implementation of the Legume Innovation Lab's communications and promotion strategy. Since having established this new staff position in 2011 in response to USAID's guidance, the MO has grown a greater appreciation of the importance of information dissemination (of Innovation Lab achievements) and the potential effectiveness of new electronic communications tools (e.g., blogs, LinkedIn and other social media, electronic newsletters and briefs, and web sites). This increased appointment, therefore, reflects the expanded responsibilities and expectations of the Communications Specialist.

Impact Assessment Specialist (0.25 FTE)

Dr. Mywish Maredia, Agricultural Economist at Michigan State University, will continue to provide leadership in project performance monitoring, ex ante and ex post impact assessment and impact pathway analysis, and implementation for Legume Innovation Lab technologies. In addition to providing consultative services to subcontracted project PIs on strategies for maximizing the impact of research outputs and on baseline data collection for long-term impact assessment, Dr. Maredia will advise the director and deputy director on research priority setting and impact assessment.

Administrative Program Assistant (0.8 FTE)

A new position will be established to support the following functions of the Management Office.

- Collecting, filing, compiling, and preparing program documents (Scopes of Work [SOWs], annual workplans, technical progress reports, and performance indicators) from project PIs for submission to the TMAC and USAID
- Coordinating the distribution of RFPs, collection of proposals, and the compilation of evaluations from peer reviewers
- Creating program databases for training and resource outputs, and assisting with the posting and maintenance of current documents on the Legume Innovation Lab's website

- Assisting the MO and the TMAC in arranging meetings and global conferences, including travel arrangements, and in the preparation of meeting materials
- Providing support to the director, deputy director, administrative officer, and communications specialist in processing important internal program documents (e.g., travel authorizations and expense reports, legers, financial reports, etc.)

Program Advisory Groups

Technical Management Advisory Committee (TMAC)

The TMAC will continue to serve as the principal advisory group to the Management Office and USAID on technical program performance evaluation matters relative to the Legume Innovation Lab. USAID's Agreement Officer's Representative (AOR) for the Legume Innovation Lab is an active member with voting privileges but without veto authority on the TMAC. The MO was highly pleased with the performance of the TMAC, which was reaffirmed by the EET.

The MO agrees with a TMAC recommendation that its membership be expanded. The proposed composition of the TMAC for FY 2013–2017 will include three elected PIs or co-PIs from Legume Innovation Lab projects, a USAID representative (the AOR), a CRP3.5 representative (appointed by the CRP3.5 director), a second CGIAR scientist with expertise in grain legumes (selected by the MO), a U.S. bean industry representative, and two independent scientists with expertise in legumes and international agriculture development (one of whom should be a nutritionist and the other a soil scientist). The MO is also proposing that Dr. Douglas Maxwell continue as chair of the TMAC for one additional year (FY 2013) to provide continuity and facilitate the transition.

As an external expert advisory panel, the TMAC also provides guidance to subcontracted project teams, both continuing and new, in developing Project Technical Descriptions that reflect the technical priorities, strategic objectives, research and capacity building output targets, and alignment with FTF and CRP3.5 as outlined in this Legume Innovation Lab Technical Application. To this end, the MO will be inviting the TMAC to send a member to project team planning meetings and to review and provide feedback on all project Technical Descriptions, workplans, and budgets. By doing this, the TMAC will be providing a valued support role to the MO in ensuring that subcontracted projects are well conceived, with technical focus and direction aligned with FTF and program SOs, and appropriate team composition, collaboration, and communication.

Implementation of Subcontracting of Projects

As with the original award for FY 2007–2012, the Management Office will retain a streamlined management approach to establish and administer a portfolio of “high quality, innovative, and integrated research, training, and outreach projects on grain legumes that speak to the needs of the stakeholders, policy makers, and development professionals.”

The Legume Innovation Lab for FY 2013–2017 includes two categories of projects to be subcontracted: (1) three new projects to be openly competed and awarded, and (2) eight Phase II or III projects to be extended with significant technical refocusing. The following describes the processes to be followed for subcontracting and implementing these two groups of projects.

Establishment of New Projects (SO1.A1; SO3.1; and SO3.2)

The MO will issue a Request for Proposals (RFP), to be distributed widely to U.S. universities utilizing various networks (APLU, CRSPs, etc.) as soon as USAID finalizes the contract for the Legume Innovation Lab with MSU. The RFP will identify the technical domains, justifications, and the general research objectives and methods/approaches for the three new projects (SO1.A1; SO3.1; and SO3.2) to be funded through the Legume Innovation Lab. A DRAFT RFP is attached in Appendix III.

Upon receipt of proposals, the MO will send them out for peer review to selected scientists at U.S. universities and USDA with expertise related to the proposal's technical area and without conflicts of interest. Based upon the reviewers' recommendations regarding funding through the Legume Innovation Lab and in consultation with the TMAC and the AOR, the MO will select proposals and institutions to award 2 to 2.5 year contracts (FY2013-2015) with an opportunity for a two-year extension (FY2016 and 2017) based upon performance and availability of funding. If none of the proposals are acceptable as submitted, the MO will either negotiate with the highest evaluated proposal to incorporate recommended changes to the satisfaction of the TMAC and MO or will again issue an RFP.

Once a quality proposal has been selected, the MO will establish a subcontract with a lead U.S. university with adequate funding to convene a meeting between the project team of U.S. and HC PIs. The objectives of this team planning meeting are to prepare (1) a multiyear Technical Project Description and Budget for the proposed research, extension, and capacity building activities, and (2) a FY 2013–2014 Workplan and Budget. Experience has shown that a team meeting at the start of a new project is extremely valuable in creating a team dynamic, providing opportunity for the sharing of diverse multidisciplinary perspectives regarding the research problem and project objectives, enabling the team to come to consensus on effective research and training approaches with assignment of appropriate division of responsibilities and coordination of activities. A member of the Management Office and/or of the TMAC will attend each of these meetings to ensure that the Technical Project Description, workplans, and budgets adhere to the technical priorities and framework approved by USAID for the Legume Innovation Lab.

Upon receipt of the Technical Project Descriptions, FY 2013–14 workplans and budgets for the new projects from the lead U.S. PIs, these docs will be reviewed by the TMAC. Once Technical Projects Description, acceptable to the TMAC, are in place, MSU as the Management Entity will award cost-reimbursable subcontracts for the 2.5 year projects to the respective lead U.S. universities. The lead U.S. universities will be responsible for establishing fixed-price sub-subcontracts with all HC institutions partnering and receiving funding through the project.

Subcontracting of Continuing Projects (SO1.A2; SO1.A3; SO1.A4; SO1.A5; SO1.A6; SO1.B1; SO2.1; SO2.2; and SO4.1)

The lead PIs of seven continuing projects will also be required to convene team planning meetings at the onset of the Legume Innovation Lab 4.5-year extension for many of the same reasons as new projects. It is important to recognize that all the continuing projects reflect refocusing of technical objectives, many involve new HC and U.S. collaborating scientists and partner institutions, and all

involve a redirection of technical efforts toward priority FTF cropping systems, countries, or regions. The MO and TMAC will provide guidance to each project's lead PI(s) based upon a review of the prospectuses in advance of the project team meetings. At these meetings, the project teams will be asked to prepare detailed Technical Project Descriptions, FY13–14 workplans, and budgets. Technical Project Descriptions and workplans will be reviewed by the TMAC and MO before subcontracts for project extensions are awarded by MSU to the lead U.S. universities. The expectation is that all this can be completed within the first three to four months after USAID finalizes its contract with MSU for a program extension.

ME Guidelines for Subcontracted Projects

The 2012 *Operations and Policy Manual (of the Dry Grain Pulses CRSP)* will continue to be the basis for administrative decisions by the Management Entity and for subcontractual arrangements with participant institutions. (http://www.pulsecrsp.msu.edu/pulsecrsp/policies_and_forms)

Proposed changes in the policy for subcontracted projects in the five-year extension of the Legume Innovation Lab include:

- Allow budgets for subcontracted projects to financially support up to three months per year of salary for PIs. (Justification: Many university faculty are on nine-month academic year appointments.)
- Require subcontracted U.S. universities to provide a 15 percent match (contributions-in-kind) for direct funds received for U.S. research activities (training expenses at U.S. universities exempt). (Consideration will be given to reducing the match requirement for U.S. universities that experience financial constraints and can provide a compelling justification for a waiver.)
- Discontinue requirement for lead U.S. universities to provide a 15 percent match for direct project funds awarded in support of research activities of USDA/ARS scientists with adjunct appointments. (Justification: USDA/ARS scientists are unable to match federal funds with federal funds, placing undue hardship on the subcontracted lead U.S. university.)
- Require subcontractors of Legume Innovation Lab projects to establish annual FTF *Performance Indicator Targets* as defined by USAID when preparing annual workplans and to arrange for the collection of appropriate data during the course of each fiscal year for reporting on achievement of *Actual Performance Indicators*. (Justification: Setting and reporting of project *Performance Indicators* are the responsibility of subcontractors and must be based on demonstrable quantitative data collected in the field.) Projects will also be required to establish semiannual milestones and report on completion.

Technical and Administrative Performance Monitoring and Advisement

The Legume Innovation Lab will continue to implement a two-phase contractual relationship for all projects subcontracted to lead U.S. universities. Initial subcontracts will be for a 2.5-year period (up to September 29, 2015) with some opportunity for two-year extensions (FY16 and FY17), based on a positive technical performance assessment by the TMAC, continued relevance to USAID FTF agriculture research and development priorities, and the availability of funds.

A two-phase program is supported by the EET Report (p. 56) since it allows for midterm assessment of project performance (as evidenced by achievement of technical output goals), of future research objectives, and of potential need for changes in research approaches or collaborators. It also provides a decision point for the Management Office in consultation with USAID and the TMAC to determine how best to make investments to successfully achieve program Strategic Objectives.

The MO will continue to assume primary responsibility for monitoring projects to ensure successful implementation in accord with annual workplans and budgets. Monitoring, however, is best achieved through regular, helpful, and constructive communication with both U.S. and HC PIs to encourage functional team dynamics and a sense of scientific community within the Legume Innovation Lab. Communication within a scientific community contributes to improved networking, multidisciplinary collaboration, coordination of research and training activities, potential for shared learning and synergies between projects, accountability, and a sense of PI ownership of the success and impact of the Legume Innovation Lab.

Performance and Monitoring Plan

Under FTF, USAID has invested in developing new tools for program performance monitoring as well as a results framework with indicators to assess progress toward the FTF global objectives of (1) improved agriculture productivity, (2) increased resilience of vulnerable communities and households, (3) improved access to diverse and quality foods, and (4) improved nutritional status of women and children. FTF Performance Indicators were initially identified under the Pulse CRSP in consultation with USAID and can be seen in Appendix IV with the FY2012 reported results and the estimates of Targets for FY2013 through FY2015. In FY2012, as the FTF Monitoring System (FTFMS) was developed, not all indicators were collected at the level of disaggregation currently required. In the FY2013–FY2017 work and monitoring plans, all subcontracted projects will report their identified indicators with gender and other disaggregation, as needed. These indicators are consistent with the FTF results framework and will enable the program to demonstrate contributions toward FTF goals.

Given the differences between subawards to be established, a final PMP will be developed with Project PIs, including performance indicators for each, timing and systems for data collection, and frequency of reporting. Semiannual milestones will be established by each subaward as well as performance indicators, responding to FTF requirements for performance monitoring and reporting. Working with the subawards, the MO will assist PIs in identifying challenges for performance reporting and will document data limitations as well as steps to address those limitations. The Semiannual Technical Progress Reports based on established Milestones and Performance Indicators, submitted every six months by sub-subcontracted HC institutions to lead U.S. PIs, as required by Fixed Price contracts, are a critical component in the PMP. The MO is responsible for guiding the process of performance monitoring, ensuring the quality of the data collected, and for aggregating these results in reporting to USAID within the FTFMS on a semi-annual and annual basis.

In addition to the performance monitoring described above, with the review of annual technical progress reports and Performance Indicator Data, the MO will complement the monitoring function through site visits to participant U.S. and HC institutions, interactions with PIs on workplan preparation, follow-up of TMAC recommendations with PIs, and interactions at various meetings that bring Legume Innovation Lab scientists together. With the contributions of the PIs and the TMAC, the MO will be able to provide an effective mechanism to monitor progress in research, training, and outreach.

Impact Assessment and Advisement of the MO

Dr. Maredia will continue to provide leadership to impact assessment for the entire Legume Innovation Lab program. As a staff member in the Management Office, which was advocated by the EET (p. 59 of report), she will serve as an advisor to the Legume Innovation Lab directors on performance monitoring and evaluation, the integration of impact pathway planning into subcontracted projects, the inclusion of baseline and performance indicator data collection into project design, and ex ante and ex post impact assessment of Legume Innovation Lab investments in research, institutional capacity building, and technology dissemination. Because of Dr. Maredia's prominent role in impact assessment within the CGIAR system, the insights gained regarding innovative research strategies and investments with high potential for impact and of lessons learned regarding successes in product lines will enable the MO to make more informed, science-based decisions. Impact assessment is addressed in more detail under project SO4.

One of the key decisions for the Legume Innovation Lab is the collecting of baseline data. Baseline data is considered essential for documenting current conditions and quantifying the adoption of future outputs from CRSP research (technologies, practices) and their subsequent contribution to development outcomes in specific countries. The MO plans to identify, in consultation with Dr. Mywish Maredia, specific projects in which the collection of baseline data would be a justified expenditure. Criteria that might be used to determine such justification include the availability of data sets, potential for CRSP research outputs to achieve widespread impact within the near term, a compelling need to understand current socioeconomic, political, and agroecological situations for priority setting, research design, and/or the formulation of impact pathway plans. If baseline data collection is deemed important for certain projects, as was recommended by the EET (p. 58), the MO will request that such instruments and mechanisms be developed and data collection be integrated into the workplans and budgets for the respective projects.

Strategy for Communications and Promotion

The impact of Legume Innovation Lab investments in research and capacity building depend in part on their visibility among stakeholders (especially [USAID](#) and its many Missions), strategic partners ([CIAT](#), [IITA](#), [ICRISAT](#) and other Centers in the [CGIAR](#)), PIs and other collaborators in the United States and elsewhere, host country educators and policy makers, private sector partners, and other agriculturalists across the globe. It is critical that information on research advances reaches the people who can most utilize them. Furthermore, increasing access to grain legume research findings and outputs will particularly benefit collaborating host country institutions by enhancing the visibility of their work among the international legume research community as well as domestic public and private organizations serving smallholder farmer populations in the host country.

The MO recognizes that each potential Legume Innovation Lab stakeholder will have distinct interests in knowledge and technologies and will probably receive that information through different communications mechanisms. Moreover, these stakeholder groups often require different depths of information from communications. Scientists often prefer thorough technical reports that can be downloaded from the internet and distributed to fellow researchers, while USAID Mission staff may prefer concise and attractive brochures that describe technologies and document impact. Local institutions seek formats that are appropriate for policy makers. NGOs, private sector, and public extension agents may want simple videos that can be adapted for local distribution to demonstrate the use of a technology. Educators value social media to reach students and to network with colleagues.

To ensure that information on the Legume Innovation Lab and its achievements and impact are available to diverse stakeholders, the Management Office has employed a Communications Specialist (Dr. Marguerite Halversen) to provide leadership and innovation for the implementation of the program's communications strategy. This strategy is based on the premise that multiple communications approaches and media are essential to reaching diverse audiences and the wide breadth of program stakeholders. Dr. Donovan, the deputy director, will work closely with the communications specialist to ensure a tight link with the program's technical aspects and to ensure effective information sharing with strategic partners, especially USAID Washington and HC Missions.

The MO proposes to develop several new outreach products and to enhance others currently being utilized:

- Enhance the Legume Innovation Lab website by including videos and other materials
- Publish annual *Technical Highlights Reports* on progress within each project
- Develop quarterly electronic newsletters for wide distribution to partners and stakeholders
- Publish a series of short research briefs and success stories, including the *Impact Briefs* series already initiated
- Establish an electronic photo and video library
- Facilitate participation in selected social media, such as facebook, Twitter, and LinkedIn, to encourage dialogue and the exchange of research articles and updates
- Provide access to informational videos produced by PIs (e.g., animated videos developed by PI at University of Illinois)
- Forward data, recent news, communications products, and information on development impacts of the Legume Innovation Lab to Cultural Practice LLC to support coordinated efforts across the Innovation Labs on Collaborative Research
- Encourage translation of critical information into appropriate languages for greater impact
- Contribute to USAID reporting and news media to enhance the profile and visibility of the Legume Innovation Lab

Mission Engagement by the MO

As indicated earlier in this technical proposal, the Legume Innovation Lab proposes multiple strategies to more effectively engage USAID Missions, especially in FTF focus countries. Within the MO, Deputy Director Dr. Cynthia Donovan will have primary responsibility for implementation of these strategies. She will coordinate communications with key USAID Mission staff and BFS staff. Dr. Donovan will also inform principal investigators of Mission development priorities and programs and interact with Missions to explore ways in which the Legume Innovation Lab might support their FTF in-country strategies. Periodic visits by both the deputy director and the director to USAID Missions will be vital to cultivating good relationships with Mission staff.

Dr. Donovan's extensive professional field experience in numerous African and Latin American countries through Mission-funded projects with the MSU Food Security Program make her well suited for this role. For the past three years, she lived in Mozambique and managed an FSP project in partnership with the USAID Mission in that country. Her familiarity with the use of Associate Awards will enable her to work with Missions to identify good candidates for such awards and to help shepherd them through design and implementation. The MO is committed to working with USAID's Office of Agriculture Research and Policy to implement strategies that enable USAID Washington's investments in grain legume research and capacity building to better support field USAID Mission FTF programming.

Strategy for Strengthening Global Partnerships and Global Meetings

Participation by Legume Innovation Lab scientists in international meetings on grain legumes affords opportunities for the sharing of research outputs with other international grain legume research and development programs. The Global Pulse Researchers Meetings convened by the Pulse CRSP in Barcelona, Spain; Quito, Ecuador; and Kigali, Rwanda, were highly successful at bringing together Pulse CRSP HC and U.S. scientists and graduate students along with grain legume scientists representing IARCs, NGOs, and international grain legume research and development programs and foundations. The MO believes that these global meetings have contributed to greater dialog on edible grain legumes and needed research to address global challenges facing smallholder legume farmers in developing countries, and to fostering a spirit of enhanced collaboration.

To this end, the Legume Innovation Lab proposes the following activities over the coming 4.5 years:

- a. Three global grain legume research meetings organized by the Legume Innovation Lab
- b. Co-Sponsorship of one or two international meetings with the CGIAR and/or potentially other Innovation Labs
- c. Support for Legume Innovation Lab PI and graduate student participation in annual national and regional grain legume research meetings

Global Grain Legume Research Meetings

Three global meetings of the Legume Innovation Lab are envisioned for 2013–14, 2015, and 2017, with each to be held in geographically different venues and with distinct objectives and mixes of participants. Underpinning the selection of venues will always be cost and accessibility in terms of air travel and the ability of international participants to obtain visas for the host country. It would be highly desirable, nonetheless, to convene at least two of the meetings in two of the FTF and Legume Innovation Lab focus regions (e.g., West Africa, Eastern and Southern Africa, or Central America). This would encourage greater participation by scientists and technical staff from NARS and universities as well as from NGOs and USAID staff and development partners in these regions.

A priority objective of the 2013–14 global Legume Innovation Lab meeting will be team building, focusing on common program goals (SOs), and the coordination of project research, training, and outreach activities to position the program for success and impact. Since the 2013–2017 Legume Innovation Lab will have redefined Strategic Objectives and a new mix of scientists and partner institutions (even though many projects are continuing), it is imperative that this new cohort of participant U.S. and HC scientists share a common vision and understanding of Legume Innovation Lab program objectives and USAID expectations under FTF. Because coordination of activities with CRP3.5 is important at the early implementation stage, grain legume scientists from CIAT, IITA, ICRISAT, and ICARDA will be invited to the 2013/14 global meeting.

At the 2015–16 and 2017 Global Legume Innovation Lab Research Meetings, a much greater emphasis will be placed on sharing research findings and technical achievements, networking with other international grain legume programs and development partners, and informing USAID country and regional Missions of technologies, management practices, and information that could contribute to agriculture sector development efforts in FTF focus countries.

International Legume Conferences

The Legume Innovation Lab will also be pursuing conversations with the CRP3.5 leadership about cohosting an international grain legume researchers meeting in Sub-Saharan Africa, perhaps in 2015 or 2016. CIAT has already expressed interest in assisting with the planning of such a meeting, but support from the other IARCs (IITA, ICRISAT, ICARDA) would be essential for success. It would be desirable to identify a particular theme for the conference and to establish specific objectives so that the meeting results in clear outputs of benefit to USAID and other donors supporting international grain legume research.

National and Regional Legume Meetings

The Legume Innovation Lab remains committed to supporting PI participation in national and regional grain legume research meetings as it fosters networking, expanded collaboration, and scientific exchange. This is especially important for young HC grain legume scientists who are forming their professional identity and need access to expertise and analytical capacity from other scientists and institutions. Lead PIs will, therefore, be encouraged to include financial support in subcontracted project budgets for participation of PIs, graduate student trainees, and collaborators in the following meetings:

- Regional meetings of PABRA, ECOBREN, and SABREN

- Annual meetings of the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos y Animales (PCCMCA), Mesa de Frijol
- U.S. annual meetings of the Bean Improvement Cooperative (BIC) and the Crop Science Society of America (CSSA)

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