# Feed the Future Innovation Lab for Collaborative Research on Grain Legumes

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Legume Innovation Lab

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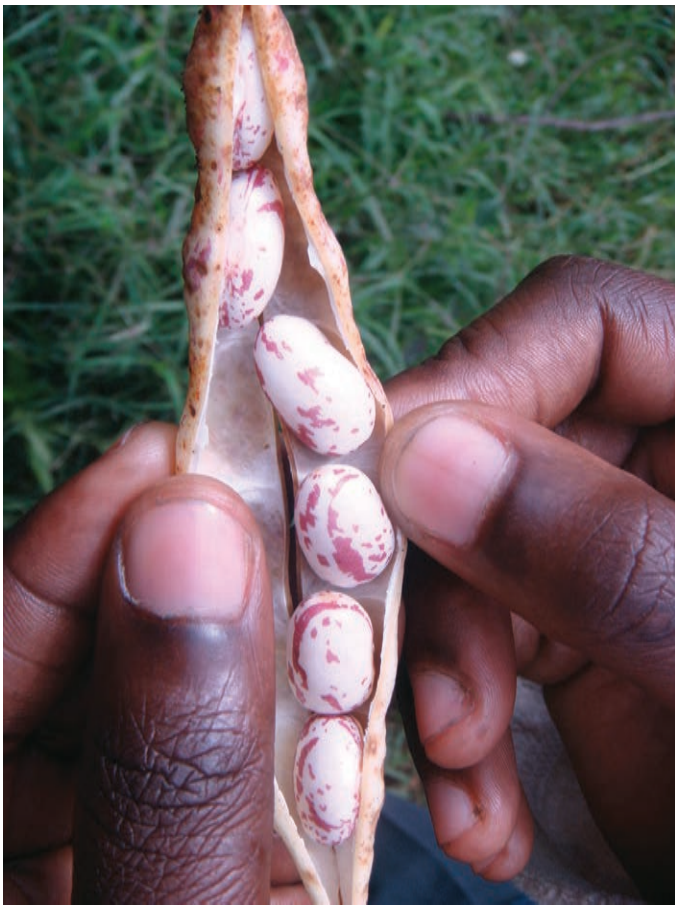
Cover art: A cowpea field

## WHAT ARE INNOVATION LABS?

Innovation Labs are programs contracted to U.S. universities by the Office of Agriculture, Research and Policy, Bureau for Food Security, USAID–Washington, under the Presidential Initiative *Feed the Future*. These programs support long-term, innovative collaborative research and capacity building projects aimed at transforming agricultural production systems and enhancing the food and nutritional security of the rural poor in developing countries.

"Collaborative Research" Innovation Labs partner scientists from U.S. universities and developing country national agricultural research systems/ universities to address major constraints and opportunities facing agriculture and natural resource sectors and systems in USAID priority countries in sub-Saharan Africa, Asia, and Latin America. New knowledge, technologies, and practices resulting from cutting-edge research are adapted, validated, and applied by partners to achieve development outcomes, including improved policies, increased productivity and profitability for smallholder farms, and improved nutrition and livelihoods for resource-poor rural families. Concurrently, Innovation Labs empower developing country institutions, contributing to the expansion of local human resource and research capacities in strategic areas of agricultural science, agribusiness, nutrition, and natural resources.

Common bean



## GRAIN LEGUMES AND WHY THEY ARE IMPORTANT

Grain legumes represent a diverse group of edible leguminous crop species, including common bean, cowpea, lima beans, pigeon pea, chick peas, lablab, and lentils. Grain legumes are nutrient-dense, affordable staple foods that contribute to household food and nutritional security. Additionally, grain legumes are produced as cash crops by smallholder, resource-poor farmers, especially women, in many countries in Africa, Latin America, and Asia.

As traditional staple foods, grain legumes constitute an important source of affordable protein, complex carbohydrates, essential micronutrients, dietary fiber, vitamin B, and anti-oxidants in the nutritionally challenged diets of both the rural and urban poor. Recent research suggests that grain legumes also promote gut health and function critical for strong immune systems and the growth of young children. Moreover, grain legume crops are valued by farmers for their contributions to the sustainability of cropping systems through biological nitrogen fixation and improvements in soil fertility.

## THE LEGUME INNOVATION LAB

The Feed the Future Innovation Lab for Collaborative Research on Grain Legumes (Legume Innovation Lab) 2013–2017, an extension of the Dry Grain Pulses Collaborative Research Support Program (Pulse CRSP), is an integrated research and capacity building program focusing on edible grain legumes administered by Michigan State University (MSU).

An African farmer near her bean field

This program supports a diverse portfolio of competitively bid, multidisciplinary projects involving U.S. universities and host country agriculture research institutions that generate research outputs to increase grain legume productivity and enhance access to nutrient-dense grain legumes for improved food security, nutrition, soil health, economic welfare, and livelihoods of the rural poor, especially women, in developing countries in Africa and Latin America.

A Technical Management Advisory Committee (TMAC) comprised of external, internationally recognized scientists advises the MSU Management Office and USAID on technical and administrative matters, including project monitoring and evaluation, strategic planning, and operational guidelines.

## PROGRAM FOCUS AND STRATEGIC OBJECTIVES

The Legume Innovation Lab seeks to achieve four Strategic Objectives (SOs).

*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.

> *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, 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.
>
> *SO1.B*. To sustainably reduce the yield gap for selected grain legume crops 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 effective management of legume value chains by stakeholders, including smallholder farmers and consumers.

Amadeus 77 bred by EAP-Zamorano

*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.

*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.

## PROJECTS

A portfolio of nine four-year projects, led by U.S. universities in partnership with developing country institutions, are supported to achieve the four strategic objectives.

### Strategic Objective 1 (S01): Advancing the Productivity Frontier for Grain Legumes

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

**Lead PI**: Juan M. Osorno, North Dakota State University

**Co-PIs**: Phil McClean, North Dakota State University; Julio C. Villatoro, Fernando Aldana, Karla Ponciano, Julio Martinez, and Edgardo Carrillo, Instituto de Ciencia y Tecnología Agrícola (ICTA), Guatemala

The highlands of Guatemala are a unique bean producing region where intercropping (*milpa*) is still the main production system, mostly with maize–bean association. The system involves planting climbing beans that grow and develop concurrently with maize or planting in relay.

On-farm productivity of climbing bean landraces is approximately one-third of their genetic yield potential, mostly due to the lack of improved cultivars that are able to withstand biotic and abiotic stresses. This low productivity adversely affects food and nutritional security of households of largely indigenous Mayan families in the region, especially 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. In addition, the Guatemalan Middle-American 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.

A Guatemalan woman in the *milpa* system among her intercropped beans and maize

This new Legume Innovation Lab project will focus on developing genetically improved varieties of climbing beans that can enhance the productivity of the highland *milpa* system. The main objectives are:

1. to breed varieties with improved disease resistance and agronomic performance,
2. to characterize the genetic diversity of this unique set of germplasm,
3. to improve understanding of constraints to increasing climbing bean productivity in an intercropped system, and
4. to train the next generation of plant breeders for Guatemala.

## 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 PI**: James Kelly, Michigan State University

**Co-PIs**: Karen Cichy, USDA-ARS, Wayne Loescher, Michigan State University, James Steadman and Carlos Urrea, University of Nebraska; Stanley Nkalubo, National Crop Resources Research Institute (NaCCRI), Uganda; Kennedy Muimui, Zambia Agriculture Research Institute (ZARI), Zambia; Eduardo Peralta, Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP), Ecuador

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 because of their high potential for adaptation 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.

Nitrogren-fixing nodules on bean roots

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 needed.

The development of improved bean varieties and germplasm with high yield potential, healthy root systems, improved biological nitrogen fixation (BNF) with resistance to multiple diseases, and sustained or improved water use efficiency under limited soil water conditions are needed to increase profit margins and lower production costs. The project will use QTL (Quantitative Trait Loci) analysis and SNP (Single Nucleotide Polymorphism)-based genome-wide association mapping to uncover regions associated with drought tolerance, disease resistance, enhanced BNF, and shorter cooking time.

Middle-American climbing beans

Cowpea grain

### 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 PI**: James Beaver, University of Puerto Rico

**Co-PIs**: Consuelo Estevez de Jensen, University of Puerto Rico; Timothy Porch, USDA/ARS/TRAS; Juan Osorno and Phil McClean, North Dakota State University (NDSU); 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

This project will develop, release, and disseminate improved common bean cultivars with enhanced disease and/or pest resistance and greater tolerance to abiotic stresses for the lowland tropics in Central America and Haiti.

Drought and heat tolerant tepary bean lines (*Phaseolus acutifolius*) will be bred for improved seed and agronomic traits and greater disease resistance. Bruchid resistance genes (arcelin 2 and null phaseolin) resulting from an interspecific cross will be introgressed into black, small red and white beans with resistances to BCMV, BCMNV, and BGYM for Central America and the Caribbean regions. In Guatemala, breeding efforts will focus on increasing resistance to common bacterial blight and web blight in humid tropical lowland regions, such as the Petén. The next generation of breeder-friendly molecular markers linked with pathogen-resistant genes will be developed. These markers will improve the efficiency and effectiveness of selection for traits of economic importance.

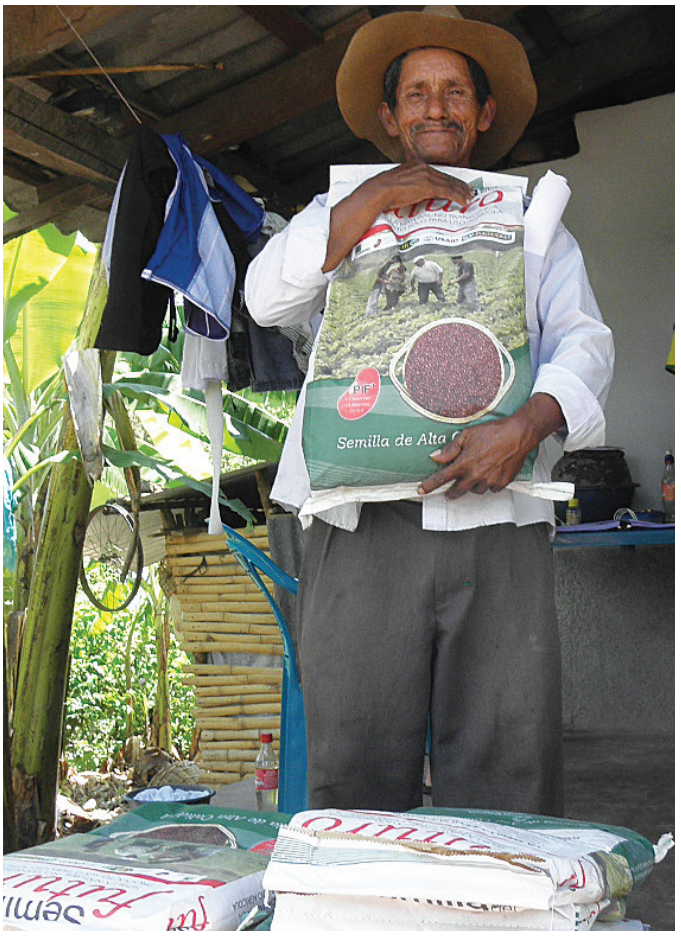
Graduate and undergraduate training will be supported by the project to address the need to strengthen bean research programs in the target countries. In-service training and workshops will be sponsored to improve the quality and reliability of field research and to permit target country breeding programs to take advantage of molecular tools to increase the efficiency of the selection of economically important traits.

### Genetic Improvement of Cowpea to Overcome Drought and Biotic Constraints to Grain Productivity (S01.A5)

**Lead PI**: Philip Roberts, University of California, Riverside

**Co-PIs**: Timothy Close, University of California, Riverside; Issa Drabo and Jean-Baptiste Tignegre, Institut de l'Environnement et de Recherches Agricoles (INERA), Burkina Faso; Ibrahim Atokple and Francis Kusi, Savanna Agricultural Research Institute (SARI), Ghana; Ndiaga Cisse, Centre National Recherches Agronomie, Bambey, Institut Senegalais de Recherches Agricole (ISRA), Senegal

A Central American farmer holding a bag of Quality-Declared Seed of a CRSP-developed improved variety



Women from Niger watching an educational animation on a cell phone to learn about the control of bruchids in cowpea grain

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 10–20 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 will focus on cowpea breeding with an 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 will be 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. Advanced breeding lines will be 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 investments. 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.

## IPM-omics: Scalable and Sustainable Biological Solutions for Pest Management of Insect Pests of Cowpea in Africa (SO1.B1)

**Lead PI**: Barry Pittendrigh, University of Illinois at Urbana–Champaign

**Co-PIs**: Manuele Tamò, International Institute for Tropical Agriculture (IITA), Benin; Clémentine Dabiré-Binso, l'Institut de l'Environnement et de Recherches Agricoles (INERA), Burkina Faso; Ibrahim Baoua, L'Institut National de la Recherche Agronomique du Niger (INRAN), Niger; Stephen Asante, Savannah Agriculture Research Institute (SARI), Ghana; Haruna Braimah, Crops Research Institute, Ghana; Leonard Hinnou, Institut National des Recherches Agricoles du Benin (INRAB), Benin; Julia Bello-Bravo, University of Illinois at Urbana–Champaign

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 manage these pest populations. The logical strategy is *Integrated Pest Management* (*IPM*), involving a pipeline of diverse biological control situations. This project focuses 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 (Geographic Information Systems) to help direct the most effective deployment of these approaches, as well as testing and deploying cutting-edge ICT (Information and Communications Technology) tools as part of the scaling of these solutions.

IPM-omics involves defining the pest problems, bringing forward appropriate solutions through a biocontrol/biopesticide pipeline, and scaling of solutions through multipronged strategies that will include farmer field flora, ICT approaches, women's cooperatives, and partnerships with small-scale industries. The project will continue to develop online interfaces that make solution options easily available to other groups that can benefit from the materials. The project will also develop, deploy, and test training/technology packages/programs that will be passed off to groups (e.g., NGOs and national/international agencies).

## Strategic Objective 2 (SO2): Transforming Grain Legume Systems and Value Chains

### Farmer Decision-Making Strategies for Improved Soil Fertility Management in Maize–Bean Production Systems (SO2.1)

**Lead PI**: Robert E. Mazur, Iowa State University

**Co-PIs**: Eric Abbott, Andrew Lenssen, and Ebby Luvaga, Iowa State University; Russell Yost, University of Hawaii at Manoa; Julia Bello-Bravo and Barry R. Pittendrigh, University of Illinois at Urbana–Champaign; Moses Tenywa, Makerere University, Uganda; Onesimus Semalulu, National Agricultural Research Laboratories (NARL), Uganda; Ricardo Maria, Instituto de Investigação Agrária de Moçambique (IIAM)

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

To contribute to widespread and sustainable improvements in bean productivity and soil fertility, the research objectives are to:

1. characterize smallholder farmers' agricultural motivations, current knowledge, and practices; problem diagnoses; and livelihood and risk management strategies;
2. develop and refine models about their decision making;
3. develop and validate appropriate diagnostic and decision support aids; and
4. develop and assess the effectiveness of innovative approaches for disseminating information and decision support aids, training, and follow-up technical support.

Working with smallholder farmers in rainfed maize–bean cropping systems in the Masaka district in Uganda, and the Gurué district in Mozambique, at 1000–1200m altitude with annual rainfall 1000–1500mm, the approach and methods involve:

1. participatory rural appraisal and baseline surveys for activity planning; taking into account critical social, economic, and cultural factors that impact decision making and adoption of new strategies and technologies; and monitoring changes over time;
2. farmer innovator and scientific analyses of soil-related constraints;
3. participatory on-farm studies using identified possible solutions;

A bean trader in a local market in Southern Africa

4. participatory, gender equitable development and validation of diagnostic and decision support aids; and
5. development and pilot-testing of innovative sociotechnical approaches for communication, dissemination, and scaling up.

### Enhancing Pulse Value-Chain Performance through Improved Understanding of Consumer Behavior and Decision Making (SO2.2)

**Lead PI**: Vincent Amanor-Boadu, Kansas State University
**Co-PIs**: Gelson Tembo, University of Zambia; Lawrence Mapemba, Lilongwe University of Agriculture and Natural Resources; Fredy Kilima, Sokoine University of Agriculture; Allen Featherstone and Kara Ross, Kansas State University

Despite knowledge about their high nutritional benefits and profile, grain legumes are not prominent on the food hierarchy in Malawi, Tanzania, and Zambia. The challenge confronting grain legume producers and their supply chains is how to enhance their competitiveness in their local markets and gain the necessary policy support from their government to sustain it. This project seeks to make two critical contributions to this challenge. First, it will seek to develop a clearer appreciation of the factors influencing grain legume consumption in these three countries to provide empirical direction for market and policy development. Second, it will also seek 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.

The project has three integrated dimensions: an empirical foundation for understanding factors and their influence on food choices; application of the empirical results in crafting policies and facilitating knowledge and skill development in managing value chains; and 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


A Ugandan farmer examines his bean crop

the well-being of smallholder producers. This project, therefore, provides innovative and unique pathways that bring smallholder producers and public and private stakeholders together to help achieve the underlying objectives of the Feed the Future initiative.

## Strategic Objective 3 (SO3): Enhancing Nutrition

### Legumes and Growth (SO3.1)

**Lead PI**: Mark Manary, Washington University School of Medicine in St. Louis
**Co-PIs**: Ken Maleta and Chrissie Thakwalakwa, University of Malawi College of Medicine; Indi Trehan, Washington University School of Medicine in St. Louis

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 when complementary foods are introduced, places them at high risk for stunting, malabsorption, and poor oral vaccine efficacy. Here we propose 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.

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 12 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.

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 the national agricultural university. By amalamgating the power of the clinical trial and advanced biological analyses, we will elucidate the potential of legumes to significantly impact child health in sub-Saharan Africa.

## Strategic Objective 4 (S04): Improving Outcomes of Research and Capacity Building

### Impact Assessment of Dry Grain Pulses CRSP Investments in Research, Institutional Capacity Building and Technology Dissemination in Africa, Latin America and the U.S. (S04.1)

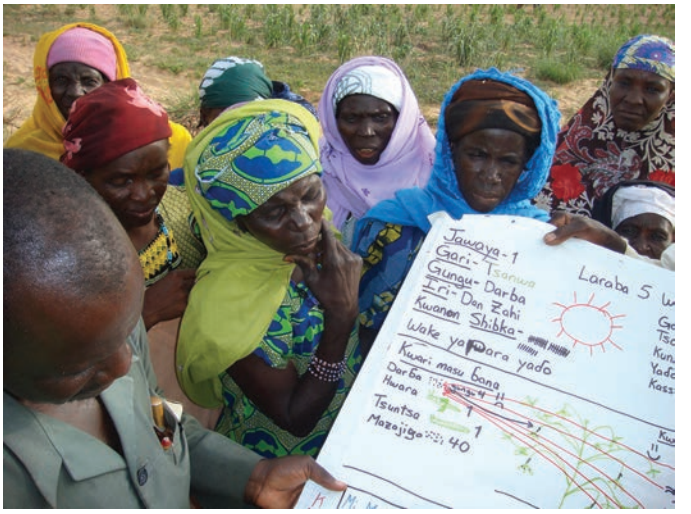
**Lead PI**: Mywish Maredia, Michigan State University

**Co-PIs**: Eric Crawford and Byron Reyes, Michigan State University

Building on the momentum and experience gained over the last three years, this project proposes to contribute to evidence-based, rigorous 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) to 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 into 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 endline 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 U.S. It also proposes to conduct systematic analysis of existing data or to conduct field studies to address strategic research questions on the role of grain legumes in household food security, nutrition, and income.

West African women farmers participating in a Farmer Field School



## INSTITUTIONAL CAPACITY BUILDING

The Legume Innovation Lab strengthens institutions by:

- Providing degree and short-term training to address strategic needs and priorities of host country institutions,
- Facilitating regional and international networking with scientists and public and private sector organizations, and
- Supporting equipment purchases and training to enhance institutional research and outreach capacity.

## FEED THE FUTURE ALIGNMENT

The Legume Innovation Lab contributes to Feed the Future goals as defined in the FTF Global Food Security Research Strategy by:

- Supporting a purpose-driven grain legume research agenda to 1. advance the productivity frontier, 2. transform production systems, and 3. enhance the nutrition of the poor, especially young children;
- Focusing on the needs and roles of women as producers, entrepreneurs, scientists, and consumers of grain legumes;
- Focusing efforts on FTF priority countries and cropping systems in West, Eastern and Southern Africa, and Central America;
- Responding to country-identified challenges facing the grain legume sectors and collaborating with national institutions to find solutions;
- Supporting FTF's whole of government and strategic partnership approach by engaging USDA-ARS scientists and forming a strategic partnership with the CGIAR's Grain Legume program;
- Empowering and strengthening capacity of agriculture research institutions in USAID FTF priority countries; and

Zorro, a CRSP-developed, improved black bean variety released by the MSU Bean Program

- Being accountable for grain legume research performance monitoring and achievement of sustainable and scalable development outcomes and impacts.

The Legume Innovation Lab Management Entity, Michigan State University, and its U.S. and host country institutional partners are committed to supporting USAID regional and country mission FTF strategies. To this end, they are willing to mobilize capacities to disseminate productivity-enhancing technologies and management practices as well as nutrition and market knowledge to potential beneficiaries in strategic FTF countries and regions.

## PARTICIPANT COUNTRIES IN THE LEGUME INNOVATION LAB

**West Africa**: Benin, Burkina Faso, Ghana, Mali, Niger, Senegal

**Eastern and Southern Africa**: Malawi, Mozambique, Tanzania, Uganda, Zambia

**Latin America and the Caribbean**: Ecuador, Guatemala, Haiti, Honduras

## PARTICIPANT U.S. UNIVERSITIES

- Iowa State University
- Kansas State University
- Michigan State University
- North Dakota State University
- Northwestern University, Evanston, Illinois
- University of California, Riverside
- University of Hawaii, Manoa
- University of Illinois, Urbana–Champaign
- University of Nebraska, Lincoln
- University of Puerto Rico
- Washington University School of Medicine in St. Louis

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A technician cleaning Certified Bean Seed for dissemination to smallholder farmers


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