Dry Grain Pulses
Collaborative Research Support Program (CRSP)

2010
Technical Highlights

This publication was made possible through support provided by the Office of Economic Growth, Agriculture and Trade, U.S. Agency for International Development, under the terms of Cooperative Agreement No. EDH-A-00-07-00005-00. The opinions expressed herein are those of the Dry Grain Pulses CRSP and do not necessarily reflect the views of the U.S. Agency for International Development.

For Further Information, Contact:
Dry Grain Pulses CRSP
321 Agriculture Hall
Michigan State University
East Lansing, MI 48824-1039, U.S.A.
Phone: (517) 355-4693
Fax: (517) 432-1073
Email: dgpcrsp@msu.edu
http://pulsecrsp.msu.edu

USAID
FROM THE AMERICAN PEOPLE

Table of Contents

Preface

Preface

Dry Grain Pulses Collaborative Research Support Program (CRSP)

FY 2010 Technical Highlights Report
(October 1, 2009 to September 30, 2010)

The global pulse industry is entering a new era characterized by the globalization of markets and fundamental changes in food value chains, presenting many challenges as well as opportunities for smallholder farmers in developing countries and the United States to access these markets. At the same time, many developing countries around the globe continue to face food and nutritional insecurity and smallholder, grain-legume farmers continue to achieve unacceptably low levels of productivity.

Pulse crops, including such edible grain legumes as common bean, cowpea, pigeon pea, chickpea, lima bean, lablab, etc., represent an important group of staple food crops that contribute to addressing household food security, generating income, enhancing soil quality—and thus the sustainability of agricultural systems, and, perhaps most importantly, providing nutrients (e.g., protein, vitamin B, essential micronutrients, and complex carbohydrates) essential for nutritious and healthy diets for countless rural and urban poor around the world.

In September 2007, the U.S. Agency for International Development (USAID) awarded a five-year (2007–2012) contract (Cooperative Agreement No. EDH-A-00-07-00005-00) to Michigan State University to serve as the Management Entity for the Dry Grain Pulses Collaborative Research Support Program (CRSP).

The global vision of the Dry Grain Pulses CRSP, as outlined in the Technical Application, is to contribute to:

- Economic growth and food and nutritional security through knowledge and technology generation,
- Sustainable growth and competitiveness of pulse value chains, utilizing socially and environmentally compatible approaches,
- Empowerment and strengthened capacity of agriculture research institutions in USAID priority countries,
- USAID's development goals, as defined in the Feed the Future Research Strategy for Global Food Security, and
- Achievement of Title XII legislation objectives, including the provision for dual benefits to developing country and U.S. agriculture.

The Dry Grain Pulses CRSP seeks to achieve its technical vision through support for a portfolio of multidisciplinary collaborative research, outreach, and institutional capacity building activities that focus on beans, cowpeas, and related pulses in accord with the following four strategic "Global Themes":

- To reduce pulse production costs and risks for enhanced profitability and competitiveness,
- To increase the utilization of pulse grain food products and ingredients so as to expand market opportunities and improve community health and nutrition,
- To improve the performance and sustainability of pulse value chains, especially for the benefit of women, and
- To increase the capacity, effectiveness, and sustainability of agriculture research institutions that serve bean, cowpea, and related pulse sectors and developing country agricultural industries.

For the initial five-year authorization of the Dry Grain Pulses CRSP, a two-phase technical program is being implemented with two project award cycles: Phase I (April 1, 2008 – September 30, 2010) and Phase II (October 1, 2010 – September 29, 2012). To this end, the Management Office (MO) issued a Request for Proposals (RFP) in November 2007. Among the proposals that were received and reviewed by an External Advisory Panel, eight projects were selected that best met the priority criteria established in the Technical Application of the Dry Grain Pulses CRSP and provided the highest likelihood of achieving developmental outcomes that benefited pulse value chains in developing countries and the United States. The MO subsequently issued subcontracts to seven "Lead" U.S. universities for the implementation of these Phase I collaborative projects.

In 2009, following an increase in USAID's authorization to the Dry Grain Pulses CRSP, a second RFP was announced and four new projects were selected following a competitive, peer-review process. These four new projects, named "Phase III" projects, address strategic technical gaps in the Pulse CRSP research program, including biological nitrogen fixation, nutrition, and value chain research. These awards were subcontracted mid-fiscal-year 2010. The Phase III projects, therefore, are unable to give evidence of significant technical progress in this 2010 Technical Highlights Report.

The eight Phase I and five Phase III projects presented in the FY 2010 Technical Highlights Report involve collaborative research, long- and short-term training, and technology dissemination activities in 13 sub-Saharan African countries (Burkina Faso, Mali, Niger, Nigeria, Senegal, Kenya, Rwanda, Uganda, Tanzania, Mozambique, South Africa, Zambia, and Angola) and three Latin American countries (Haiti, Honduras, and Ecuador). Of this group, nine countries have the distinction of being designated as USAID Feed the Future focus countries. More than 25 host country institutions, including National Agriculture Research Institutions, agriculture universities, and NGOs are collaborating with the lead U.S. universities in the Phase I and III projects of the Dry Grain Pulses CRSP.

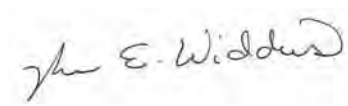
The objective of this report is to highlight the technical progress and achievements made by the Phase I and III projects in the Dry Grain Pulses CRSP. We hope that readers will be able to appreciate the importance and potential of the research and capacity-building investments to benefit smallholder pulse farmers and to improve the nutrition of the poor in developing countries. Readers should be aware that the FY 2010 Highlights Report of the Phase I and III projects is only a one-year snapshot. Moreover, these highlights are condensed versions of more comprehensive technical reports that subcontracted U.S. universities are required to report annually to the Management Entity and ultimately to USAID. These technical progress reports are valued and utilized for assessing Pulse CRSP program performance and reporting by USAID on Title XII and Feed the Future achievements and impacts to the United States Congress.

For those who will take the time to read the *2010 Technical Highlights Report*, I want to encourage you to focus on identifying the vitally important outputs generated by each of the Phase I and III projects, and the new knowledge, management practices, and technologies resulting from the research activities. It is these outputs that will benefit stakeholders of pulse value chains, extending from producers in Africa and Latin America to the United States.

For more detailed information on the Dry Grain Pulses CRSP, including the global program technical vision, project workplans, technical progress reports, project funding, brief bio-sketches of principal investigators, and links to websites with valuable information regarding pulse commodities, visit the program's web page at www.pulsecrsp.msu.edu.

As the director of the Dry Grain Pulses CRSP, I want to thank the Office of Agriculture Research and Technology, Bureau of Food Security, USAID-Washington for its financial support for this worthy program. USAID's investment in the Pulse CRSP reflects its recognition of the vital importance of pulse crops in contributing to the nutritional and food security of the rural and urban poor as well as to providing opportunities for resource-poor farmers and other value chain stakeholders to generate income and escape poverty. The host country and U.S. scientists and institutions partnering in this endeavor are also to be thanked and commended for their commitment to scientific excellence, to generating new knowledge and technologies that bring the hope of a better tomorrow, and to training a new generation of scientists and professionals who will provide leadership to the agricultural development of many African and Latin American countries.

Dr. Irvin E. Widders



Director
Dry Grain Pulses CRSP
Michigan State University

Using Improved Pulse Crop Productivity to Reinvigorate Smallholder Mixed Farming Systems in Western Kenya

PI-CU-1

Principle Investigators

Julie Lauren (Lead PI), Cornell University, USA

John Ojiem, Kenya Agricultural Research Institute (KARI), Kenya

Collaborating Scientists

James Muthomi, University of Nairobi, Kenya

John Nderitu, University of Nairobi, Kenya

John Okalebo, Moi University, Kenya

Martins Odendo, Kenya Agricultural Research Institute (KARI), Kenya

Samuel Mwonga, Egerton University, Kenya

Beth Medvecky, Cornell University, USA

Alice Pell, Cornell University, USA

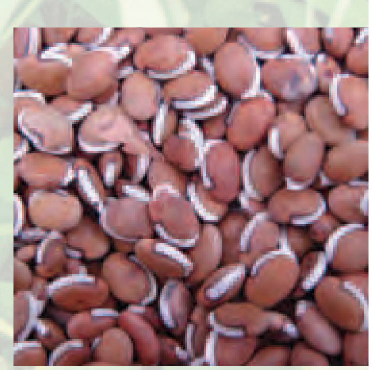
John Duxbury, Cornell University, USA

Peter Hobbs, Cornell University, USA

Rebecca Stoltzfus, Cornell University, USA

Christopher Barrett, Cornell University, USA

Robin Buruchara, Centro Internacional de Agricultura Tropical (CIAT), Uganda



Abstract of Research and Outreach Achievements

A second Short Rains–Long Rains cropping cycle was completed in the South Nandi region of Western Kenya, focusing on crop vigor enhancing strategies that improve production of staple crops, maize, and bean while also introducing a new multipurpose grain legume, *Lablab purpureus*, with good potential for improving household food security and addressing soil degradation. Major activities in FY10 have included:

- participatory evaluation of vigor enhancing strategies by 70 collaborating farmers across a soil fertility gradient
- training and on-farm testing of the strategies by 175 farmers associated with NGO/CBO groups in the Busia, Teso, Butula, and Vihiga districts
- facilitating exchange visits to promote farmer learning and knowledge sharing
- implementation of researcher managed replicated experiments at four sites across the gradient, and
- technical/financial support for six students (three women and three men) pursuing master's degrees at Kenyan universities.

Short Rains 2009–10 results were consistent with those obtained last year, despite higher than normal rainfall due to El Nino climate conditions and intense disease/pest pressure. Averaged across all verification trials, farmers were able to realize a 15 percent yield increase by substituting improved bean variety KK8 for their own variety. By substituting KK8 and adding TSP fertilizer, farmers were able to achieve a 41–71 percent yield gain. Lablab grain production in 2010 was variable due to the climate and severe halo blight (replicated experiments); nevertheless at three of the sites, unfertilized lablab grain yields ranged from 677 to 1200 kg/ha and were 1.4 to 2.2 times greater than farmers' local bean varieties. Phosphorus fertilizer increased lablab grain and biomass productivity, although the effect was not as pronounced as with beans.

During the Long Rains season, farmers were able to make substantial gains in maize productivity by utilizing the alternative fertilization strategies, particularly incorporated lablab residues or half compost plus half DAP. Maize yield gains relative to farmer practices were greatest at the low soil fertility site (25–59 percent) and smallest at the high soil fertility site (-2–10 percent). In the replicated experiments, incorporated lablab increased intercropped bean yields by 22 percent, but in most of the farmer verification trials, lablab residues did not increase yields relative to farmer practices.

During the 2010 exchange visits, farmers reported using some or all of the vigor enhancing strategies on other parts of their farms. Within the Kapkerer–Koibem exchange group, 32 percent of the participants had upscaled boma compost, 40 percent were using KK8 beans instead of local varieties, 75 percent were growing lablab, and 8 percent were following improved spacing/seed rate strategies. Boma compost was being used by 42 percent of farmers from the Kiptaruswo–Bonjoge exchange group; KK8 bean and lablab were being grown by 38 percent and 80 percent of the farmers, respectively.

Project Justification and Objectives

Many rural households in the East African highlands are no longer self-sufficient in beans, a critical source of food and income. Farmers' inability to afford fertilizer inputs coupled with continuous cropping on ever shrinking land holdings has led to degraded and infertile soils and a concomitant decline in crop vigor, pest and disease tolerance, and overall system productivity.

Low bean and maize productivity in Western Kenya is related to both soil fertility and biological constraints. Legumes can be important options for rebuilding soil fertility, but poor utilization of applied P fertilizers, conflicts between soil renewal and immediate food and income needs, and low fixed nitrogen returns from many grain legumes have limited expected returns. Additional production constraints and risks for beans in Western Kenya are presented by diseases and pests. Angular leaf spot and anthracnose are major bean foliar diseases, and root rots, bean stem maggot, nematodes, and root-feeding insects are particularly serious problems in intensively cultivated, degraded soils. Bean root rot can become so severe that the amount of seed harvested becomes less than the amount planted, causing farmers to abandon bean cropping altogether. We hypothesize that vigorous establishment of pulse crops leads to increased pest/disease resistance, improved N fixation, and nutrient accumulation, which ultimately reduces risk, benefits system productivity, food security, and human nutrition. Practices promoting early plant vigor and growth encourage bigger and deeper root systems that can explore larger volumes of soil for limiting nutrients and compete more effectively with soil borne pathogens.

Consumption of pulses is essential for addressing iron deficiency, anemia, and stunting caused by inadequate intakes of zinc. Knowledge about the mineral nutrient content of staple food products, including iron and zinc, is needed to inform selection of appropriate cultivars that will benefit consumers' health and to assist policy makers in meeting desired national health outcomes. Mineral nutrient contents of major foods grown under a representative range of smallholder farmer conditions are needed to develop local food composition tables and to determine food system nutrient outputs.

Determining how to effectively increase productivity of seriously degraded soils and to maintain the fertility of still productive lands is of paramount importance to all farmers living in the East African Highlands. To achieve this outcome, farmers and scientists need to form genuine partnerships, combining farmers' highly sophisticated and nuanced understanding of local conditions with scientists' insight into underlying processes and the powerful problem-solving ability of their scientific methods.

Objectives

1. To develop and assess farmer capacity for improving vigor and growth of pulse crops on nutrient accumulation, pest/disease resistance, and system productivity across a soil degradation gradient.
2. To disseminate and evaluate through participatory approaches simple, low cost strategies for vigorous establishment/growth of pulse crops, leading to increased system productivity and sustainability.
3. To research factors (nutrients, pest/diseases, and their interactions) affecting pulse productivity across a soil degradation gradient

Research and Outreach Approaches, Results, and Achievements

Objective 1: To develop and assess farmer capacity for improving vigor and growth of pulse crops on nutrient accumulation, pest/disease resistance, and system productivity across a soil degradation gradient.

On Farm Verification Trials – During FY10, the project continued support for on-farm verification trials across the established soil fertility gradient sites of Kapkerer (low soil fertility), Kiptaruswo (low-medium soil fertility), Bonjoge (medium-high soil fertility); and Koibem (high soil fertility).

During LR 2010, 58 farmers conducted a final round of verification trials on alternative fertilization strategies for their main maize-bean intercrop

A total of 70 farmers participated in lablab and common bean verification trials during the Short Rains 2009–10, including an additional 20 farmers from the surrounding communities. Farmers selected root rot tolerant KK8 bean and/or lablab treatments according to their interests and available resources. Fifty-eight farmers compared their own bean varieties and planting practices to the following treatments: unfertilized KK8 beans, bean seed priming, KK8 fertilized with 20 kg/ha P fertilizer MRP or TSP, or a combination treatment that included both priming and P fertilization.

Fifty-six farmers experimented with various strategies for growing lablab. Farmers compared a control plot of unfertilized and unprimed lablab to various treatments, including lablab seed primed, lablab planted with 20 kg/ha P fertilizer (TSP, MRP), and lablab primed and planted with P fertilizer. The three treatments that were tested by the largest numbers of farmers were TSP (55 farmers), priming (44 farmers), and TSP plus priming (43 farmers).

During LR 2010, 58 farmers conducted a final round of verification trials on alternative fertilization strategies for their main maize-bean intercrop—13 farmers in Kapkerer, 14 in Kiptaruswo, 19 in Bonjoge, and 12 in Koibem. Farmers tested the following treatments, according to their interests and resources:

1. a more targeted and concentrated application of DAP (1 level soda cap /plant)
2. compost applied in the planting furrows (three 2-kg cooking fat containers/6 m row) or
3. a half dose of compost mixed with half the amount of the DAP applied in treatment #1
4. a lablab residue treatment that consisted of all lablab residues (less any harvestable grain and pod) produced in situ the previous season, incorporated into the soil several weeks before planting, and
5. a half lablab DAP treatment with half the quantity of residue used in treatment #4 combined with half the quantity of DAP used in treatment #1.

Farmers compared the above treatments to their own fertilization strategies, which mostly consisted of low application rates of diammonium phosphate (DAP) fertilizer spread thinly over a larger area. Several farmers used compost, manure, or no fertilizer at all. Farmers used their own seed of their preferred bean and maize varieties in the LR trials. For beans, 89 percent of the farmers preferred KK8 beans. For maize, farmers chose either early or late-maturing hybrids or their own local landraces, depending on the community. Late maturing hybrids were most important at Koibem (92 percent of farmers) and Kiptaruswo (72 percent), the two communities that have a more market-oriented agriculture. In contrast, local landraces were more important in Kapkerer (60 percent) and Bonjoge (62 percent). At Kapkerer, approximately 20 percent of the participating farmers chose to plant early maturing maize hybrids, possibly because this is a community where farm sizes are small and households are more food insecure.

Objective 2: To disseminate and evaluate through participatory approaches simple, low cost strategies for vigorous establishment/growth of pulse crops leading to increased system productivity and sustainability.

Collaborations with NGO and farmer groups – The project continued to support two NGOs (ARDAP and REFSO) and one CBO (AVENE) working with farmers to scale-up and disseminate vigor enhancement strategies and monitor farmer's reaction and crop responses to these strategies in the Busia, Teso, Butula, and Vihiga districts of Western Province.

ARDAP – A total of 60 farmers were recruited to participate in verification trials that compared the performance of different vigor enhancement strategies with farmers' production practices. Strategies evaluated by ARDAP farmers included seed priming, MPR, TSP, compost, and lablab. At the conclusion of the Long Rains, farmers continued to be impressed with priming and MRP, and a majority settled on MRP as the preferred choice of fertilizer. Despite severe diseases and pests (especially aphids), all the tested crop vigor enhancement options substantially outperformed farmer practices.

REFSO – worked with Agro-Farmers, a CBO in Busia district, to bulk KK8 bean seed for distribution to farmers during the Long Rains season.

AVENE is working with a total of 65 farmers in five locations of Sabatia and Chavakali divisions of Vihiga district, Western Province. Farmers tested a variety of crop vigor enhancement options on bean, lablab, or both, depending on land availability and preference. The treatments farmers found promising and wanted to verify further were: 1) KK8 beans plus TSP, 2) KK8 Beans primed plus compost, and 3) KK8 beans+lablab residue.

Figure 1 shows the results of bean and maize grain yields in response to the vigor enhancing options tested by AVENE farmers during the Long Rains 2010. Plots planted with KK8 bean plus compost or DAP outperformed farmer practice on most of the farms that were involved in the trials. The superiority of compost and lablab residues was especially found on farms with low soil pH and lower soil fertility.

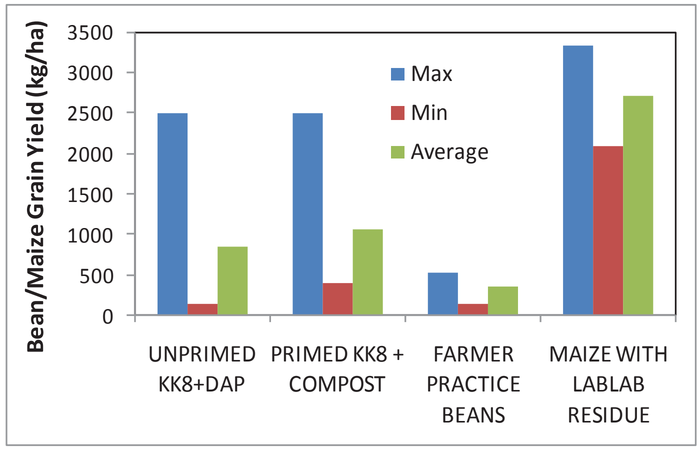


Figure 1. Maximum, minimum, and average bean and maize grain yields obtained with vigor enhancing strategies by 40 AVENE farmers during Long Rains 2010.

Bean Performance SR 2009–10

Bean productivity did not follow the gradient this season due to more intense disease pressure at Kiptaruswo and Bonjoge. On average, farmers were able to realize a 0–31 percent yield increase (going across the fertility gradient from Kapkerer to Koibem) simply by substituting improved germplasm for their own variety. By substituting KK8 and adding TSP fertilizer, farmers were able to achieve a 41–71 percent yield increment.

When comparing trends in the difference between the average numbers of pods/plant for KK8 versus the average numbers for farmers' own varieties, the data show that KK8 plants have consistently more pods at harvest across sites and farmer varieties.

Making the same type of comparison used above for the difference between average numbers of KK8 pods with and without fertilizer, the results showed that, at the lower fertility sites, applying TSP fertilizer increased the numbers of pods per plant even further relative to unfertilized KK8. Moreover, TSP application also enhanced the survival of plants to harvest. Across farms, an average of 43 more KK8 plants/plot survived to harvest when they were fertilized compared to those not fertilized.

Lablab Performance SR 2009–10

As in previous seasons, lablab grain yields followed the fertility gradient, with yields increasing from the lowest to highest fertility sites (Figure 5).

Bean Performance LR 2009–10

Across the communities, the most popular alternative Long Rains fertilization strategies evaluated were the concentrated application of DAP, incorporated lablab residues, and the half lablab – half DAP mixture.

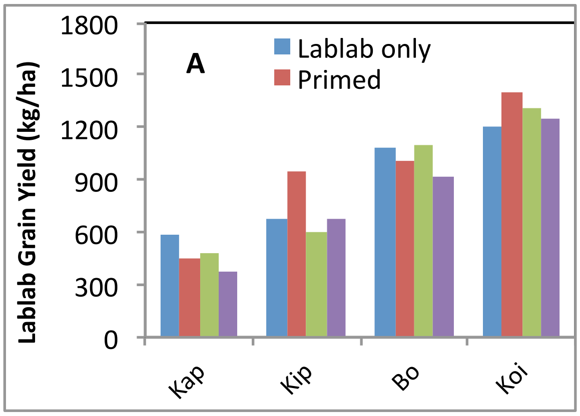


Figure 5.

The bean seedling mortality data show extremely similar mortality trends to those observed last year. The highest postemergence damping off tended to occur on the lower fertility soils (Kiptaruswo and Kapkerer) and in those treatments with either the lowest level of nutrients (i.e., farmer practice or compost) or in the incorporated lablab residue treatment.

Overall, bean stand establishment was better at Bonjoge (66 percent of target stand) and Koibem (63 percent) than at Kapkerer (57 percent) and Kiptaruswo (59 percent) (Figure 8). Also notable was that the two full organic treatments (compost; lablab) had a higher percent stand establishment, 67 percent, compared to an average of 58 percent for the other fertilization strategies, including the farmers' practice. This result suggests that the residues may have been important for helping to retain moister conditions more suitable for seed germination.

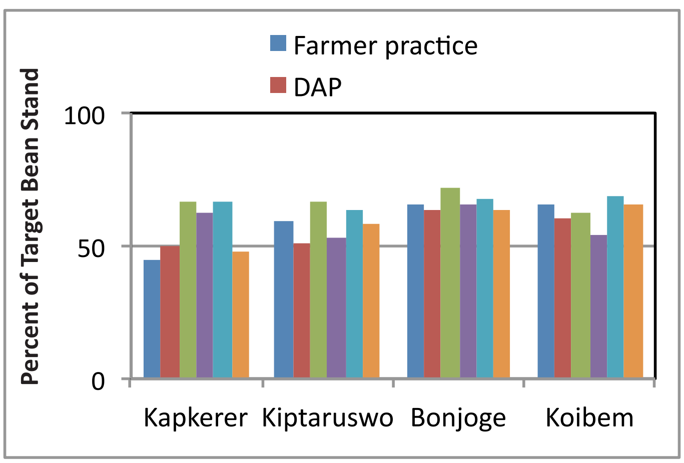


Figure 8. Bean stand establishment at 3 WAP by fertilization strategy and site, Long Rains 2010.

Overall, mean yields of the bean intercrop were slightly higher in 2010 than in 2009. Bean performance was best at Kapkerer and worst at Kiptaruswo, likely due to differences in weather and late season disease pressure. Bean productivity was poorest in farmer practice, lablab, and compost and best in the half DAP and full DAP treatments. Yields of the companion maize crop were also higher in 2010 than in 2009. Maize yield gains relative to the farmer practices were greatest at the lowest fertility site and smallest at the highest site.

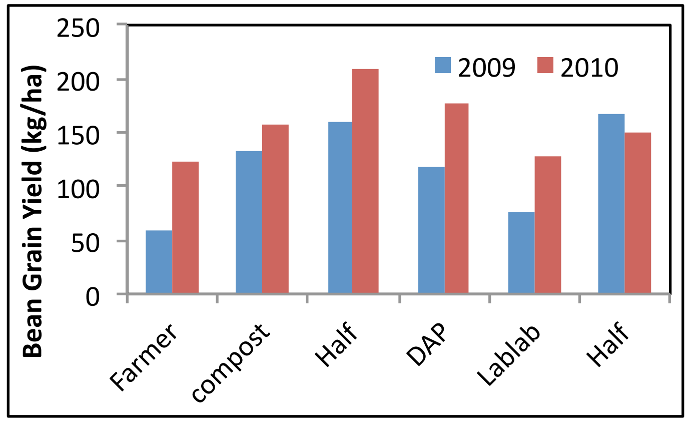


Figure 9. Mean bean yields by treatment for the 2009 and 2010 Long Rains season.

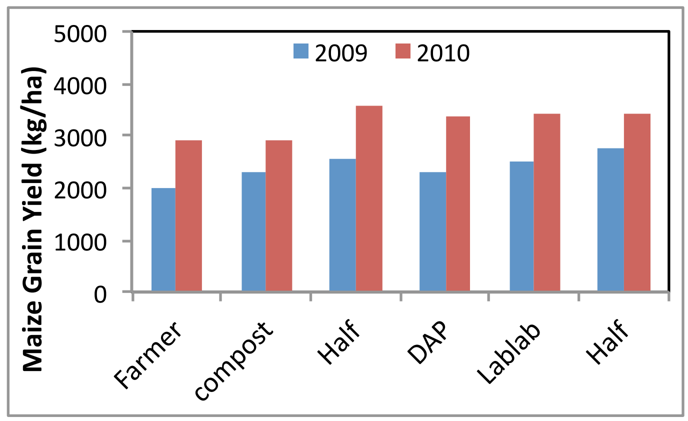


Figure 10. Mean maize yields by treatment during the 2009 and 2010 Long Rains seasons.

Across communities, mean maize yields in the alternative fertilization treatments were consistently higher than mean farmer practice maize yields (17 out of 20 comparisons).

Farmer-to farmer exchange visits

Farmer exchange groups in 2010 exposed the participants to different agroecological conditions, in particular, the effects of soil fertility degradation. As a result Kapkerer farmers (low soil fertility) exchanged with Koibem farmers (high soil fertility); and Kiptaruswo farmers (medium low soil fertility) swapped with Bonjoge farmers (medium high soil fertility).

Incorporated lablab residues (lablab only) were ranked highest at Bonjoge and Kiptaruswo sites, while half boma compost plus half DAP was given the highest rating at Kapkerer and Koibem. Lower rankings were given for other alternative fertilization treatments but all were greater than the farmer practice which was uniformly ranked poorest.

Intercropped beans had been harvested by the time of the exchange visits, but all participants recalled that bean yields were generally poor. Despite the poor performance of beans, participants noted that KK8 performed consistently better than local bean varieties Rosecoco, Kaangumu, or Nyayo. No treatment stood out as having a positive effect on bean yields, although at Koibem, some farmers perceived that beans did not perform well where lablab had previously been cultivated.

Across all sites, farmers reported using some or all of the vigor enhancing strategies on other parts of their farms. Within the Kapkerer–Koibem exchange group, 32 percent of the participants had upscaled boma compost, 40 percent were using KK8 beans instead of local varieties, 75 percent were growing lablab, and 8 percent were following improved spacing/seed rate strategies. Boma compost was being used by 42 percent of farmers from the Kiptaruswo–Bonjoge exchange group, and KK8 bean and lablab were being grown by 38 percent and 80 percent of the farmers, respectively.

Project-related training materials

Simple, pictorial training materials for farmers and development workers have been prepared. These materials focus on: (i) how to grow lablab and its multipurpose benefits; (ii) use of boma compost, organic/inorganic fertilizer mixtures, and lablab residues as alternative fertilization strategies for intercropped maize and beans; and (iii) P fertilizer use to improve productivity of grain legumes. The materials will be distributed through KARI to NGO, CBOs and other extension trainers in Kenya.

Socioeconomic survey completion and technology diffusion trends

A total of 130 households were surveyed in the South Nandi project area focusing on the four core communities of Kapkerer, Kiptaruswo, Bonjoge and Koibem. Project participants were asked to indicate which of the vigor enhancing strategies they preferred and which they planned to scale up. They were also questioned about the extent of labor involved with the lablab residue incorporation. Survey questions for the nonproject participants focused on farmer-to-farmer knowledge dissemination.

Project participants indicated that half compost plus half DAP and incorporated lablab residues (lablab only) were most preferred, but seed priming was not mentioned by many of the farmers. Preference responses differed across the soil fertility gradient. For example, at the high soil fertility site (Koibem), lablab only was least preferred compared to the other strategies but at the lower soil fertility sites (Kapkerer, Kiptaruswo) lablab only was highly ranked. Improved maize seed rates/plant spacing was highly ranked at Koibem but not at the other sites.

Farmers who had not participated in the DGPCRSP project were quite aware of the various strategies and a number were either using the approaches or planning to use them in the upcoming season.

Objective 3: To research factors (nutrients, pest/ diseases and their interactions) affecting pulse productivity across a soil degradation gradient.

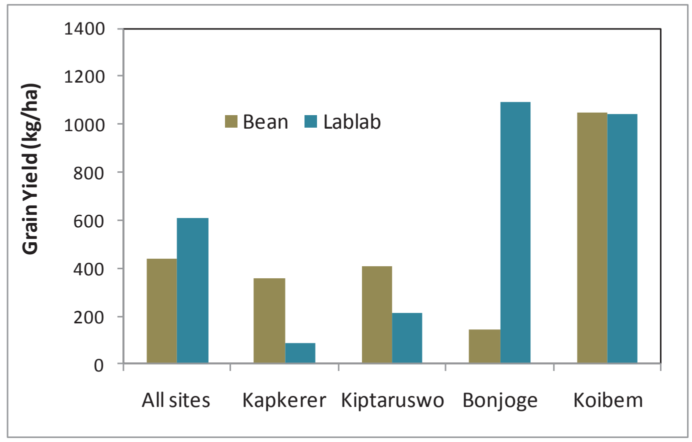


Figure 12 Mean bean and lablab grain yields by site from replicated experiments, Short Rains 2009–10.

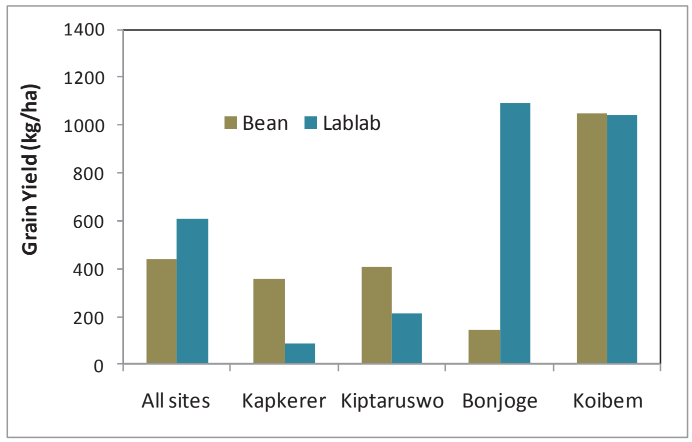


Figure 13. Mean lablab (A) and bean (B) plant populations from replicated experients, Short Rains 2009–10.

SR 2009–10 Replicated Experiment (Lablab or Bean)

Higher than normal rainfall in 2009–10 associated with the El Nino phenomenon depressed lablab and bean yields compared to 2008–09. Nevertheless, at Bonjoge and Koibem, average lablab yields were greater than 1000 kg/ha and either outperformed or gave comparable grain yields as bean (Figure 12). The Bonjoge and Koibem results were similar to the farmer verification plots in the same clusters, but at Kapkerer and Kiptaruswo halo blight reduced the replicated experiment lablab grain yields to very low levels compared to the farmer plots in the same communities. Likewise, bean yields from the replicated plots at all sites except Koibem were 50 percent less than those obtained on the farmer trials. Koibem bean yields were good and comparable to the farmer plot yields.

Lablab plant populations were similar between sites and with an average stand loss of only 12 percent over the course of the season (Figure 13). Emergence plant populations were less than optimal (82 percent of seed sown) due to heavy rains shortly after planting. Halo blight was the dominant disease found at Kapkerer (80 percent of stand) and Kiptaruswo (27 percent of stand) but was less severe at Bonjoge (13 percent) and Koibem (19 percent). Root rot incidence ranged from 7 percent to 19 percent of the stand across the sites. Aphids were found on 28 to 71 percent of the lablab stands at Kiptaruswo, Bonjoge, and Koibem, but no aphids were observed at Kapkerer.

The Short Rains treatments had little/no impact on pest-disease incidence or survival of lablab plants in 2009–10. The TSP treatment had significantly reduced aphid incidence across all sites and reduced halo blight at Kapkerer but had no effect on plant stand or root rot. Seed priming significantly reduced plant stands by 5 percent across all sites; however, there were no priming treatment impacts on lablab pests or diseases.

At Kiptaruswo, Bonjoge and Koibem bean populations dropped dramatically over the season with stand losses between 47 percent and 62 percent. At Kapkerer bean stands were higher and relatively stable with a decline of only 19 percent over the season, primarily by beanfly. Root rot incidence was very low at Kapkerer (1.6 percent of stand) and no aphids were observed. A combined effect of root rot, aphids and beanfly were the main causes of the bean stand declines at Kiptaruswo, Bonjoge, and Koibem. Bonjoge had the highest incidence of aphids (44 percent of stand) and root rot (35 percent of stand).

El Nino climate conditions also reduced lablab biomass yields in 2009–10 compared to 2008–09. TSP significantly increased lablab biomass yields by 18 percent across all sites (Figure 15).

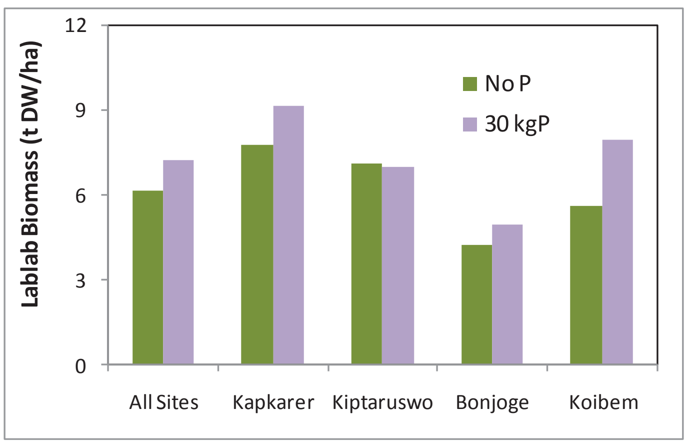


Figure 15. Mean lablab biomass yields by P treatment across sites from replicated experiments, Short Rains 2009–10.

LR 2010 Replicated Experiment (Maize–Bean Intercrop) – At all sites bean yields were substantially higher than 2009 yields and were comparable with typical intercropped bean yields in Western Kenya. Across all sites and treatments, bean yields averaged 237 kg/ha, with peak yields occurring at the low fertility site, Kapkerer (356 kg/ha), which we attribute to lower seasonal rainfall and diseases/pests compared to the other sites. Maize yields in 2010 were similar to 2009 despite a substantial amount of lodging due to high winds just after cob set.

The lablab residue treatments alone produced a 22 percent increase in bean yield, but the effect was dominated by Kapkerer and Bonjoge, while at Kiptaruswo and Koibem lablab residues had a slight negative or negligible effect on bean yields.

Both the fertilizer and bean variety treatments had large and significant impacts on bean yield at all sites. The half compost half DAP fertilizer treatment increased bean yields on average 37 percent compared to the no fertilizer treatment. The greatest response was at Bonjoge (96 percent) while at the other sites half compost half DAP increased bean yields 12 percent to 44 percent over no fertilizer. Yields from the root rot tolerant bean variety, KK8, were on average 84 percent higher than the root rot susceptible bean variety, GLP2. This was particularly the case at Kapkerer, where there was a threefold increase in bean yield with KK8 compared to GLP2. Responses to KK8 relative to GLP2 were substantial but lower at Kiptaruswo (26 percent), Bonjoge (20 percent), and Koibem (68 percent).

Due to timely planting and low pest/disease incidence, bean plant populations at two weeks were high averaging 91 percent of seeds sown across all sites. Over the course of the season, plant populations with KK8 were higher than GLP2.

In addition, the lablab residue treatments did not appear to exacerbate root rot severity in 2010. Data from all sites combined indicated that lablab residues had a slight but insignificant impact in reducing root rot severity (Figure 19A).

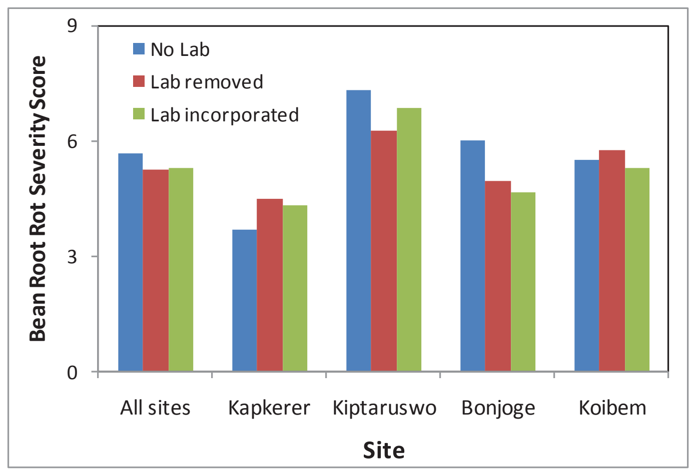


Figure 19A. Mean bean root rot severity scores per plot by lablab residue (A) and fertilizer–bean variety (B) treatments across sites from replicated experiments, Long Rains 2010.

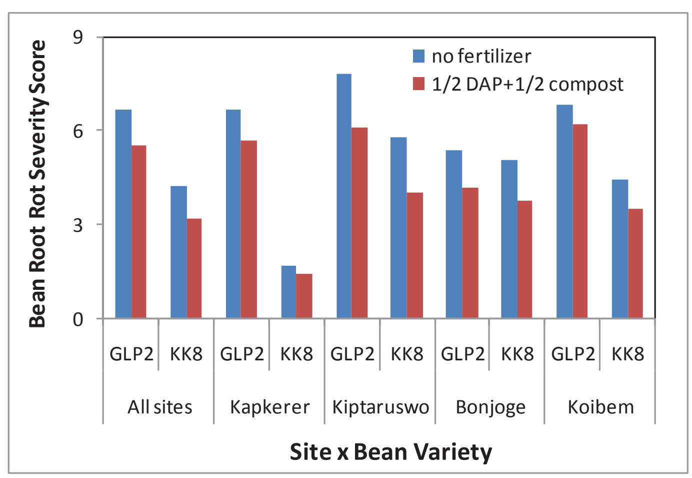


Figure 19B. Mean bean root rot severity scores per plot by lablab residue (A) and fertilizer–bean variety (B) treatments across sites from replicated experiments, Long Rains 2010.

The impacts of lablab residues on seedling mortality and root rot severity in the replicated experiments were quite different from those observed in the farmer verification plots. In the replicated experiments, lablab residues were cut, windrowed, and then incorporated in the soil to a depth of ~ six inches. Maize and bean seeds were planted to the side of the incorporated residues. Once the lablab was cut, farmers incorporated shallowly (~ 2–3 inches) and planted the maize and beans directly on top of the incorporated residue. Planting the maize and bean seeds directly into the decomposing lablab residues appeared to improve stand establishment compared to the other fertilization practices. Farmer results indicated that this management practice also increased postemergent damping off in the lablab only treatments. No negative effects on seedling mortality were observed in the replicated experiments where seeds were planted to the side of the incorporated residue.

As observed last year, no chafer grubs were recorded at Kapkerer. At Kiptaruswo, Bonjoge and Koibem there was a consistent increase in chafer grubs associated with the lablab residue incorporation treatment (Figure 20) but no impact of the half – half fertilizer treatment or the bean variety treatments on chafer grub counts. At Kiptaruswo, increasing chafer grubs was associated with greater bean mortality and lower bean yields. However at Koibem, chafer grubs were not correlated with either bean mortality or yield. At Bonjoge chafer grubs correlated negatively with bean mortality and positively with yield which is not consistent with our model. So while the replicated experiment data to date have not demonstrated a negative impact of chafer grubs in association with incorporated lablab residues, the lower bean yields in the farmer verification trials with incorporated lablab residues does suggest that chafer grubs may be a contributing factor that needs continued monitoring.

Lablab residue treatments had the biggest impact on maize grain and stover yields. Averaged across all sites, lablab treatments increased maize grain yields 52 percent (lablab removed) to 78 percent (lablab incorporated), while stover yields were increased 34 percent (lablab removed) and 46 percent (lablab incorporated) (Figure 21). Also a significant impact of the, half – half, fertilizer treatment on maize yields was found across all sites, but the increase was only an additional 13–17 percent.

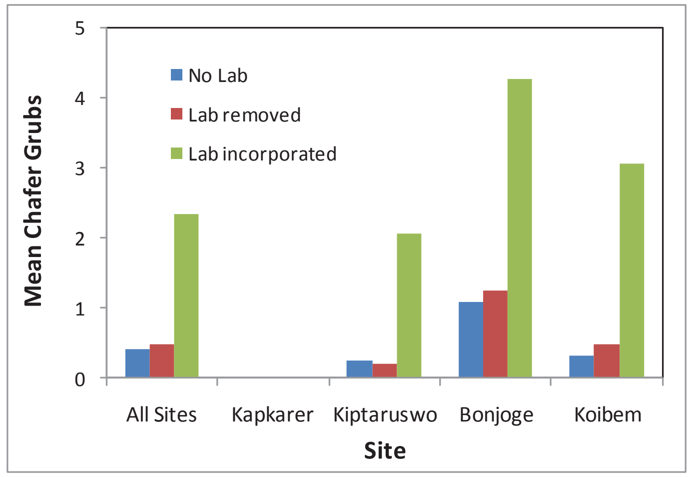


Figure 20. Mean chafer grub counts per plot by lablab residue treatments across sites in replicated experiments. Long Rains 2010.

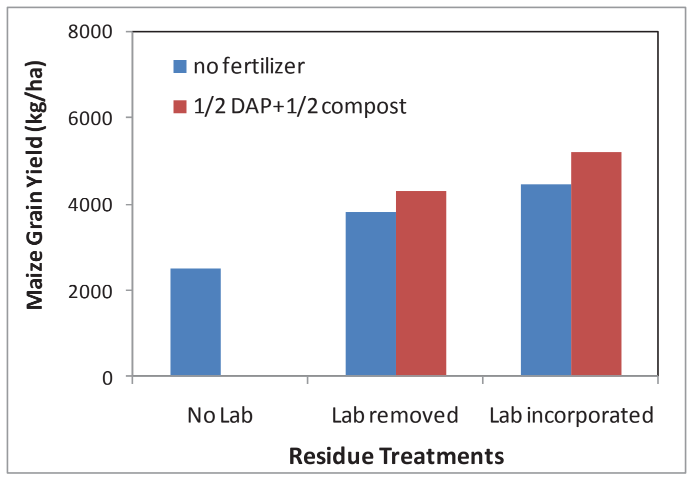


Figure 21. Mean maize grain (A) and stover (B) yields by lablab residue — fertilizer treatments from replicated experiments, Long Rains 2010.

Germplasm testing

Cowpea materials from UCR – Silvester Odundo, a master's student at Moi University worked with cowpea cultivars obtained from the University of California, Riverside, to identify varieties with the most potential for cowpea grain production in the wet, cool, and higher elevation environments of Western Kenya.

Mean cowpea grain yields at Bonjoge were 65 percent greater than at Koibem, which is at a higher elevation and generally cooler than Bonjoge. The warmer and drier environments of Kapkerer and Kiptaruswo should have favored cowpea grain production over that of Bonjoge and Koibem.

P efficient bean varieties from Zamorano–PSU program – During the 2009–10 Short Rains season, the KARI Grain Legume Program did further evaluation and selection with 23 nutrient efficient bean lines from the Zamorano–PSU program. A local, small seeded, red variety and medium seeded, mottled variety were also included as checks. Varieties were planted in a completely randomized design with three replications. Seeds of each line were sown in two m long rows without any added P fertilizer.

The soil used for the evaluation was tested and found to be deficient in phosphorus (Olsen P = 8.4 mg/kg).

Days to flowering and days to maturity did not vary much across the introduced lines (42.7–44.5 days; 80.7–82.7 days) and were not strikingly different from the local checks (43 days; 81 days). Plant mortality was quite variable ranging from 21.9 percent to 77.1 percent across the introduced lines and 49.6 percent to 53 percent by the local checks. Mortality was most strongly associated with bean common mosaic necrotic virus (BCMNV). The incidence of angular leaf spot, rust, and common bean mosaic virus was generally low across all lines including the local checks.

Yields from the introduced bean varieties ranged from 133 g/plot to 1000 g/plot and the local check yields averaged 467 g/plot (GLP585) and 458 g/plot (GLP2). Seven of the lines tested in SR09-10 were selected for utilization in future breeding efforts by the KARI Grain Legume program.

Screening for resistance to BCMV and BCMNV
A total of 32 breeding lines from the KARI-Kakamega breeding program were tested at each site using an alpha lattice design with three replications. Three lines from the Zamorano-PSU program were included in the testing. Stand counts, number of plants with BCMV and BCMNV symptoms, and severity of BCMV and BCMNV symptom scores were collected along with grain yields at maturity. Preliminary results indicated that both BCMV and BCMNV were prevalent across all sites within the South Nandi project area. In addition, sufficient genetic variation for manipulation was observed to develop bean varieties with multiple disease tolerance to BCMV and BCNMV.

Networking and Linkages with Stakeholders

Collaborations with two NGOs (REFSO, ARDAP) and one CBO (Avene) continued in FY10.

Collaboration with Leldet, Inc., a private seed company based in Nakuru, Kenya, continued in FY10. Lablab, KK8 and KK15 bean seed were produced from materials sourced by the project.

Leveraged Funds

Cornell University scientists affiliated with this Dry Grain Pulses CRSP project have successfully leveraged more than $3,500,000 in external funding for research, outreach, and educational programs.

Enhancing Nutritional Value and Marketability of Beans Through Research and Strengthening Key Value Chain Stakeholders in Uganda and Rwanda

PI-ISU-1

Principal Investigators

Robert Mazur, Iowa State University (ISU), USA

Dorothy Nakimbugwe, Makerere, Uganda

Michael Ugen, NaCRRI, Uganda

Henry Kizito Musoke, VEDCO, Uganda

Collaborating Host Country and U.S. PIs and Institutions:

Hilda Vasanthakaalam, KIST, Rwanda

Gabriel Elepu, Makerere, Uganda

Paul Kibwika, Makerere, Uganda

Agnes Nakimuli, VEDCO, Uganda

Helen Jensen, ISU, USA

Mark Westgate, ISU, USA

Suzanne Hendrich, ISU, USA

Manju Reddy, ISU, USA

Patricia Murphy, ISU, USA

Abstract of Research and Outreach Achievements

Significant progress in addressing research and development objectives has been made. Activities to improve bean yields and quality involve refresher trainings on improved management practices for production, harvesting, drying, and sorting; experiments with hermetic storage; a farmer-led field day to demonstrate and explain practices and technologies; and sharing knowledge gained with other farmers. Field experiment data for three cropping seasons have been quantified and analyzed in relation to seed variety and methods and techniques of soil fertility enhancement (manure and phosphorus), which includes assessing some new early maturing (60–65 days), drought tolerant, and anthracnose resistant NaCRRI bean lines. Extension training materials have been updated to reflect research results. Experiments at ISU focused on physiological bases for accretion and partitioning of iron and zinc in bean seed and drought tolerance. We increased seed quantities at ISU for processing and nutritional studies.

Regarding the second objective, enhancing the nutritional value and appeal of beans through appropriate handling and processing, there are several important research accomplishments. We analyzed the effects of soaking, malting, and steaming on protein and starch digestibility, and polyphenol and phytate content. Optimizing the bean flour processing protocol for production of porridges and sauces was followed by sensory evaluation for consumer acceptance. Optimization involves Nutreal, a private company collaboration with Makerere University's Technology Business Incubation Centre, which provides technical support to refine, brand, and market bean-based composite flour. Given the focus in Rwanda on processing methods designed for application in rural communities, research focused on development and organoleptic evaluation of composite flour for cold extruded snacks and extrusion demonstrated in two rural communities was enthusiastically received. Additional experiments on processed bean flour examined oil absorption, wettability, emulsion capacity, and foaming capacity—characteristics useful in community-based and commercial applications. In Uganda's Kamuli district, recipe competition and the bean cook day identified popular new methods of bean preparation that can promote increased consumption. A rapid market survey of diverse market channels in Kampala to identify market opportunities for bean products focused on nutrient enhanced flours for porridges, weaning foods, supplementary feeding for children, ready-to-eat snacks and foods, and bread.

Collaborative work to increase marketing and consumption of beans and bean products (third objective) involved weekly updating of public market price boards in all VEDCO operation areas in Kamuli and disseminating market prices for crops via cell phone messages. VEDCO organized the first value chain stakeholder workshop in Kamuli that identified marketing constraints in the bean value chain and strategies for collaboration to overcome them.

Project Justification and Objectives

Agriculture in East Africa is characterized by women and men working in small-scale, rain-fed production averaging two hectares per household. Erratic bimodal rainfall patterns in recent years further challenged cropping results. Farmers have limited access to extension training for improved agronomic practices, inputs, new technologies, and credit. Producers are not well linked with profitable markets, especially to emerging sectors of domestic and regional markets. Private traders operate on a small scale with limited investment capability. Availability and use of processed products at present remain very modest. As a result of low production levels, hunger is widespread and the vast majority of the rural population lives in absolute poverty.

Our recent efforts to introduce new agronomic practices and technologies demonstrate encouraging progress. Ongoing collaboration since 2004 between Iowa State University (ISU), Makerere University (MAK), and Volunteer Efforts for Development Concerns (VEDCO) in Uganda's Kamuli District using a sustainable livelihoods approach increased food security and market readiness from nine to 77 percent among 800+ farm households. The main crops are maize, beans, sweet potatoes, cassava, bananas, rice, and coffee. Most (90 percent) of participating households produce beans, but few (20 percent) sell some. The SL approach focuses on understanding and supporting individual and community capabilities, assets (natural, physical, human, financial, social, cultural, and political capital), goals, strategies, and activities. In combination with SL approaches, scientific knowledge, improved technologies, financial assistance, and changes in government policies can have significant positive local impacts. Participatory research methods can generate knowledge that people can apply to improve their individual and collective well-being.

Beans provide a strategic opportunity to help meet the Millennium Development Goal targets of reducing hunger and poverty. Improved bean production in Uganda and Rwanda offers unique opportunities to address the deteriorating food security situation there and elsewhere in sub-Saharan Africa. The short growth period and two growing seasons offer great opportunities to contribute to rural poverty alleviation, playing an essential role in sustainable livelihoods of small-scale farmers and their families and providing food security and income to the most vulnerable group, women and children. Testing whether yield improving technologies result in beans with better nutritive value (Objective 1) or processing characteristics (Objective 2) is an important underresearched issue in this region. Improved linkages to emerging markets are also essential (Objective 3).

Central problems limiting production of quality beans and higher yields:

- Declining soil fertility and inefficient cropping systems unable to utilize available resources effectively and efficiently
- Limited accessibility and affordability of quality seeds, nonseed inputs, and other yield improving technologies

- Effects of drought and other weather-related factors compromise productivity and quality
- Diseases (root rot, anthracnose, angular leaf spot, common bacterial blight, viruses, rust, ascochyta blight) and insect pests (bean stem maggots, aphids, bruchids)

Central problems relating to nutritional value and processing of beans
Pre- and post-harvest losses for beans are very high throughout the value chain, mostly due to poor harvest and postharvest practices and poor on-farm storage facilities. Poor pre- and post-harvest handling also results in the majority of beans on the market being characterized by mixed varieties and poor quality with high levels of foreign matter, rotten or shriveled beans, and infestation. The lack of value-added bean products having reduced preparation times makes bean preparation laborious with high fuel requirements; consumers also tire of monotonous flavor, which may be improved by processing and creation of value-added bean-based food products. As a result, an increasing number of people are abandoning or reducing their bean consumption despite its documented high nutrient content and health benefits.

The nutritional value of beans may be affected by phytates, trypsin inhibitors, polyphenols, lectins, saponins, oligosaccharides, and hemaglutinins. Phytates and polyphenols limit iron uptake, and optimizing bean processing to improve iron bioavailability is a key need. Treatments such as dehulling, soaking, milling, fermentation and germination (malting), and cooking enhance the digestibility and nutritional value by lessening some of the above constituents, but optimizing bean processing for nutritional value is needed.

Central problems inhibiting increased marketing of beans and derived food products
Prospects of marketing increased quantities of beans and new agro-processed bean products within the Ugandan and regional markets require carefully examining production and marketing constraints (increased farm productivity, producer incentives, and access to better markets). Equally important is examining prospects for increasing demand for beans and agro-processed products (understanding consumers' tastes and preferences, increased consumer awareness of the benefits of consuming beans and other value-added products, increasing consumer choices of value-added products, etc.).

Objectives

1. To Improve Harvested Bean Quality and Yields
2. To Enhance Nutritional Value and Appeal of Beans Through Appropriate Handling and Processing
3. To Identify Solutions for Constraints to Increased Marketing and Consumption
4. To Increase the Capacity, Effectiveness, and Sustainability of Agriculture Research Institutions that Serve the Bean Sector in Uganda and Rwanda

Research and Outreach Approaches, Results, and Achievements

Objective 1: To Improve Harvested Bean Quality and Yields

Meta-analysis of the effects of water and temperature stress on yields is underway. Preliminary experiments on sensitivity of varieties to water stress have been completed. Morphological plasticity and varietal differences to stress were determined. Two varieties (K131 and NABE2) were more tolerant to stress while NABE4 was the most prone to water stress, probably due to its luscious growth under the adequately fertilized greenhouse soil mix. Initial research to document the impact of stress on seed nutrient composition has involved assessing commercial varieties from Uganda (K131, K132, NABE2, NABE4 and NABE6) in the greenhouse.

At present, results are inconclusive because we could not sufficiently control the stress due to the wide plasticity in plant growth. Water stress studies at ISU will be completed this winter following replication in the greenhouse.

Collaboration has been initiated and a Material Transfer Agreement (MTA) signed between CIAT–Colombia and Iowa State University. With this agreement, we shall receive germplasm from breeders that reflects variation in drought and seed nutritive composition.

We are also working to increase the quantities of seed for processing and nutritional studies. A total of 60 kg of clean bean seed was produced at ISU.

The National Crops Resources Research Resource Institute (NaCRRI) at Namulonge has developed early maturing varieties of lines that are drought tolerant and resistant to anthracnose. These lines are being evaluated in Kamuli and will be included in physiology studies at ISU. NaCRRI recently received more than 200 nutri-bean lines (lines high in iron, zinc, and protein) from the University of Nairobi through our CIAT partners for multiplication this season. The seeds planted at NaCRRI for multiplication will facilitate evaluation next season. ISU will use some of the seeds for physiological studies once the multiplication increases the quantity of seeds available.

Improve Quality and Yields through Evaluation of Better Production Practices
In 2009, 30 trial sites were established for both seasons one and two. Data were collected from planting through harvest. After harvesting, samples were taken to NaCRRI where measurements of seed total weight, clean seed weight, 100 seed weight, and moisture contents were taken.

Four improved varieties (K132, NABE4, K131, NABE6) developed at NaCRRI and a popular local variety (Kanyebwa) were evaluated at each site. The fertility trial involved application of 10 T/ha organic manure applied at planting. Seed yield per plot was quantified on cleaned seed (shriveled seed removed) and adjusted to kg/ha.

Only K131 yielded significantly more than the local variety, Kanyebwa (Figure 1). The yield of all varieties was far below the potential yield of 1500–2000 kg/ha observed on NaCRRI research station fields. Manure application increased seed yield of all varieties except NABE4. Yield increases up to 34 percent for K131, 53 percent for K132, and 70 percent for Kanyebwa were observed. However, even the best yields with manure were less than 50 percent of the yield potential.

Based on these results, other sets of experiments have been initiated to assess on-farm the effect of phosphorous, manure, and the interaction between manure and phosphorous on the yield of common beans. Further, pest and disease incidence and severity as affected by soil fertility treatments and intercropping will be assessed.

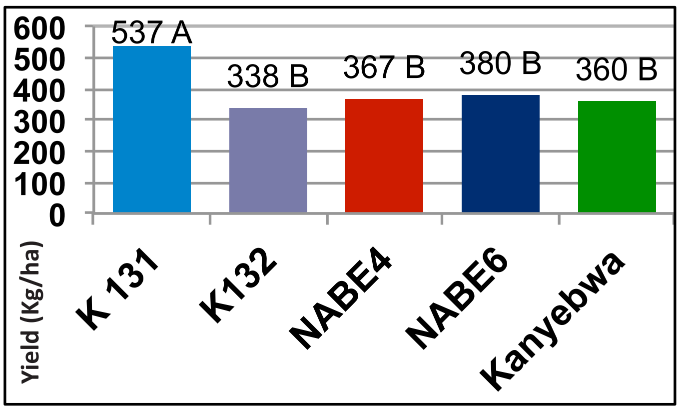


Figure 1. Genotypic variation in yield of common beans under farmers' conditions. Data are the mean for two growing seasons. Means with the same letters are not significantly different at $p < 0.10$.

To determine the effect of soil fertility on seed composition, seed samples from Kamuli were analyzed for mineral composition, total carbon, and percentage protein content. There were no significant effects of manure application on seed composition for Phosphorous (P), Potassium (K), Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn), Aluminum (Al), Calcium (Ca), Magnesium (Mg), percent total carbon (TC), and protein content. Significant manure effects were only documented for Sodium (Na). Significant variety differences in composition were only present for K, Fe, Mg, and protein content.

The first season 2010 trials were established April 7–25—a total of 30 sites. The amount of phosphorous applied was 60, 40, and 20 kg/ha. For this report, results from plots where 60 kg/ha of Phosphorous was applied are reported.

Results showed there was a significant effect of Location x Variety interaction for total seed yield, clean seed yield, and seed size; however, there were no significant differences in the total yield among varieties (see Table 1). K131 had the highest clean yield while NABE4 had the lowest clean yield, with 48 percent of the seed classified bad seed (poorly filled, diseased). Drought and heavy rain affected growth and yield in some locations.

Variety	Total Yield (kg/ha)		Variety	Clean Yield (kg/ha)		Variety	Seed Wt. (g)
K132	567A		K131	372A		K132	46.4A
Kanyebwa	527A		K132	351A		NABE4	39.7B
K131	526A		Kanyebwa	341AB		Kanyebwa	35.8C
NABE6	522A		NABE6	319AB		NABE6	17.8D
NABE4	517A		NABE4	270B		K131	17.0D

Table 1. Variety differences in the mean yields of five common bean genotypes. Means values with the same letter are not significantly different ($p \leq 0.10$).

In this trial, three varieties—K131, NABE4, and Kanyebwa—were compared in 3m x 3m plots. The on-farm trials were arranged in Randomized Complete Design with two replicates per treatment. Soil fertility treatments included farm yard manure (10t/ha), single super phosphorous (60 kg/ha), farm yard manure (10t/ha) super single phosphorous (30 kg/ha), and a control

There were significant differences in yields among farmers but no significant effect of soil fertility treatments, variety, and soil fertility x variety interaction on the total and clean seed yields.

Despite the overall lack of significant differences, the fertility treatments generally yielded higher than the control, with higher yields where phosphorous was part of the treatment (see Table 2). Application of phosphorous alone led to a 32 percent increase in clean yield compared to the control. Analysis of the 100 seed weight showed significant differences among varieties and a significant soil fertility treatment effect on seed weight; however, the variety by soil fertility interaction was not significant.

Treatment	Total Yield (kg/ha)		Treatment	Clean Yield (kg/ha)		Treatment	Seed Wt. (g)
Control	633B		Control	415B		Control	31.0B
Manure	747A		Manure	509A		Manure	33.7A
Phosphorous	787A		Phosphorous	552A		Phosphorus	31.0B
M x P	752A		M x P	516A		M x P	32.3B

Table 2. Effect of Manure (M), Phosphorous (P), and Manure by Phosphorous (M x P) by interaction on the yield of common beans. Mean values with the same letter are not significantly different.

Drought is becoming increasingly common in Uganda, including in the Kamuli district. Farmers are in no position to time planting as they used to as weather has become unpredictable. NaCRRI has identified eight early maturing lines, with two already released for farmer use. These varieties/lines mature in 60–65 days and are currently being evaluated in Kamuli for their performance.

Evaluate and Reduce Post-Harvest Losses

Members of the six farmers groups were mobilized in their respective subcounties for training. NaCRRI research technicians Richard Sekabembe and John Sulume trained 70 farmers (59 women and 11 men) on proper methods of harvesting seeds as soon as they reach physiological maturity. To avoid losses, farmers were shown how to use string or banana fibers to tie bunches of harvested beans and to use sacks for transport to their homes. Using tarpaulins for a clean drying environment was emphasized as were sorting and redrying of seeds. Farmers were shown that using less violent methods of threshing avoids splitting the seeds. They were also trained on proper storage. For seeds, proper use of fungicides and pesticides was demonstrated to minimize losses during storage and maintain seed quality. For consumption, regular drying and use of preservatives from the neem tree and ash can be used.

Farmers indicated that adoption of recommended post-harvest management practices (harvesting, transporting, drying, threshing, sorting, and storage) resulted in loss reductions.

NaCRRI Research Technicians

An experiment was conducted in rural Kamuli during July–August, 2010, to determine the effectiveness of hermetic storage in controlling insects in beans and corn. Heavily infested beans (bruchids) and corn (weevils) were purchased in the local market and stored in used but clean edible oil 10L plastic containers under two conditions: 1. hermetically sealed (airtight) and 2. open to air infiltration but closed to insect migration in or out of the container. After four weeks of storage, the total number of insects approximately doubled in the hermetically sealed containers and tripled in the open containers. However, the hermetically sealed containers resulted in 100 percent insect mortality. In the open containers, approximately 50 percent of the insects were alive and actively feeding on the beans and corn beans, which resulted in significant quality deterioration compared to hermetic storage.

Strengthen Farmers' Collective Capabilities to Learn and Share Innovative Practices

Continued training on research methods and procedures for the 2010 field trials involved all six farmer groups. The topics covered included farmers roles and benefits, site selection, plot layout, treatments, and randomization.

The first CRSP field day was held on July 2, 2010, in Butansi sub-county. CRSP and non-CRSP farmers were mobilized and all the partners in the CRSP project participated. Approximately 150 farmers (two-thirds of them women) and other stakeholders participated. The objectives of this field day were to enable farmers to share with others the knowledge that they have acquired through research, demonstrate and explain new management practices and technologies (germination testing, site selection, land preparation, row planting and spacing, timely weeding, pest management, harvesting methods, post-harvest handling, moisture content, seed preservation), storage technologies and methods (triple bagging, airtight plastic containers), and community-based seed production. In addition to demonstrations and discussions, both in-field and at stations regarding management practices and technologies, CRSP farmers used peoples theatre to communicate—often with greatly appreciated humor—to field day attendees.

Farmer Field Day Planting

Farmer Field Day Display

The field day enabled the project team and participating farmers to obtain suggestions from other farmers and stakeholders to improve practices or approaches which will be useful in dissemination and scaling up

Objective 2: To Enhance Nutritional Value and Appeal of Beans through Appropriate Handling and Processing.

Farmer Field Day People's Theater

Determine the Influence of Agronomic Conditions on Nutritional Quality of Beans

We tested the hypothesis that implementation of improved farming practices would increase yield and the nutritional value of the beans. We also sought to determine the most effective processing parameters to maximize the nutritional value of beans with respect to decreasing anti-nutritional factors and increasing protein and starch digestibility. Application of farm yard manure over two growing seasons had no significant effect ($p<0.05$) on anti-nutritional factors (phytate and polyphenols), although significant differences existed between varieties and between harvests.

Determine the Influence of Processing on the Nutritional and Sensory Quality of Beans

The effect of soaking, malting, and steaming on protein and starch digestibility as well as on polyphenols and phytic acid were determined using K131 and NABE6 varieties. Individual processing techniques had significant effect on total polyphenol and phytate content.

In Uganda, the protocol initially developed for processing bean-flour, using K131 as the model variety, involved the following steps:

> Soaking (12 hours) → malting (48 hours) → dehulling → steaming (15 minutes) → roasting (15minutes). It was then refined to: soaking (12 hours) → malting (24 hours) → steaming under pressure (20 minutes) → oven drying (at 65°C for eight hours) → fine milling. The malting time was reduced from 48 to 24 hours because the beans were sufficiently sprouted after that time. Steaming replaced roasting, followed by oven drying because when the roasted flour was used for porridge, it tasted burnt.

Since soaking, malting, and steaming times have greater influence on nutritional quality and sensory acceptability of the processed bean flour, they were selected for optimization. Three levels of each of the three processes were tested as shown in Table 4.

	Processes and Duration		
Level	Soaking (hours)	Malting (hours)	Steaming (minutes)
Low	6	0	0
Middle	15	24	10
High	24	48	20

Table 4. Criteria used for optimizing bean flour processing protocol.

The influence of different levels of the independent variables on starch digestion, protein digestion and polyphenol/phytate contents were optimized using Statease software. Optimal levels of the three sets of variables were 24 hours soaking, 48 hours malting, and 18.7 minutes steaming.

Develop Processing Techniques with Improved Efficiency, Feasibility and Consumer Acceptance of Bean-Based Food Products

In Rwanda, beans were soaked in water for 16 hours at ambient temperature. The beans doubled their weight upon soaking and were subjected to germination for four to six days at ambient temperature. They were dehulled and dried at 105°C for five hours. The dehulled beans were milled and made into flour. The flour was made into dough and fermented for eight hours at ambient room temperature. It was dried in a mechanical drier at 105°C for three hours and then milled to obtain uniform flour. This treatment can be applied in the development of processed weaning foods for children.

The effect of thermal processing methods on the functional properties of bean flour was also studied. The thermal processing treatments were boiling, roasting, and autoclaving.

Water absorption was higher in roasted common bean flour and no difference was observed between raw, boiled and autoclaved bean flours. Oil absorption was high in autoclaved bean flour and low in raw bean flour. The oil absorption capacity determines whether the protein material of the flour will perform well as meat extenders or analogs. Fats improve flavor and increase the mouth feel of foods. Fat absorption is therefore a significant factor in food formulations. In this research, fat absorption capacities were higher in processed common bean samples than in the raw one. In this research, the flours were very stable and there was no quick movement of water through bean flours; the most stable flour was from boiled common beans.

Emulsion capacity was high in raw bean flour and low in boiled bean flour. From our research results, it is evident that boiling as a processing method is less effective when compared to autoclaved and roasted beans for which emulsion capacity of the flour is required for spread formulation.

Differences between foaming capacity of flour from unprocessed beans and those from beans processed before blending were identified. From the study, it is recommended that boiled and roasted bean flours be used as thickeners and in child feeding because they are denser and that raw bean flour be used as aerating agents in food systems such as whipped toppings and ice cream mixes.

In Uganda, the optimized protocol for producing bean flour, using variety K131 as the model, has been up-scaled to semi-commercial level. Clean dry beans are soaked for 24 hours in large plastic bins, malted for 48 hours between moist sisal mats, roasted at 200–220°C for 40–60 minutes with constant stirring, and then milled into fine flour. The optimization was done in collaboration with Nutreal Limited, a private company partnering with the business incubation program of the Department of Food Science & Technology (DFST) at Makerere University.

In Rwanda, formulation of composite flour of bean and maize was carried out after appropriate pretreatments. They were blended in different combination, and the cold extruded snack was processed and subjected to organoleptic evaluation. Simultaneously, storage stability studies were conducted, and results indicated that the product was shelf stable for a period of four months.

In Rwanda, a metallic hand-operated extruder was used to cold press the dough before frying in oil. The extruded product was directly placed into hot cooking oil and deep fried. The cooked snack food was then cooled. Finally, the product was vacuum packed and placed in a plastic container.

Hand Held Cold Extruder

Objective 3: To Identify Solutions for Constraints to Increased Marketing and Consumption

Identify Solutions to Production and Marketing Constraints Faced by Bean Producers

Research by MSc. agricultural economics student Simon Okiror found that although there has been an increase in bean market participation among households compared to 2005, bean production has been for domestic consumption rather than for commercial purposes. Price is positively associated with the probability of selling beans. Barriers to market participation by smallholder farmers include the transaction costs of marketing, especially market distance and searching for market information.

VEDCO has recently invested in a new text-based information technology system that will initially enable messages to be sent and received in both English and Luganda to the mobile phones of registered farmers containing current market prices and/or extension information targeting specific crops and/or regions. This system conveys market information rapidly and at times when farmers are making critical production and marketing decisions. There is recognized value in encouraging and strengthening associations for collective marketing among farmers. VEDCO organized the first value chain stakeholder workshop in Kamuli in September 2010, and is committed to playing a facilitative role to achieve success in value chain development. Participants committed themselves to coordinate efforts to accomplish these intermediate and long-terms goals:

- Establish a forum for stakeholders to meet regularly and share information regarding production and marketing practices and strategies
- Strengthen the role of business principles and profit orientation in producer organizations
- Facilitate the development of farmer–trader associations and build strong networks
- Increase the expertise and capacity of all stakeholders in the value chain
- Develop an accessible and effective market information system
- Invest in the value chain (attract private sector businesses to invest in finance, extension, and related services, storage facilities, transportation infrastructure, product development)
- Advocate for governance along the value chain (self-regulation, price stabilization, etc.)
- Advocate for a food reserve agency

Characterize Consumer Demand and Preferences for Beans and Agro-Processed Products

MSc. agricultural extension student George Jjagwe carried out a rapid market survey to establish the extent to which nutrient-enhanced foods are present in different types of market channels in Kampala. The survey focused on flours used for preparing nutrient-dense porridges, e.g., weaning foods and supplementary feeding for children, ready-to-eat foods, and snacks such as bread made with nutrient enhanced flours. A very limited range of such nutrient-enhanced products was observed, implying that there is great potential to increase the range.

Increase Awareness of Benefits of Consuming Beans and Value-Added Products and their Access to New Products

In September 2010, four of Dr. Hilda Vasanthakaalam's undergraduate students from KIST demonstrated the cold extrusion method to 30 rural community members in two villages in Nyagatare in Rwanda's Eastern province. The ingredients used for processing the cold extruded snack food included composite flour (150g), rice flour for binding (15g), black pepper powder (2.5g), oil (5g), turmeric (a pinch), salt (to taste), a pinch of Asofoetida powder (to decrease flatulence), water, and oil for frying. The farmers were excited to see this

Cold Extrusion of Bean Snack

demonstration and learn about this process. Farmers also indicated their interest to mobilize 100 farmers the following month so that many more could benefit. One farmer expressed interest in becoming a bean flour processing entrepreneur.

In September 2010, recipes developed by NaCRRI were used for training 68 CRSP farmers in Uganda's Kamuli district in the preparation of a variety of bean recipes. Recipes included cakes, cookies, shortcakes, bean fingers, half cakes, bean pie, and "daddies" – snacks traditionally made with wheat flour and eggs, and then fried. Some of these recipes were identified by participants as potentially very useful for generating household income. A video recording to be used in future community training was made.

A "bean cook day" was organized in Naluwoli parish in the Kamuli district, during which the farmer group members in the CRSP project participated in a cooking competition using beans. A quick-cooking bean flour, developed at Makerere University's DFST, was available for farmers to utilize and evaluate. The participating farmers/farmer groups were evaluated on knowledge of the nutritional benefits of beans, ways of combining beans to have a balanced diet, the importance of hygiene in food preparation, and the appropriateness of different bean dishes for different age groups and individuals. Members of the community from different backgrounds and age groups tasted and evaluated the prepared food for their overall acceptance and such attributes as taste, flavor, and appearance. Following the competition, winning recipes were promoted in the community.

Objective 4: To Increase the Capacity, Effectiveness and Sustainability of Agriculture Research Institutions that Serve the Bean Sector in Uganda and Rwanda

The training programs of two M.Sc. Ugandan students at Makerere are essentially completed. Two new MSc. students at Makerere University are making contributions to the project. Another student from KIST wrote an initial research proposal and helped with KIST B.S. students in their research. In Rwanda, four undergraduate student projects are progressing. Two Ph.D. students are making excellent progress on their research

Project collaborators in VEDCO, Makerere, and NaCRRI communicate regularly and co-organize events and activities in Kamuli. Occasionally, Ugandan collaborators visit the Rwandese collaborator and vice versa.

Networking and Linkages With Shareholders

- NaCRRI recently received more than 200 nutri-bean lines from the University of Nairobi through CIAT for multiplication.
- Collaboration has been initiated and a Material Transfer Agreement (MTA) signed between CIAT–Colombia and Iowa State University.
- NaCRRI researchers Michael Otim (entomologist) and Pamella Paparu (pathologist) are developing research activities that will involve advanced training of farmers to identify insect pests (bean aphids, thrips, bean stem maggot, and flower beetles) and diseases (bean root rot, web blight, and bean rust) and participatory evaluation of biological and cultural control for key pests and diseases to reduce crop losses and diseases.
- VEDCO organized the first value chain stakeholder workshop in Kamuli in September 2010, and is committed to achieving success in value chain development for beans and maize.
- ISU faculty members visited Uganda, bringing expertise in agricultural and biosystems engineering, agronomy, development communications, human nutrition, and sociology.

Leveraged Funds

The PIs involved in this project have leveraged more than $92,000 from Iowa State University to partially support the graduate degree training of two Ph.D. students from Uganda in Agronomy and Food Science and Human Nutrition.

Publications

Habanabakize, Telesphore. 2010. "Processing and product development of orange flesh sweet potato and dry beans blended flours for weaning foods." Final project report for B.S. degree. Department of Food Science & Technology. Kigali, Rwanda: Kigali Institute of Science and Technology.

Habiyaremye, Idrissa. 2010. "Potential utilization of improved dry bean in the processing of cereal-legume weaning flour." Final project report for B.S. degree. Department of Food Science & Technology. Kigali, Rwanda: Kigali Institute of Science and Technology.

Karuhanga, William. 2010. "Processing of extruded snack food products using decalaya and colta varieties of bean based flour." Final project report for B.S. degree. Department of Food Science & Technology. Kigali, Rwanda: Kigali Institute of Science and Technology.

Mulinda, Noel Valentin. 2010. "Effects of thermal processing techniques on the functional properties of dry common bean flours." Final project report for B.S. degree. Department of Food Science & Technology. Kigali, Rwanda: Kigali Institute of Science and Technology.

Musaazi, Aisha Nakitto. 2010. "Developing a quick-cooking bean flour." Final thesis for M.S. degree. Department of Food Science & Technology. Kampala, Uganda: Makerere University.

Nkundabombi Marie Grace. 2010. "Processing of cold extruded deep fat fried snack food from bean (RWR22-45 and white variety) based composite flour." Final project report for B.S. degree. Department of Food Science & Technology. Kigali, Rwanda: Kigali Institute of Science and Technology.

Okiror, Simon. 2010. "Analysis of Factors affecting market participation of smallholder bean farmers in Kamuli district, Uganda." Thesis for M.S. degree. Department of Agricultural Economics & Agribusiness. Kampala, Uganda: Makerere University.

Combining Conventional, Molecular and Farmer Participatory Breeding Approaches to Improve Andean Beans for Resistance to Biotic and Abiotic stresses

PI-MSU-1

Principle Investigators

James D. Kelly, Michigan State University, USA

Eduardo Peralta, Instituto Nacional Autonomo de Investigaciones Agropecuarias (INIAP), Ecuador

Louis Butari, Institute des Sciences Agronomique du Rwanda (ISAR), Rwanda

Collaborating Scientists

George Abawi, Cornell University, USA

Sieglinde Snapp, Michigan State University, USA

Abstract of Research and Outreach Achievements

The bean breeding program at MSU recently released a new black bean variety, *Zorro*. The variety was the highest yielding black bean grown across six locations in statewide trials in Michigan in 2010. Zorro produced an average yield of three tons per hectare and top yields exceeded 3.7 tons at two locations. Zorro's first major production year was 2010, and it has exceeded growers' yield expectations, suitability for direct harvest, and excellent uniform dry down when mature. In trials conducted by Dr. Abawi in Geneva, New York, Zorro had the highest level of resistance to the root rot complex at that location.

In 2010, the first vine cranberry bean variety, *Bellagio*, was released by MSU. The variety has improved plant structure, uniform maturity, excellent seed quality for canning, and resistance to anthracnose and bean common mosaic virus. In statewide trials in 2010 it outperformed the commercial variety Chianti.

The program continues to evaluate black, navy, red, pink, pinto, great northern, and kidney lines for resistance to common bacterial blight, rust, white mold, virus and anthracnose, and drought tolerance. In New York, root rot screening of new germplasm from MSU and Puerto Rico was conducted in the field and selections were made and returned to the research programs for use in breeding; greenhouse screening of lines from Ecuador against Rhizoctonia was also conducted.

In Ecuador two new bean varieties were released to farmers in the Choto Valley. INIAP 481 Rojo del Valle is a large-seeded red mottled type and INIAP 482 AfroAndino is a small black-seeded variety released for the canning industry. The varieties were released through evaluation and participatory selection with members of the CIALs in the provinces of Carchi and Imbabura. The program expanded grower participatory variety selection to seven new CIALs in 2010 and continues to refine its nonconventional seed production in the Mira and Chota Valleys with specialized seed growers. More than 17 tons of basic seed of seven varieties was produced for distribution to growers in the region. The expansion of the Portillo red mottled variety into a broad area of the Intag Valley supports the substantial outreach component of the program as well as the interest and need for new bean varieties in the region. In Rwanda, the breeding dramatically expanded the crossing program and successfully produced 24 tons of breeder seed that were distributed to NGO partners, who multiplied more than 100 tons of bean seed for distribution to farmers in small quantities. Seven climbing bean varieties for mid to high altitude zones, three semi-climbers, and four bush bean varieties for low to mid altitude zones, and one snap bean variety were officially released in 2010.

Project Justification and Objectives

Common bean (*Phaseolus vulgaris* L.) is the most important grain legume consumed in Ecuador and the most important protein source in Rwandan diets. Around 120,000 hectares of beans are cultivated annually in Ecuador, and common bean is the most widely grown pulse in Rwanda on 300,000 hectares. Both bush and climbing beans constitute an important economic income for farmers, staple food for thousands of Ecuadorian families, and the crop for the vast majority of small scale farmers in Rwanda. Improvement of bean genotypes for Ecuador environments has a potentially significant spinoff for adaptation to Rwanda upland farming systems, which is one of the most bean-dominated production areas in the world. Smallholder farmers, many of them widows supporting families, are keenly

interested in rebuilding their bean genetic stocks and expanding into new market opportunities as stability has returned to their country. Building on international bean germplasm, particularly the Ecuador experience and germplasm, presents a tremendous opportunity to develop and deploy improved bean varieties in Rwanda, using the latest molecular and client-oriented plant improvement techniques. An improved understanding of plant traits and genotypes with resistance to multiple stresses from abiotic (e.g., drought) and biotic (root rot and foliar pathogens) sources provide unique materials for small-holder farmers, while also providing insights into plant tolerance mechanisms for enhanced plant breeding methods. Results of this project contribute to improved yield, farm profitability, and human resources in the host countries and indirect benefit to participating U.S. institutions and bean producers.

Objectives

1. Develop through traditional breeding and marker-assisted selection (MAS) a range of large-seeded Andean bean germplasm, with differing combinations of resistance to major foliar diseases in contrasting bean growth habits for distribution and testing in the highlands of Ecuador, Rwanda, and the Midwestern United States.

2. Develop inbred backcross lines in a range of commercial seed types for testing under drought and root rot pressure in Ecuador, Rwanda, and the United States.

3. Collect and characterize pathogenic and genetic variability of isolates of root and foliar pathogens in Ecuador and Rwanda.

4. Employ participatory plant breeding to assist the breeding process in Ecuador and Rwanda to enhance productivity and marketability of beans under development.

Research and Outreach Approaches, Results, and Achievements

Objective 1: Develop a range of large-seeded Andean germplasm for Ecuador, Rwanda, and the United States.

The MSU breeding program released a new vine cranberry bean variety, *Bellagio*. The plant type is less decumbent than the current vine varieties and produces a large (55g) round seed with excellent canning quality. Bellagio is a full-season variety with resistance to anthracnose and mosaic virus. The seed type would have commercial appeal in both Ecuador and Rwanda.

The new black bean variety, Zorro, was the highest yielding bean grown across six locations in statewide trials in Michigan in 2010. Zorro produced an average yield of 3 tons per hectare, with top yields exceeding 3.7 tons at two locations. The year 2010 was the first major production year for Zorro and it would appear to have exceeded expectations of growers in terms of yield, suitability for direct harvest, and excellent uniform dry down when mature.

The performance and acceptance of the new Santa Fe pinto and Fuji tebo bean in different production states in 2010 was encouraging.

Approximately 3,000 yield trial plots were harvested and 2,600 single plant selections were made as part of the MSU breeding program activities in 2010.

Research continues to develop a stable transformation system for common bean. Progress has been slow and the research is no longer a student project but has been fully assigned to the Plant Transformation Center.

In Rwanda, 191 multiple crosses were made to improve commercial and new varieties, mostly of the Andean types in diverse seed color types. The full set of differential materials for angular leaf spot, anthracnose, bean rust, and BCMV that were received from Ecuador, the United States, and Puerto Rico were maintained and used in additional crosses to create new F1 Andean recombinant populations during 2010 A. The harvested F1 populations were evaluated and about 100 individual plant selections were made and advanced for further screening at the Rubona site during 2010 B. A total of 130 new crosses were made during 2010B in the Rubona screen house to generate three- and four-way crosses to incorporate anthracnose in the newly released climbing and bush varieties.

Selection for micronutrient rich lines from advanced populations (F6 to F8) that were introduced from CIAT continued in 2009A. Altogether, 282 advanced lines were selected in the three mid- or high-altitude stations of Rubona (121 lines), Rwerere (107 lines), and Musanze (54 lines). Of these, 77 F8 or F9 homozygous lines were introduced into preliminary yield trials, while individual plant selections will be made among the remaining segregating populations in 2010B.

Under regional and international collaboration, more than 600 breeding or pure lines were received from partner research institutions, notably CIAT Colombia, Ecuador, Puerto Rico, and MSU. They represented different market classes (navies, red kidney, red mottles, large white, carioca, zebra) or sources of different constraints (diseases and nutritional deficiencies). The lines were introduced in the breeding scheme under adaptation and yield trials or as donor parents to improve commercial cultivars (Table 1). CIAT also contributed more than 500 new lines, including NUA, NUV, MAC, and MAB lines as well advanced breeding populations that were bred for high micronutrients content, BCMV, or for adaptability to different agroecological regions. Evaluation and selection among the different nurseries is ongoing.

By building on the previous breeding work and selection and leveraged funding from the Alliance for a Green Revolution in Africa (AGRA), advanced multilocation yield trials and farmer participatory selection were expanded on a wider scale. The final selection and characterization resulted in the release of 15 new bush, semiclimbing, climbing, and snap bean varieties. The major achievement was the release of three new climbing and two semiclimbing bean varieties that were earlier maturing and heat tolerant and were adapted to the semi-arid conditions in the Nyagatare and Bugesera regions of eastern Rwanda. They were selected from 56 and 41 entries that were introduced from CIAT, respectively. The new climbing varieties (MAC lines) matured earlier relative to the traditional climbers and had mean on-station yields of three to four tons per hectare and on-farm yields of 2.2 to 2.5 tons per hectare, ranging in yield from 141 percent to 198 percent over the local checks. The semiclimbers had potential yields of between 2 and 2.5 ton ha-1, about one-and-a-half tons more than the local checks.

The names and characteristics of the 15 new varieties officially released in Rwanda in 2010 are shown in Table 1.

In April 2010, the National Program in Ecuador initiated the release of two new bean varieties: through the process of evaluation and participatory selection with members of the CIALs in Tumbatú (Carchi) and Juncal (Imbabura). A climbing bean type with a cargamento seed type for green shell was also released for the region of Pallatanga.

In Ecuador, crosses were made using parents principally for rust, anthracnose, angular leaf spot-ALS, and Fusarium wilt caused by *Fusarium oxysporum*. Sources of resistance came from both gene pools that have been previously evaluated to confirm resistance.

In the first cycle of 2009–2010, field studies were planted in six new CIALs to test new materials in different seed types, red mottled, white, yellow, red kidney, and blacks. Selection from the best adapted materials was made with members of the CIALs. Selection parameters included plant vigor, yield, and seed quality. Selection was continued for the same traits in the next growing cycle.

Objective 2: Develop inbred backcross lines under drought and root rot pressure.

During this year, 137 intergene pool Recombinant Inbred Lines (RILs) from a cross between SEA 5 (Middle American gene pool) and CAL 96 (Andean gene pool) were sent to Rwanda for future field studies. This population will be evaluated under both irrigated and nonirrigated conditions in Rwanda starting in early 2011.

Preliminary and on-farm participatory trials evaluation and selection identified small red seeded SER 12, SER 13, SER 14, SER 16, and SER 30 lines among the new bush types well adapted to the semi-arid conditions of the Umutara and Bugesera zones of eastern Rwanda. The small red seed types are associated with good taste and red broth color, important qualities in mixed diets with tubers and cereals. The variety SER 16 was the most appreciated by both the male and female participating farmers, traders, and consumers.

Greenhouse experiments at MSU were conducted by Gerardine Mukeshimana to identify bean lines with higher levels of drought tolerance. Eight cultivars with varying levels of drought tolerance were tested in the study. Three experiments were conducted in 9-cm square plastic pots in the greenhouse where moisture is withheld. Since the root is constrained in this system, we were able to investigate shoot mechanisms underlying drought resistance in bean seedlings. Various variables, including wilting, leaf abscission, maintenance of stem greenness, recovery after resuming irrigation, pod number yield, and biomass were recorded. For wilting, leaf abscission, and stem greenness traits, the cultivar Jaguar showed less wilting as well as less leaf senescence and stem greenness followed by Phantom in all cases. Cultivar B98311, which has a deep tap root that sustains it through intermittent droughts was the more susceptible in this study based on the above variables. The capacity of seedlings to set pods after the recovery from the drought was determined. Researchers hope to better separate root and foliage responses to drought so that these can be combined into a single cultivar to further enhance tolerance to drought.

Replicated field evaluation trials consisting of a total of 40 bean materials were established in the experimental bean root rot field at the Vegetable Research Farm of the NYSAES near Geneva, New York. Twenty-six of the entries came from MSU, while the other 14 entries were selected from the 2009 bean evaluation trials conducted at the same location with bean germplasm provided by Drs. Porch, USDA/P.R., and Kelly, MSU; and the NY Bean Breeding Program. Root rot development was only moderate due to the dry and warm weather conditions that prevailed during the early part of the 2010 season; however, the tested materials differed considerably in their reaction to root rot diseases that prevailed at this location, primarily those caused by *Fusarium solani* f. sp. *phaseoli*, *Pythium ultimum*, and *Rhizoctonia solani*.

Other activities include a greenhouse test to characterize selected bean lines/germplasm for reaction to Cucumber Mosaic Virus (CMV). In addition, three greenhouse tests were conducted to determine the most effective inoculum pressure for assessing the reaction of promising bean germplasm against infections by *Rhizoctonia solani* (Rs). Pinto Zapata and Cornell's 2114-12 have exhibited the highest tolerance to Rs in these tests. Finally, we are currently testing a modification of a protocol for assessing the reaction of bean lines to infection by the Fusarium-wilt pathogen, *Fusarium oxysporum* f. sp. *phaseoli*.

In Ecuador, drought tolerance from the best Middle American sources L88-63 black and RAB651 red lines was introgressed into six inbred backcross IBL F8 lines from this program. White, yellow (canario), and red mottled seed types were selected under conditions of terminal drought at the research farm in Tumbaco. In the same cycle, 44 RILs with potential resistance to root rots were evaluated and 13 lines were selected for drought tolerance, yield, and seed quality in red mottled types. In the second cycle (January 2010), the same lines were evaluated under terminal drought, and seven high-yielding lines were identified with resistance to rust superior to Portillo and Concepcion check varieties.

Eighteen cranberry lines developed at MSU were evaluated for resistance to *F. solani* in the greenhouse at the Santa Catalina station. Only one line was resistant along with NSL parent and Negro Bola Pallatanga. This represents a major advance as the resistance was effectively moved from small-seeded black bean to larger seeded cranberry bean.

Objective 3: Characterize pathogenic and genetic variability of isolates of root and foliar pathogens.

Anthracnose was a problem in Michigan in 2010. Isolates were collected from growers' fields and all typed out as race 73. Adequate levels of resistance to this MA race are present in current cultivars, but farmers continue to plant bin-run seed of susceptible varieties without having them verified as disease free. The problem is most obvious on white beans because the anthracnose lesions are quite noticeable but is less obvious on black beans, where the problem continues to persist.

Rust was collected again from bean fields in Michigan, but it was more widespread and severe in 2010. The strain is similar to that collected over the last three seasons. The new strain characterized as race 22-2 defeats many of the current resistance genes deployed in Michigan. A similar race 20-3 was recently detected in North Dakota. Resistance has been identified in elite MSU black and navy bean germplasm and crossing has been initiated to transfer resistance. Given the persistence of this race, an extensive screening of all MSU germplasm is being conducted in the greenhouse this winter.

The collection of new samples of leaves, roots infected with major pathogens (angular leaf spot, bean rust, and anthracnose) has been a continuous activity in Rwanda since 2009. This activity has been ongoing mainly in the east and southern Rwanda. A fresh and more extensive sample collection is expected in the current season and their characterization by conventional and molecular means is planned in collaboration with MSU and Cornell.

Fusarium wilt is becoming an increasingly serious disease in many bean production areas of Ecuador. In addition, some of the most recently released varieties have proven susceptible to the disease in certain localities. The program initiated the collection of isolates of Fusarium oxysporum in the localities of Urcuquí, Pablo Arenas, and Intag. Some of these isolates did not prove to be pathogenic, so additional collections will be made in order to have a virulent isolate for greenhouse screening. Dr. Abawi is assisting the local pathologist with the process of isolate identification and screening methodologies, since field screening at Tumbaco is limited to a specific region of the farm where the pathogen currently is localized.

Objective 4: Employ participatory plant breeding to enhance productivity and marketability of beans under development.

Several on-farm sites were planted to demonstrate the performance of improved varieties versus the local ones in Rwanda. In particular, trials were conducted on the effect of different combinations of fertilizers on yield of an improved variety, RWR 1668, and a local mixed variety (LM—Local Mixture) at nine locations in the Nyagatare district where livestock farming is common. Overall, combinations of organic (farm yard manure—FYM) and inorganic (NPK) amendments produced the best effects. Improved variety RWR 1668 had better yield than the check local variety across sites and fertilizer treatments.

In each of the last two growing seasons, at least 10 tons of breeder and prebasic seed of old, prereleased, and released bush or climbing bean varieties were produced on different research stations. In 2010B alone, 13.9 tons of seed were produced in seven stations. Seed was sold and distributed to farmers and farmers' cooperatives; NGOs, such as ADR;, and to RWASECO, IMBARAGA, DERN, COAMV, and RADA partners for secondary seed multiplication and distribution to more farmers. Under this arrangement, more than 100 tons of basic and certified seed was produced by these partners and thousands of households were expected to be reached under the strategy of small seed packages (0.5 kg, 1.0 kg, 2 kg, 5, 10, 50 kg) for distribution.

Evaluation and participatory selection of bush bean germplasm with local CIALs continued in Ecuador. In the two growing cycles, different colored breeding lines were evaluated in six new CIALs in the Salinas and Choto valleys. During the same two growing cycles at the end of 2009 and the beginning of 2010, more than 17 tons of seed of the bush bean varieties Portilla, Rojo del Valle, Rocha, Canario de Choto, Afroandino, Concepción, and Paragachi Andino were multiplied by eight specialized seed growers in CIALs in the Choto and Mira Valleys.

In a new CIAL in the Mira Valley, four red kidney beans and six black bean varieties were planted with the intention of providing beans for the industrial canning market. The farmers selected BRB 195 and DRK 105 red kidney types and three black bean lines: G21212, L88-63, and Negro San Luis. These lines will continue to be tested to confirm their suitability to this region and their potential for the canning industry.

Networking and Linkages With Shareholders

Jim Kelly has visited the Agricultural Officer, Ryan Washburn in the USAID Mission in Kigali, on two occasions to discuss the role and work of the PULSE CRSP in Rwanda and to introduce HC partners Mr. Musoni and Ms. Mukeshimana. The Mission in Quito is aware of CRSP activities in Ecuador and publications of the project on variety releases and bean production practices prepared by INIAP were provided to the Mission Director during a visit made by the PI in 2006 and again in 2010.

Networking was seen as critical in technology development and reaching out to the intended beneficiaries of the project. ISAR and the bean program strengthened its collaboration with internal, regional, and international partners to carry out participatory research, demonstration, and dissemination of new innovations to farmers and other end users. In the country, there was increased support from government funding. Stronger linkages and collaboration were built with more than 30 partners under the government extension services (Rwanda Agriculture Development Authority [RADA]); local and international NGOs, such as Rwanda Development Organization (RDO), DERN, CRS, AFRICARE, and ADRA; seed companies such Rwanda Seed Company (RWASECO); farmers cooperatives, such as One Acre Farm (TUBURA), COAMV, GFRWACO, and many other cooperatives under the umbrella federation URUGAGA IMBARAGA spread across the country.

The project also forged closer collaboration with the Kigali Institute of Science and Technology (KIST). ISAR provided KIST with four additional newly released varieties for postharvest and processing studies under CRSP MSU/ISU collaboration.

Two seminars were organized in Bujumbura (April) and in Rwanda (June), bringing together all actors in the research, training (University of Rwanda), and seed chain (NGOs, seed companies, private) in Burundi and Rwanda, and in Rwanda respectively.

Five posters and more than 500 brochures and technical notes were made and were used to disseminate information about varieties and integrated agronomic management practices. A technical booklet was written in English and translated into the local Kinyarwanda language for mass production and distribution to farmers.

The program interacts with the following NGOs in Ecuador: PRODECI, PRODER, CRUZ ROJA, Agricultural Organizations; COPCAVIC, 10 CIALs, Grupo de Evaluadores de Frijol de Bolivar, Assoc. de Productores de Frejol de INTAG. Government Organizations; MAGAP, INIAP, Univ. Tecnia del Norte, and Univ. Catolica de Ibarra.

Publications

Kelly, J.D., G.V. Varner, and B. Long. 2010. Registration of "Santa Fe" pinto bean. *J. Plant Registrations* 4:12-16.

Kelly, J.D., G.V. Varner, and E.M. Wright. 2010. Registration of "Bellagio" cranberry bean. *J. Plant Registrations* 4: 171-174.

Kwapata, K., R. Sabzikar, M. B. Sticklen, and J. D. Kelly. 2010. In vitro regeneration and morphogenesis studies in common bean. *Plant Cell Tiss Organ Cult: J. Plant Biotechnology.* 100:97–105.

Musoni, A., P. Kimani, R. D. Narla, R. Buruchara, and J. Kelly. 2010. Inheritance of Fusarium wilts (*Fusarium oxysporum* f. sp. *phaseoli*) resistance in climbing beans. *African J. Agric. Res.* 5(5):399-404.

Heilig, J.A. 2010. *Evaluation of dry bean genotypes for performance under organic production systems; Evaluation of early nitrogen fixation in dry bean.* M.S. thesis, Michigan State University, East Lansing MI. 139pp.

Musoni, A., L. Butare, D. Mnkubana, E. Gasigwa, F. Nsanzabera, M. Blair, and R. Buruchara. 2009. Climbing beans for increased productivity: Participatory selection of new varieties adapted in semi-arid regions in Rwanda. In *Proceedings of International Conference on Program for African Seed Systems.* Alliance for a Green Revolution in Africa (AGRA). Bamaako, Mali. October, 2009.

Extension publications were published on new varieties in the U.S.; in Spanish, in Ecuador; and in Kinyarwanda, in Rwanda.

Variety release name	Research code	Zone (masl)	Maturity (months)	Yield (t/ha)	Special characteristics
ISAR-CB-101	RWV 2070	1600 -2010	3.0 - 4.0	4.5 - 5.0	Resistant to Anthracnose and BCMV
ISAR-CB-102	RWV 1129	1600 - 1800	3.0 - 3.5	3.5- 4.0	Early, marketable seed type; BCMV & Root Rot resistant
ISAR-CB-103	Gasirida	1600 -2200	3.0 - 3.2	4.5 - 5.0	Marketable large purple; early maturing climber with high yield and wide adaptation
ISAR-CB-104	CAB 2	1800 - 2200	3.5 – 4.0	4.5 - 5.0	Navy with canning quality and high urban market; Root Rot, Ascochyta & Anthracnose resistant
ISAR-CB-105	MAC 49	1400 - 1600	2.7 – 3.0	2.5 – 3.0	Heat & drought tolerant; extra early; Rust & CBB resistant
ISAR-CB-106	MAC 9	1400 - 1600	2.7 - 3.0	3.0 - 3.3	Heat & drought tolerant; extra early; ALS, RR resistant
ISAR-CB-107	MAC 44	1400 - 1600	2.8 - 3.0	3.0 - 3.5	Heat & drought tolerant; extra early; BCMV, Rust resistant
ISAR-SCB-101	SER 30	1000 - 1400	2.0 - 2.5	2.0 - 2.2	Drought tolerant
ISAR-SCB-102	SER 16	800 - 1400	2.0 - 2.5	2.0 - 2.5	Drought resistant
ISAR-SCB-103	RWR 2245	1000 - 1600	2.0 - 2.5	1.5 - 2.0	Highly marketable red-mottled grain type
ISAR-BB-101	RWR 1180	1000 – 1400	2.0 - 2.3	1.2 - 1.5	Highly marketable red-mottled grain type
ISAR-BB-102	RWR 2154	1400 - 1700	2.5 - 2.6	1.5 - 2.0	ALS tolerant; sugar grain type with export potential
ISAR-BB-103	RWR 3042	1500 - 1800	2.5 - 3.0	2.0 - 2.5	Multiple tolerance to diseases; red-kidney for high market
ISAR-BB-104	RWR 2076	1200 - 2000	2.5 - 2.7	1.5 - 2.0	Plastic adaptability marketable red-kidney
ISAR-SB-101	Pyramide	1500 - 1700	1.5 - 1.6	5.0 - 7.0	Snap bean variety for export

Table 1. High yielding climbing and bush beans varieties released by ISAR bean program in January 2010.
CB = Climbing; SCB = Semiclimbing; BB = Bush; SB = Snap bean varieties

Expanding Pulse Supply and Demand in Africa and Latin America: Identifying Constraints and New Strategies

PI-MSU-2

Principle Investigators

Richard H. Bernsten, Michigan State University, USA

Cynthia Donovan, Michigan State University, USA

David Kiala, Universidade Agostinho Neto (UAN), Angola

Feliciano Mazuze, Instituto de Investigação Agrária Moçambique (IIAM), Mozambique

Juan Carlos Rosas, Escuela Agricola Panamericana—Zamorano (EAP), Honduras

Abstract of Research and Outreach Achievements

Angola. MS student Chaves' visits to Luanda's market are pending his field research in 2011. Chaves' U. Vicosa advisor recommended more time for studies before he develops a thesis proposal. World Vision will provide price data for beans in the Planalto. A national parastatal marketing chain has been identified as a buyer of local beans with expansion potential. Two UAN students, who conducted surveys in two zones of Huambo Province to better understand smallholder production and marketing systems, completed their respective theses based on interviews with traders and farmers. The baseline document from the smallholder survey with the World Vision ProRenda project was finalized and results were presented to stakeholders and USAID. About 60 percent of households produce beans; almost none cultivate cowpeas. Beans are a major income source for farmers in the ProRenda target zones. Donovan conducted a class on agricultural policies, focusing on price policy for 35 UAN undergraduates and faculty.

Mozambique. Traders visited during the Windshield market information survey indicated higher use of cell phones, less waiting time for transit, and demand for 24-hour bank machines. A preliminary bean and cowpea report was drafted but will be revised to incorporate maps based on recent GIS training and price analysis. The SABREN and PSU projects have been contacted about collaborating with MSU. The MS student's University of Pretoria advisors requested delaying developing her research proposal until she completes research methods and econometrics courses. The 2002–2008 TIA (household) data are available. Combined with information from rapid appraisals and price data collected through the market information system (SIMA), the student will have access to an excellent data set. SIMA data continue to be collected weekly for beans and cowpeas.

Honduras. The project was refocused to produce third party certified fair trade (FT) beans. Whole Foods Markets prefers FT certification via IMO and agreed to buy 20 mt of beans for delivery in late 2011. Based on the results of ECOFRIJO trials (organic vs. conventional beans), CIALs from Yojoa Lake implemented organic fertilizer production. Organic fertilizer was produced using compost and/or bokashi techniques. Practices to control diseases and insects are being used by these farmers. Previously, two farmer groups expressed interest in organic bean production. Both groups participated in training activities and the ECOFRIJOL trial, but during the current year we continued to interact only with the Yojoa Lake CIALs. Data were collected to estimate the supply-chain related costs for marketing beans. We determined that the farmer association is able to process the beans and a broker has agreed to provide export-related services.

Capacity Building included MS training in South Africa and MS training in Brazil. Short-term training was conducted in Mozambique.

Project Justification and Objectives

Markets are critical to farmer adoption of new technologies and management practices because they offer farmers an opportunity to specialize and take comparative advantage to capture gains from trade. Market-oriented pulse production depends on many factors in addition to technology, including the level of pulse prices and price risk, quantity premia and discounts, and the cost of bringing products to market. These factors are influenced by the level of market infrastructure and public and private institutions, including enforceable contracts (to reduce risk), formal grading systems, the availability of price information, the ability of farmers to reduce transaction costs via membership in an association, and the physical proximity of markets. Pulse markets in Angola, Mozambique, and Honduras present a continuum in terms of the level of market infrastructure. Angola is characterized as having minimal price information, low yields/production, unpredictable market channels, and poor quality— although improving—infrastructure. Mozambique is characterized by a relatively effective market information system, low yields/production, and some farmer organizations, but minimal production for markets (market participation) due to a lack of information on quantity and demand. In contrast, Honduras is characterized by an effective market information system, strong farmer organizations, widespread adoption of improved bean varieties, market-oriented production, and a potential to produce for specialty and niche markets. The proposed action research will help to better understand how different levels of market development affect incentives for technology adoption—a ladder of learning. A key priority of the research is to expand market opportunities and accelerate the transformation from semisubsistence to commercial farming.

Minimal research has been conducted to identify constraints and opportunities to expanding market participation in the three countries, which is the focus of this project.

Angola. Improving smallholder productivity and marketed surplus is a key element of the Government of Angola's (GOA) poverty reduction strategy. Expanding bean and cowpea production is key to the strategy's success, since they are the country's most important legume crops (370,000 ha), are grown throughout the country, and have been identified by the government as high potential crops. Currently, imports are required to meet demand, as demand exceeds domestic production. Smallholders are in the process of shifting from subsistence to more market-oriented production, and the GOA is making investments in developing markets. This project contributes to these efforts.

Mozambique. Beans and cowpeas, the most important legume crops after peanuts, have considerable production potential. The Ministry of Agriculture's (MINAG) development strategy recognizes the importance of strengthening value chains for market-led development. Bean and cowpea production flows into different market-sheds, each with different consumer preferences. However, consumer preferences of the different markets are not well documented. To date, little work had been done to improve the market performance and the sustainability of dry pulse value chains, which are the foci of this proposal.

Honduras. Common beans, the second most important food crop (95,000 ha) after maize, are an important source of cash income for smallholders. However, typically most smallholders sell their surpluses to traders at the farm-gate and receive low prices. With the recent ratification of CAFTA, bean imports are expected to increase, thereby reducing bean prices and farmers' incomes. Smallholders need new markets that will add value to their crops. This project focuses on developing a new market opportunity for smallholders producing and exporting organic fair trade beans to the U.S. market.

Objectives

1. To better understand bean and cowpea production and marketing in Angola, including the identification of market channels and marketing margins with the goal of identifying constraints, opportunities, and potential pilot interventions to improve competitiveness.

2. To understand spatial and temporal patterns of bean and cowpea production and marketing in Mozambique, including the mapping of market-sheds, documentation of market preferences, and econometric analysis of market participation by producing households, including sex of household head, as an explanatory variable.

3. To contribute to the establishment of local market linkages required for smallholder bean farmers in Honduras to export organic fair trade beans to U.S. markets

Research and Outreach Approaches, Results, and Achievements

Objective 1: Angola.

Subobjective 1.1: Summarize secondary data on bean and cowpea production and marketing, including the identification of gaps to guide future research; Visit Key Informants to Identify Information and Data Sources. Market visits in Luanda for the major consumption market are pending Esteveo Chavez's field research in 2011. World Vision will provide price data for common beans in the Planalto, but there is no price dataset for cowpeas in the country. The national parastatal marketing chain Nosso Supermercado has been identified as a buyer of local beans with expansion potential.

Subobjective 1.2: Identify production areas, marketing channels, and marketing margins. Based on interviews with farmers and traders in two key markets areas of the Planalto, the two undergraduate students from UAN have successfully completed their theses. Robertinho Txocaine's thesis is titled *Identificação de circuito de comercialização a Londuimbale (Identification of marketing channels for Londuimbale)* and Adolfo Catuti's is *"Identificação de circuito de comercialização a Bailundu" " (Identification of marketing channels for Bailundu).* Txocaine's research identified constraints in both input provision and output marketing in Londuimbale, resulting in low profitability of beans for farmers. Catuti found that farmers could profit by transporting and selling their beans directly in the Huambo market, but market uncertainty and transport scarcity constrains farmer access to the Huambo market. Instead, the majority sell to traveling traders in the closest market.

Subobjective 1.3: Identify constraints, opportunities, and potential pilot interventions to improve competitiveness. The baseline document from the smallholder survey with World Vision ProRenda project was finalized in early 2010 and the data are available for student research. The results were presented to various stakeholders, primarily World Vision staff members and UAN faculty member Kiala. Donovan talked about the diagnostics on farmer marketing, identifying potential problems, which were then discussed by participants, related to World Vision extension activities with farmers. The sales strategies used suggest dependence on itinerant farmers in the region as well as on local markets, with basically no information systems in place, a gap that World Vision is seeking to fill through extension agents.

About 60 percent of the households in the zones under study produce common beans, but almost no households cultivate cowpeas. Common beans are a major income source for farmers in the ProRenda target zones. Women farmers tend to get higher prices for the beans that they sell, resulting in higher total revenues, even though they produce an average of only 112 kilograms, selling 75 percent of production, compared to 314 kilograms produced among males, of which 86 percent is sold.

Objective 2: Mozambique.
Subobjective 2.1: Analyze spatial and temporal patterns of bean and cowpea production and marketing, using national survey data (TIA), disaggregated by gender. The Windshield survey indicated higher use of cell phones by all traders, less waiting time for transit, and continued demand for 24-hour bank machines, compared to the 2008 survey.

Subobjective 2.2: Map marketsheds for bean and cowpea production areas, document market preferences, and work with breeders to test varieties with desirable market characteristics to improve competitiveness and spur adoption of improved bean and cowpea varieties. Stakeholders in Mozambique are more likely to organize around concrete substances, such as varietal release, market information, and policy decision making. With the increasing emphasis on value chains, the Bean/Cowpea Task Force will be convened in early 2011. The SABREN and Penn State Pulse projects have both been contacted about collaborating to move this forward with the MSU project.

Subobjective 2.3: Capacity building with MS student undertaking econometric analysis of the determinants of market participation by producing households, including sex of household head as an explanatory variable. The MS student was delayed in her studies at the University of Pretoria and is only now developing the analytical skills necessary to conduct the econometric analysis. Her advisors have requested that the development of the research proposal await her completion of the research methods and econometrics courses in early 2011. Donovan met with one of her research advisors in September 2010 and confirmed that they will be incorporating Mozambican bean and cowpeas research into her plan. The 2002–2008 TIA (household) data are available and, combined with information from rapid appraisals and the price data collected through the market information system, SIMA, will provide an excellent set of data for her research. The SIMA data continue to be collected on a weekly basis in several relevant markets for common beans and cowpeas, and so the dataset evolves.

Objective 3: Honduras.
Available evidence indicates that there is a demand for fair trade, organic small beans in the United States. A recent study found that there was considerable interest among U.S. retailers (who market organic and ethical food products) in purchasing and selling fair trade organic small-red beans. Leaders and farmer-members of the cooperative ARSAGRO expressed strong interest in growing small-red beans for export to the United States, which met USDA organic and Rainforest Alliance standards for sustainably produced and fair trade beans. Currently, approximately 500 members of this cooperative plant more than 1,000 hectares of beans in the primera season.

Subobjective 3.1: Put in place arrangements for exporting small-red beans from Honduras to U.S. retailers, which are certified as organic and produced using sustainable production practices. Due to the costs and difficulties in obtaining organic certification and insuring that farmers comply with organic standards, the project was refocused to produce third-party certified fair trade beans. We will obtain fair trade certification through IMO.

The bulk commodity buyer at Whole Foods Markets' headquarters in Austin, Texas, has agreed to purchase 20 mt of fair trade beans from the farmer association at the price the farmers requested. The date of delivery was set as August 2011. However, due to extremely heavy rains this year, we are now planning to produce the beans for export to Whole Foods Markets during primera 2011 (May–August).

Subobjective 3.2: Validate via field trails existing agronomic recommendations for growing organic small-red beans. Based on the results of ECO Frijol field trials comparing organic vs. conventional bean production conducted in 2009–10, several Local Farmer Research Committee (CIAL) from the Yojoa Lake have implemented organic fertilizer production in their communities. In those sites where farmers use very low inputs, the organic practices gave better yield, resulting in increase of bean productivity. In those sites where farmers use some inputs (chemical fertilizers and pesticides), yield was similar to or less than from conventional practices; however, organic practices are considered a good alternative because of the increasing costs of fertilizers and pesticides and the similar productivity observed in organic plots. Farmers are aware of the effect chemical products have on the environment and are in favor of organic alternatives.

Most organic fertilizer is produced on the farm, using compost and/or bokashi techniques and includes crop residues, chicken or cow manure, household garbage, and other organic waste materials in their preparation. Additional natural practices to control diseases and insects that affect the bean crop are also being used by these farmers. The use of insect trap plants, such as sunflower and eggplant, to facilitate the control of bean pests attracted to these plants is also recommended.

Several farmers from CIAL and NGO technical personnel that assist them were trained under the project in practices for organic production of beans in previous years. This training has been offered in collaboration with the Organic Agriculture Unit from Zamorano. The project has facilitated the construction of modest shaded spaces for preparation of organic fertilizer and natural pesticides.

Subobjective 3.3: Recruit interested smallholders and train the farmers to produce organic small-red beans that meet the grades and standards required by U.S. retailers. In previous years, two farmer groups were identified as potential candidates for involvement in the production and export of beans produced under project assistance. Meetings were held with the leaders and farmer members of ARSAGRO—one of the largest bean farmer association in Honduras. The PIs outlined the goals of the project, including the requirements that the beans be grown in accordance with organic and sustainable production practices. The association members noted that Danli was a good place to grow beans and expressed interest in participating in the project. The association recently built a new processing and bagging facility. The association is a major player in domestic bean marketing and has previously made export sales to traders. We have also met with CIALs (farmer groups involved in participatory plant breeding activities) that have expressed a good level of interest in getting involved in organic bean production.

Small and poor farmers from the hillsides of Yojoa Lake and Yorito with very small plots to cultivate or landless farmers that have to rent land season by season are interested in using organic practices to improve bean productivity. In contrast, farmers from the large organization ARSAGRO, who have better land and access to fertilizer and pesticides, expressed less interest in organic farming last year. During the current year, we have continued to interact only with the CIALs from the Yojoa Lake.

Subobjective 3.4: Identification of Private Sector Agents. Data were collected to estimate the supply-chain related costs associated with marketing the beans under several alternative arrangements (e.g., contracting various parties to clean the beans, transporting a container to the village and then to Puerto Cortez, fumigating the beans, clearing the beans through Honduran and U.S. customs, and shipping the bean to a U.S. port.) We determined that the farmer association is able to clean and polish the beans themselves and have contacted a broker who has agreed to provide export-related services (e.g., transporting a container to the village, transporting the packed container to Puerto Cortez, fumigating the shipment, completing U.S. Customs' paperwork, making sea transport arrangements with an export and shipping company) and ship the beans directly to Whole Foods Markets. Thus, based on analysis of these alternatives, it was decided to contract IMO to certify the beans as fair trade, have the farmers clean and polish the beans themselves, contract a Honduran broker to provide local services (i.e., transport a container to the village and then to Puerto Cortez, and to clear the shipment through customs). The project will obtain permission from the Honduran government to export the beans and make arrangements with a broker for shipping the beans to a U.S. port for delivery to Whole Foods Markets.

Networking and Linkages With Stakeholders

Angola: MSU and UAN have continued to collaborate with World Vision on their Gates Foundation Project on Horticultural Value Chains. The smallholder baseline survey and the data from that survey are some of the only farm level data available in Angola. Unfortunately, cowpeas were found among very few farmers in the zone, limiting the focus to common beans.

Donovan and Kiala have met with the Food Security Department (DSA) of the Ministry of Agriculture in Angola which is developing a market information system. The system is not functional, and DSA has requested UAN and Pulse CRSP assistance in developing a training program for market information. Donovan will work with them in forthcoming trips to Angola. The working relationship between IIA (Angolan Research Institute) and UAN is strong and both are based in Huambo, facilitating the linkages. There are two other Pulse CRSP activities in Angola, both based with IIA. Continued discussions with the breeding program with the University of Puerto Rico will be particularly important as work on the value chain proceeds.

Among the private sector agents, only Nosso Super (supermarket chain) has been contacted.

Mozambique: This is the area of greatest weakness in the project and will be a focus as collaboration between SABREN and Pulse CRSP Pennsylvania State University projects develops. The joint meeting with IIAM breeders and other stakeholders is scheduled for early 2011. Collaboration with the Pulse CRSP Penn State University project will enable the MSU project to complement Penn State farmer-level research by evaluating the outputs markets in their research zones for the 2011 harvest period. SABREN is working simultaneously on seed systems diagnosis.

Leveraged Funds

The Michigan State University and the Escuela Agrica Panamericana–Zamorano PIs in this CRSP project have successfully leveraged external funding for additional research and outreach activities on beans and cowpeas in Angola, Mozambique, and Honduras

Publications

None in 2010

Improving Bean Production in Drought-Prone, Low Fertility Soils of Africa and Latin America– An Integrated Approach

PI-PSU-1

Principle Investigators

Jonathan Lynch, Pennsylvania State University (PSU), USA

Juan Carlos Rosas, Escuela Agricola Panamericana (EAP), Honduras

Magalhaes Miguel, Instituto de Investigacao Agraria de Mocambique (IIAM), Mozambique

Collaborating Scientists

Celestina Jochua, Instituto de Investigacao Agraria de Mocambique (IIAM), Mozambique

Jill Findeis, Pennsylvania State University (PSU), USA

Soares Xerinda, Instituto de Investigacao Agraria de Mocambique (IIAM), Mozambique

Kathleen Brown, Pennsylvania State University (PSU), USA

Abstract of Research and Outreach Achievements

In the past year, significant progress was achieved in all activities connected to the project. Numerous genotypes were screened for root traits conferring adaptation to drought and low soil fertility. These include inbred backcross lines developed at Zamorano and IIAM to introgress superior root traits into elite cultivars and a range of genotypes from Africa and the CIAT core collection. Further evidence was obtained for the value of two novel root traits, BRWN and root etiolation, for enhanced P acquisition. A field study in Mozambique showed that bean genotypes with superior root traits conserve soil fertility by reducing soil erosion. Socioeconomic survey data were analyzed, providing useful information for common bean seed preferences based on a broad representation of farmer households across the villages; these will be supplemented in Phase II with PVS activities at the sites. Survey data also include network data to conduct analyses of diffusion of bean seeds through trader networks, seed sharing networks operative at the village level, and the design and greater use of information networks that can be adapted to the needs of local farmers. MS degree training continued for Malawian bean breeder Virginia Chesale, and IIAM researcher Samuel Camilo began his intensive English training at Penn State.

Project Justifications and Objectives

This project is premised on four well-established facts:

1. Drought and low soil fertility are principal, pervasive constraints to bean production in Latin America and Africa.

2. The vast majority of bean producers in poor countries cannot afford irrigation and intensive fertilization.

3. Bean genotypes vary substantially for root traits that determine their tolerance to drought and low soil fertility, making it feasible to increase yields in low-input systems through genetic improvement.

4. To exploit the potential of this approach (#3), we need intelligent deployment of root traits in bean breeding programs and better understanding of the socioeconomic and agroecological factors determining the adoption and impact of stress tolerant crops and cropping systems.

Drought and low soil fertility are primary constraints to crop production throughout the developing world; this is especially true of common bean, which in poor countries is typically a smallholder crop grown in marginal environments with few inputs. Phosphorus limitation is the most important nutrient constraint to bean production, followed by the acid soil complex of excess Al, excess Mn, and low base supply. The importance of nutritional stress in bean production systems of Latin America and Africa cannot be overstated. Fertilizer use is negligible in many developing countries, especially in sub-Saharan Africa, which generally have the poorest soils. What is needed is *integrated nutrient management*, consisting of judicious use of fertility inputs as available, management practices to conserve and enhance soil fertility, and adapted germplasm capable of superior growth and yield in low fertility soil.

We have shown substantial variation in bean P efficiency that is stable across soil environments in Latin America. Analysis of the CIAT germplasm collection identified several sources with outstanding P efficiency—from 100 to 200 percent better than existent checks such as Carioca.

Drought is a primary yield constraint to bean production throughout Latin America and Eastern and Southern Africa. Drought tolerance has been identified in several races of common bean but is complex and associated with local adaptation. Utilization of specific traits in drought breeding through direct phenotypic evaluation or genetic markers (e.g., QTL) would be useful.

Genotypes that are more responsive to inputs may promote the use of locally available inputs in improved Integrated Crop Management (ICM) systems. Several African countries have reserves of sparingly soluble rock P whose effectiveness may be improved by the use of nutrient-efficient bean genotypes. Beans are superior to maize in their ability to solubilize P in their rhizosphere. The introduction of bean genotypes with superior root systems may enhance the utilization of rock P, thereby improving P availability and N availability (through symbiotic N fixation) in maize/bean systems. Similarly, bean genotypes with deeper root systems may be synergistic with soil management techniques to conserve residual moisture. Our project will test these hypotheses.

There is also a need to better understand socioeconomic factors determining adoption of stress tolerant bean germplasm and the likely effects such adoption may have on household income and nutrition.

Drought and poor soil fertility are primary constraints to pulse production in developing countries. Recent developments in our understanding of root biology make it possible to breed crops with greater nutrient efficiency and drought tolerance. Such crops will improve productivity, enhance economic returns to fertility inputs, and may enhance overall soil fertility and system sustainability without requiring additional inputs.

Objectives

1. Develop bean genotypes with improved tolerance to drought and low P.

2. Develop integrated crop management systems for stress tolerant bean genotypes.

3. Understand constraints to adoption of new bean technologies, income and nutrition potential, and intrahousehold effects and impacts.

4. Strengthen institutional capacity of IIAM in Mozambique.

Research and Outreach Approaches, Results, and Achievements

Objective 1: Develop bean genotypes with improved tolerance to drought and low P.

EAP/Honduras: During the past years, three inbred-backcross populations were developed by crossing the small red cultivar Amadeus 77, used as recurrent parent, and the lines L88-13, L88- and L88-63, selected for root traits associated with better adaptation to low fertility and drought conditions by PSU researchers, used as donor parents. Two hundred seventy-five IB lines were screened twice during 2009–10 under field conditions for agronomic adaptation, seed yield, and commercial seed characteristics in a low N and P field plot with no fertilizer application. On these field trials, the IB lines were characterized for their growth habit, days to flowering and maturity, disease reaction and grain yield; seed samples were evaluated for seed color, shape, and size in seed lab facilities.

Fifty IB lines from the previous trials were selected for their greatest similarity in the field and on their seed characteristics with the recurrent parent Amadeus 77 and were evaluated under controlled conditions using the soil cylinder technique containing a soil: sand (1:2) substrate low in N, P, and other nutrients, to determine their differences on root whorl number, basal root number and angle, adventitious roots, root hair pubescence, root length, surface area and volume, and shoot and root dry weight at flowering. The plants were only watered until 20 DAP to provide drought stress conditions. In addition, the same lines were evaluated in the field under NP fertilized and not fertilizer conditions to determine their field performance. From these studies, we are expected to select up to twelve IB lines for testing their individual performance and in mixture under small farmer conditions, where both low fertility and drought occur frequently. The results will provide information for determining the agronomic value of two potential approaches: the use of a more stable multiline cultivar or the use of individual lines that interact more favorable with specific agroecological conditions.

IIAM/Mozambique: *Phenotyping bean root traits*—One hundred and sixty-five (165) bean genotypes from the bean core collection obtained at CIAT were evaluated in the laboratory with the following objectives:

- to access the phenotypic diversity of root traits of common bean,
- to select bean genotypes with root traits adapted to low phosphorus soils and drought, and
- to identify sources of nutrient and drought efficiency.

Preliminary data showed variation in basal whorl number, basal root number, and root hair length. Significant differences were found among genotypes in basal whorl number and basal root number and root hair length at one percent level of significance. The average whorl number varied from one to four, and the average number of basal roots varied from four to 14. The root hair lengths varied from 0.196 to 0.779 mm.

In addition, a positive correlation was observed between whorl number and basal root number evaluated in eight-day-old bean seedlings. The correlation was significant at one percent. This relationship indicates that genotypes with more whorls have the potential of having more basal roots and, therefore, will acquire more phosphorus in the up soil (shallow roots).

More data, including root hair density, are being analyzed. Results from this study indicate high variation in basal root traits, whorl number, and root hair traits in common beans. Sources of phosphorus efficiency, that is, genotypes with more whorls and basal root, and longer and denser root hairs, can be found in the common bean core collection. These traits can be selected directly in the field and used in bean breeding programs to develop bean genotypes tolerant to the low phosphorus soils of Africa and Latin America.

Screening for low Phosphorus and drought tolerance —Several genotypes are being evaluated in the laboratory to identify genotypes with root traits suitable for phosphorus and drought stresses.

About 600 F4 lines from crosses developed in phase one are being screened for root hair traits in the laboratory at PSU. The data are being collected for statistical analyses. In addition, root traits of 150 genotypes from the bean core collection were evaluated in the field in Pennsylvania under low phosphorus conditions. Additional data are being evaluated in the laboratory. Preliminary data showed high variation in adventitious, basal, and primary root traits. We expect to select several genotypes with root traits suitable for soils with low levels of phosphorus. We are still analyzing the data.

Field trial with selected genotypes—A trial was installed in June in Chokwe under drought stress with the objective of identifying common bean genotypes with better yield under drought stress.

Trait synergism—Breeders and farmers need integrated phenotypes composed of positive traits working together to enhance crop performance in target agroecosystems. Interactions among root traits are poorly understood. This activity tests the hypothesis of positive synergism between two key root traits—root hair length and density (RHLD) and basal root growth angle (BRGA).

In this experiment, 86 recombinant inbred lines developed from the cross between DOR364 and G19833 were screened and evaluated for root traits.

The results from the experiment indicate strong synergism between root traits in common bean. Genotypes exhibiting more than one root trait associated with phosphorus uptake efficiency show better performance than the sum of the root traits occurring separately. The results show the importance of the combination of several root traits in the same genotype, a characteristic with potential benefit for crop performance in low nutrient soils.

PSU/USA: *QTL Analysis of Basal Root Whorl Number (BRWN)*—Basal Root Whorl Number plays an important role in determining basal root distribution in soil profile. Genotypes with increased BRWN have roots distributed in such a way that it maximizes the soil volume being exploited by the plant. The objective of this study was to perform a quantitative trait loci (QTL) analysis for BRWN using two populations of recombinant inbred lines (RILs).

Results from the QTL analyses indicated that most of the genes associated with BRWN were found in the same region in both analyses. In addition, few genes were associated with this root trait. This high proportion of variance explained by relatively few QTL suggests that this trait can be used as a criterion for selection of plant materials with phosphorus acquisition efficiency.

Structural-functional modeling of value of root cortical aerenchyma (RCA) for P acquisition in common bean—The geometric simulation model SimRoot was used to test the hypothesis that root cortical aerenchyma (RCA) is a useful trait for bean growth in low P soil by reducing the metabolic costs of soil exploration. The model showed that at low soil P, RCA formation in bean roots could increase plant growth at flowering by up to 80 percent.

Root phenotyping under stress—Fifteen genotypes were screened under drought and low soil fertility and phenotyped for a number of root traits. The traits included basal root whorl number, basal root number, basal root growth angle root hairs, adventious roots, and root length.

Objective 2: Develop integrated crop management systems for stress tolerant bean genotypes.

IIIAM/Mozambique—Evaluation of the effect of P efficient bean genotypes on soil erosion—Water erosion is an overwhelming problem in high rainfall uplands. The major bean-growing areas in Mozambique are located in uplands with high annual rainfall (>1000 mm year-1) and predominant slopes of 4 to 15 percent. Most soils are Oxisols with low phosphorus (P) availability and high P-fixing capacity. P-efficient, shallow-rooted beans can grow fast and attain higher biomass accumulation providing better soil surface cover in low P poor soils.

The study was conducted in Lichinga Agriculture Research Station to evaluate the effect of P-efficient bean genotypes on alleviation of water erosion. The site has an average annual rainfall of 1161 mm, with 996 mm falling in four months (December to March). Soil test Olsen P was eight mg kg-1, pH was 4.9, and SOM was 1.6 percent. We hypothesized that P-efficient genotypes will reduce interrill (raindrop splash and overland flow) erosion as compared to P-inefficient (deeper rooted) bean genotypes. The treatments included two P-efficient genotypes, two P-inefficient genotypes and bare soil. The four genotypes were planted in 1.6 m by 2.0 m lysimeters delimitated with metal sheets pounded to the soil 10 to 15 cm deep to form the microbasins (runoff plots). The fifth plot was left as bare soil control. Two 25 L containers were installed at the down end of each lysimeter for collecting runoff water. The lysimeters were installed in contour lines, which were the blocks in six percent slope terrain. The treatments were randomly placed within a block and replicated five times. Runoff water was measured and water samples were collected in eight natural rainfall events. P-efficient beans had consistently and significantly lower volumes of runoff water as compared to P-inefficient genotypes in the eight rainstorms with runoff. We conclude that bean genotypes with shallow roots are effective in reducing water erosion caused by high intensity erosive rainfalls that are abundant in bean growing areas of Mozambique.

Evaluation of the synergy of water-conserving soil management with drought-tolerant genotypes—An experiment was conducted at the Chokwe Research Station consisting of three moisture techniques treatments (no mulch, mulch at three ton ha-1 of dry crop residues, and microbasins) as main plots, and four genotypes in subplots. The genotypes were two P-efficient and two draught tolerant. The analysis of variance of yield data shows no significant (p=0.6) difference among moisture conservation techniques. There was significant (p=0.008) difference among the four genotypes but no significant interaction of genotype x moisture techniques. The microbasins' mean yield was 1596 kg ha-1, followed by 1548 for plots with no mulch, and 1491 kg ha-1 for plots in which mulch was applied. The results of this year were negatively influenced by an unusually wet year; this year 125 mm of precipitation was well distributed, which interfered with the irrigation schedule set for the trial, leaving plots with mulch with excess moisture, which is not desirable for better bean growth. The two P-efficient Lichinga lines had the highest and similar yields, which differ significantly from Tio Canela with 1294 kg ha-1. The genotype BAT 477 had intermediate grain yield, which did not differ significantly from both Lichinga lines and Tio Canela.

PSU/USA: *Evaluation of the effect of root traits in maize/bean intercrops*—Intercropping is a common practice by small-scale, subsistence farmers. Currently, the most common intercropping system combines maize and bean. Historically in the Americas, maize and bean were often grown in combination with squash, a system commonly referred to as the "three sisters."

While the benefit of these intercropping systems has been studied before, competition or complementarity in nutrient acquisition strategies has never been researched, even though these systems are usually grown on soils low in fertility.

For this study, we studied squash root architecture, which is dominated by a primary root with long laterals, of which some develop into major site branches with much secondary thickening. The strong differences in root architecture of bean, maize, and squash have led to the hypothesis that these species explore different soil layers and are therefore complementary in their nutrient acquisition. We propose that niche differentiation between these species allows intercropping systems to utilize phosphorus and nitrogen resources more efficiently, increasing growth on low fertility soils.

To test our hypothesis we conducted a two-year field experiment in which we grew mono cultures, maize–bean, and maize–bean–squash intercropping systems under phosphorus and nitrogen limiting and nonlimiting conditions. We intensively sampled the system with multiple harvests, taking soil cores, root crowns, and biomass. We also performed a dual tracer study using rubidium and strontium, both a mobile and immobile tracer, to study relative uptake by the individual plants at two depths. Our tracer study indicated that uptake by the three species may not only differ due to root architectural differences but also to kinetic differences.

Objective 3: Understand constraints to adoption of new bean technologies, income and nutrition potential, and intra-household effects and impacts.

Ex ante surveys in four regions of Mozambique were completed in the previous reporting period and were coded in the current period for all regions: Angonia, Lichinga, Gurue, and Sussundenga. Data include (as examples):

1. preferences for specific common bean attributes by male and female farmers at the field research sites,
2. access to improved seed varieties by male and female farmers, and
3. access to information distribution networks relevant to seed adoption and diffusion (e.g., posters, radio, mobile phones).

Preliminary descriptive results (Angonia) indicate the following:

1. Male farmer preferences include (in order of response percent, for responses 60 percent or above) marketability to traders found in village, marketability to traders coming directly to home/farm, lower fertilizer requirements, drought tolerance, potential for intercropping with maize, and potential for intercropping with other crops.

2. Female farmer preferences (in addition to cooking time) include drought tolerance and marketability to traders coming directly to home/farm (as opposed to marketability to traders they find in the village).

3. Statistically significant differences between male and female responses were established for traders in the village (male>female), lower fertilizer requirements (male>female).

4. Males may be more attracted to a bean with good leaves on the plant than females. No difference between male/female rankings for preferences for varieties with drought tolerance, few insect pests, tolerance to plant diseases, and contribution to soil fertility.

5. Male and female responses show no statistical difference for preferences for beans that can be sold in distant markets when the analysis is limited to those who rate this characteristic as very important. However, when responses of very important and important are aggregated, males are more likely to prefer bean varieties that can be sold in distant markets. These preliminary results suggest that some women (approximately 50 percent) strongly prefer beans bred for market regardless of whether they (themselves) can sell directly to traders, whereas others only prefer marketable beans if they (themselves) can sell them directly from the farm/home.

Access to improved seed varieties

1. Access to improved seed—through traders/markets, extension workers, farmer organizations, friend and kin networks both inside and outside villages, NGOs—is limited for both men and women.
2. Women are most likely to receive improved seed from traders/in market, extension workers, kin networks in village, and friend networks in village.
3. Men are most likely to receive improved seed from extension workers, traders/in market, relative networks in village, relative networks outside village, and friend networks in village.
4. NGOs are not found to be active in seed distribution in this region, although approximately 10 percent of women respond that they have received improved seed from NGOs. Very few men or women have received improved seed from friend networks outside the village or from farmer organizations, but relatively few respondents in the sample belong to farmer associations in this region.
5. Small percentages of men and women reported receiving free bean seed in the past.
6. Females report that not having good bean seed is a problem for their households; 60 percent of men do not consider this a problem, resulting in significant differences between men and women in perceptions of ”good bean seed” availability. Analysis with the other village samples is underway to better understand this result.

Information access and seed diffusion channels
Preliminary results indicate that men and women are as likely to have received free seed in small packets in the past (may or may not include beans). Some men and some women have received loans to purchase seeds and others have received seed vouchers, but there is no statistical difference by gender.

The surveys also provide information on bean production, home consumption of beans, bean income receipt, and other indicators relevant to assessing the impacts of introducing phosphorous-efficient beans for farmer use. In addition, this research provides a better understanding of the barriers that men and women farmers face in finding out about new technologies that could benefit them and in securing seed that are consistent with their preferences.

Networking With Stakeholders

Drought and low fertility tolerant small red bean lines developed in previous years were incorporated into the bean network of nurseries and trials that are distributed on a yearly basis by Zamorano to the collaborators from the National Bean Programs of Central America and Haiti. Some of the lines are being validated under on-farm conditions in Honduras, Nicaragua, and El Salvador. In addition, some nurseries that included advanced lines developed by the project were distributed to farmer organizations and NGO involved in participatory plant breeding in the Mesoamerican region (project supported by the Development Fund from Norway). Drought and low fertility tolerant lines have been released at local levels for some of these farmer groups participating in PPB activities in Honduras and El Salvador.

Representatives of the socioeconomic team met with USAID personnel at Maputo in August 2010. Linkages are being built to facilitate low-P seed availability information diffusion via cell phones. This represents a crossover linkage with the Phase II MSU-2 Socioeconomic project. The project team in Mozambique met with Anabela Mabota and Cynthia Donovan and discussed the next steps for further collaboration on mobile technology, price information, and seed information. Trader networks will be of interest to both projects.

The socioeconomic team is starting to work more closely with CIAT in East Africa (Jean Claude R., Louise S.) and will be collaborating on design of diffusion research and potential for social certification policy and schemes.

The project has hired five technicians positioned at the research sites in Mozambique (Gurue, Lichinga, Angonia, Chokwe, and Sussundenga) that will directly be involved in project activities. In Angonia and Gurue, the hiring was made in collaboration with on-site collaborators, such as the Angonia District Directorate of Agriculture (extension services). In Gurue, the identification of the candidate was made in collaboration with World Vision International and CLUSA.

Leveraged Funds

Drs. Lynch and Findeis and their collaborators have successfully leveraged more than $4,100,000 in external funding for research related to root biology and technology diffusion in part due to the assistance received from the Dry Grain Pulses CRSP and the Bean/Cowpea CRSP for work in Mozambique.

Publications

St.Clair, SB, JP Lynch. 2010. The opening of Pandora's box: climate change impacts on soil fertility and crop nutrition in developing countries. *Plant and Soil*, DOI 10.1007/s11104-010-0328-z.

Henry, A, JC Rosas, JS Beaver, JP Lynch. 2010. Root architectural multilines: effects on resource acquisition under stress and belowground competition. *Field Crops Research*, 117:209–218.

Henry, A, NF Chaves, PJA Kleinman, JP Lynch. 2010. Will nutrient-efficient genotypes mine the soil? Effects of genetic differences in root architecture in common bean (*Phaseolus vulgaris*, L.) on soil phosphorus depletion in a low-input agro-ecosystem in Central America. *Field Crops Research*, 115: 67–78.

Postma, JA, JP Lynch. 2010. Theoretical evidence for the functional benefit of root cortical aerenchyma in soils with low phosphorus availability. *Annals of Botany*, DOI: 10.1093/aob/mcq199.

Modern Cowpea Breeding to Overcome Critical Production Constraints in Africa and the U.S.

PI-UCR-1

Principle Investigator

Philip A. Roberts (Lead PI), University of California–Riverside, USA

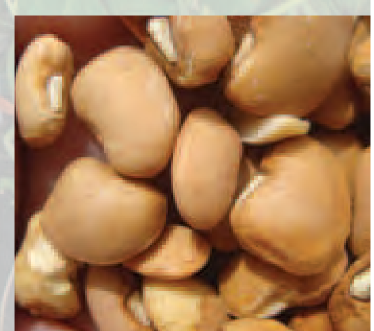
Collaborating Scientists

Ndiaga Cisse, Institut Senegalais de Recherches Agricole (ISRA), Senegal

Issa Drabo, Institut de l'Environment et des Recherches Agricole (INERA), Burkina Faso

António Chicapa Dovala, Instituto de Investigação Agronómica (IIA), Angola

Jeff Ehlers, University of California Riverside, USA



Abstract of Research and Outreach Achievements

Progress was made in three areas under "Develop improved, pest resistant, and drought tolerant cowpea varieties for target regions in sub-Saharan Africa and the U.S."

In California, new blackeye cowpea CB50 was released in 2008, and 8,000 kg certified seed was available for 2009 planting. The 2009 crop was sold by several warehouses as a premium export class and the production acreage increased in 2010. Plant Variety Protection (PVP) for CB50 was granted in early 2010. Elite, novel, dry grain all-white cowpea line evaluations in four on-station trials for grain quality, yield, and disease and insect resistance were positive in 2009 and 2010—and a release is being processed. In Burkina Faso, three new varieties are in the release process following strong farmer preference in multilocation trials. In Senegal, 30 foundation seed was produced to complete release of line ISRA-2065 with thrips and aphid resistance. Advanced multilocation yield trials were conducted in the three seasons (2008–2010) in Burkina Faso, Senegal, and California on approximately 150 lines for release selection based on grain quality, yield, and disease and insect resistance. Progenies of 40 crosses for developing new breeding lines were tested in Burkina Faso, Senegal, and California to combine high yield, grain quality, and abiotic and biotic stress resistance traits. Most crosses were advanced to the F4-F5 stage in 2010.

In Burkina Faso, breeder seed of nine improved varieties (>200 kg/entry) was grown in Pobe-Mengao; foundation seed of four varieties was produced at Saria and Pobe-Mengao, and 15 MT of foundation seed of four varieties from off-season production was sold to certified seed producers. Eighty-five lead farmers were trained as certified seed producers. In Senegal, three ha each of Melakh and Yacine foundation seed was produced at Bambey to supply the EWA NGO seed producer network. Forty-four ha each of Melakh and Yacine certified seed was produced by farmers in 2009, much in the Mekhe and Merina areas where women and men farmer groups were trained in seed production. Certified seed production and training focused on farmer organizations. A student from Angola completed the first year of degree training in cowpea germplasm and breeding and will aid in Angola seed production and distribution system assessment. Multilocation trials of diverse cowpea lines were completed in Angola.

Project Justification and Objectives

The primary project focus is to 1. increase productivity of African and U.S. cowpea producers through improved varieties that possess resistance or tolerance to the major abiotic and biotic stresses impacting production in these areas, 2. expand grower marketing opportunities by breeding cowpea varieties with desirable grain characteristics, 3. help ensure adequate seed of improved cowpea varieties, and 4. provide training and capacity building in modern cowpea breeding to African researchers.

This project addresses reducing cowpea production costs and risks for enhanced profitability and competitiveness and increasing the utilization of cowpea grain, food products, and ingredients so as to expand market opportunities and improve human health. Until now cowpea has lacked genomic resources for modern breeding despite its importance in African agriculture.

Increasing Cowpea Productivity. Low agricultural productivity is central to rural and urban poverty in Africa. On-farm cowpea yields in West Africa average 240 kg/ha even though potential yields (on-station and on-farm trials) are five to 10 times greater. Drought, poor soil fertility, insect pests, and diseases are major constraints. Cowpea varieties that yield more without purchased inputs especially benefit poor farmers, many being women who lack access to the most productive lands. Increased productivity is central to increasing rural incomes and can be achieved by developing varieties with resistance to insects, nematodes and pathogens, drought tolerance, and the ability to thrive under low soil fertility.

Increasing Marketing with Improved Varieties. New cowpea varieties must have features desired by consumers as well as farmers, including rain appearance coupled with desirable cooking qualities and processing characteristics for specific products. Landrace grain types are often preferred locally, but if over-produced, prices can be low due to limited demand. Large white grains with rough seed-coat are preferred throughout West Africa, buffering supply (and prices) in the region. Large white grains are also amenable to direct dry milling for use in value-added foods such as akara, moin-moin, and prototype value-added products. Development of adapted cowpea varieties with large white grain and resistance to pests would increase the marketing opportunities of cowpea farmers and traders in Africa and the United States. There is also considerable demand for the large rough-brown seed type, but the standard rough-brown Ife Brown is susceptible to pests and diseases. Cowpea products bred for a sweeter and milder taste could also help broaden cowpea consumption.

Increasing Seed Supply of Improved Varieties. Cowpea breeding by the CRSP, African NARS, and IITA has led to improved cowpea varieties that are near release; however, only about five percent of the cowpea area in Africa is planted to improved varieties so their potential goes largely unrealized. Rural African farmers will buy seed when it is available, suggesting that there could be a market for cowpea seed.

Effective models for production and dissemination of improved cowpea seed have evolved in Burkina Faso and Senegal based on collectives and for-profit seed cooperatives; their limited scope, however, reflects insufficient quantities of breeder and foundation seed. This project supports increased production of breeder seed and works with producers of foundation seed to strengthen their production and marketing.

Objectives

1. Develop improved, pest resistant, and drought tolerant cowpea varieties for target regions in sub-Saharan Africa and the United States using modern plant breeding tools.

2. Strengthen cowpea seed production and delivery systems in Angola, Burkina Faso, and Senegal to ensure delivery of improved varieties.

Research and Outreach Approaches, Results, and Achievements

Objective 1: Develop improved pest resistant and drought tolerant cowpea varieties

CB50 was released by the University of California, Riverside, in May 2008 as California Blackeye 50 (CB50). Approval of the Plant Variety Protection (PVP) was granted in early 2010. A variety registration article was published in June 2009. Approximately 18,000 pounds of certified seed of CB50 was planted on 400 acres in the 2009 season, along with several hundred acres planted with farmer-saved seed for a total of 900+ acres. Acreage expanded in 2010. CB50 continues to show yields competitive to CB46 but with a higher grain quality that achieves a price premium.

Selecting superior blackeye breeding lines from early and advanced generation nurseries

Breeding nurseries with early and late generation blackeye breeding lines were evaluated. About 200 single plant selections were made for further development, planted at Shafter in 2008, and 100 selections made. After several generations, the plants were advanced in the greenhouse during spring 2010 and the F2 seed harvested and then planted at Kearney. Approximately 100 single plant selections were made from these F2s. (See Table 3)

All-white and dry-green grain classes. Tests of the yield potential of the all-white 07-11-572 advanced line in 2008 and 2009 at two locations determined that it has grain yields equivalent to CB46. Twenty-nine crosses were made between California Blackeyes and green breeding lines, advanced, and the F2 planted at Kearney for selection of desirable grain quality (Table 5). For this dry green market class, further testing of new breeding lines developed from previous crosses will be done to identify more promising materials before release is considered. Now that the high-throughput marker genotyping capability is developed, a promising planned approach to expedite selection will be employed next year by using marker-assisted backcross breeding to introgress the “green genes” into a CB46 or CB50 genetic background, thus retaining the high yield potential and other component traits of CB46.

Cross No.	Blackeye Crosses
2010-066	CB46 x 09Sh-3-2
2010-067	CB46 x 09Sh-3-4- sps
2010-068	CB46 x 09Sh-3-6sps
2010-069	CB46 x 09Sh-13-6
2010-070	CB46 x 09Sh-36-2
2010-071	CB46 x 09Sh-93-3
2010-072	CB46 x 09Sh-105-2
2010-074	CB27 x 09Sh-13-6
2010-075	09Sh-93-3 x CB27
2010-077	524B x 09Sh-13-1
2010-078	524B x 09Sh-13-6
2010-079	524B x 09Sh-31-1
2010-080	524B x 09Sh-36-8
2010-088	09Sh-113-5 x 09Sh-31-10
2010-089	09Sh-113-5 x 09Sh-36-6
2010-090	09Sh-113-4 x 09Sh-93-1
2010-091	09Sh-113-1 x 09Sh-93-3

Table 3. Crosses between advanced blackeye breeding lines and blackeye cultivars that were made, advanced, and the F2 planted at Kearney in 2010.

In Burkina Faso (INERA). Field evaluations for final yield testing to support release of new varieties IT98K-205-8, KVx421-2J, and Melakh were made during the 2008 and 2009 seasons. On-farm yield tests were conducted in five villages of five different provinces of the country. In each village, three farmers conducted the evaluation trial. Average yields in 2008 obtained were 700kg/ha for IT98K-205-8 and 800kg/ha for Melakh. The 2009 trials data confirmed their good performance and farmer preference due to Striga resistance and their earliness. INERA proceeded to release them instead of making another on-farm test in 2010. Foundation seeds have been bought by seed producers to produce certified seed for large production in 2011.

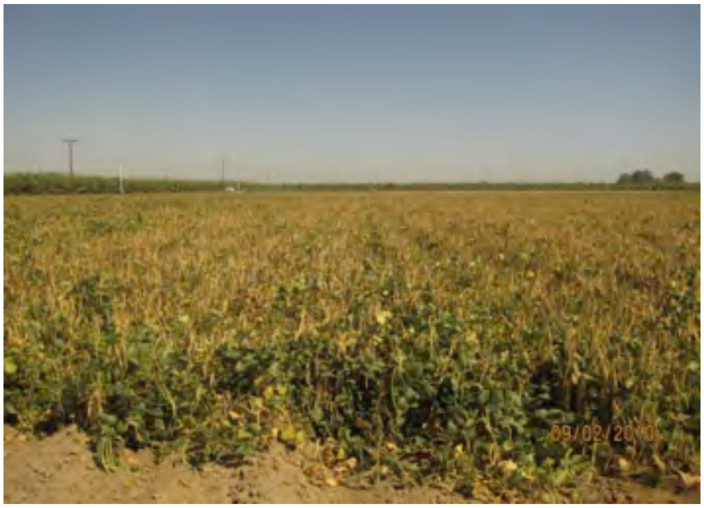
In Senegal (ISRA). The breeding line ISRA-2065 was developed under the previous Bean/Cowpea CRSP from a cross between the high-yielding CRSP cultivar Mouride and aphid- and thrips-resistant local landrace accession 58-77. ISRA-2065 is as early as Melakh (60 days from planting to maturity), has the same desirable grain quality, and is being targeted for release in the wetter part of this cowpea production zone, where flower thrips are especially damaging since it has stronger resistance to thrips than Melakh. An official release will occur during the coming off-season, for which the PADER project is multiplying three ha.

In Angola (IIA). Cowpea field evaluations were conducted at three locations (Benguela, Cela, and Malange), with the aim of identifying candidate varieties among local landraces, and Bean/Cowpea CRSP (in Ghana, Senegal, and/or Burkina Faso) and IITA varieties. Results of the 2010 plantings are being evaluated. Some Aschochyta blight disease occurred again in the recent trials but not as severely as in the 2008–2009 trials. Thus, we have initial data for making decisions on the best lines to test in additional locations in Angola. These data will be used by the CRSP student Antonio David in his diversity analysis of Angolan cowpea as a comparative study with the core IITA/CRSP germplasm lines. One or more of these candidates will become the first varieties to be formally produced under the project.

Advanced yield trials.

In Burkina Faso (INERA). Two advanced yield trials were conducted at Saria and Pobe Mengao in 2008, 2009, and 2010. Five candidate best performing lines were selected as potential varieties (KVx 908-3P2, KVx 907-2P2, KVx 912-22P1, KVx 912-1P1, and IT 98K-1111-1) and were grown in replicated yield trials at Pobe and Saria in the 2010 main season to choose the best two varieties to be evaluated on-farm in 2011. The yield and quality data from 2010 are being processed.

In Senegal (ISRA). Two advanced yield trials were conducted at the Bambey, ISRA, field station in 2010. Additionally, 20 lines with medium maturity were selected from the first trial based on 2008 performance and included in replicated yield trials in farmer fields in 2009 and 2010



Large-scale strip trial at Shafter in 2010 with new experimental entry P-87, CB50, CB46, and CB5. Each of the replicated plots is 12 rows wide x 300 feet long.

In California. Evaluation of three new advanced blackeye breeding lines for grain yield and quality, and agronomic characteristics was conducted at two locations in 2009 and 2010 (Figure 3); a set of five advanced blackeye lines were identified as potential blackeye cowpea varieties for the United States. One variety (P-87) was selected for more comprehensive evaluation in 2010 and was included in a large-scale replicated strip plot trial at Shafter and an advanced trial at Kearney. The trials are being harvested in late October.

Crosses for developing new breeding lines In Burkina Faso (INERA). Dr. Drabo made all the planned crosses. The ultimate goal of the crosses is to increase seed size of the improved varieties for Burkina Faso since large seed size is one of the most important preference characteristics in the subregion.

In Senegal (ISRA). In Senegal, all the planned crosses were made by Dr. Cisse at ISRA and are summarized in Table 8.

Recurrent Parent Line	Trait donor (non-recurrent) parent	Institution	Trait being introgressed
Yacine	IT93K-503-1	ISRA	Macrophomina
Yacine	58-77	ISRA	Flower thrips resistance
Yacine	SuVita 2 (substituted IT90K-76), IT82D-849	ISRA	Striga
Mouride	Montiero derived line	ISRA	Large grain
Melakh	IT97K-499-39, IT81D-994	ISRA	Striga resistance
Melakh	UCR 03-11-747	ISRA	Green grain

Table 8. Senegal varieties being improved by introgression of specific traits by backcrossing.

For Angola (IIA). To jump-start the Angola cowpea breeding program, selected F1 hybrids were produced at UCR using a diverse range of elite lines.

In California. The planned crosses were made at University of California, Riverside, during the summer of 2008 for use in the recurrent backcrossing program. In 2010, the most promising selection was included in replicated trials at Kearney locations, and plots have been harvested for yield and grain quality determinations but not yet analyzed.

Marker-assisted backcrossing (MABC) is a breeding strategy that can markedly increase the rate of progress and the precision of backcross breeding outcomes. The new high throughput SNP genotyping platform developed with leveraged funds under the GCP TL-1 cowpea project headed at UCR is ideally suited to the current task of introgressing key traits into locally adapted varieties via MABC.

Promising pigeon pea cultivar for the United States. A limited amount of work conducted on selecting high yielding pigeon pea for the United States has been ongoing at UCR for ten years. Most pigeon pea varieties cannot be grown in California because they require season lengths of 150 or more warm and frost-free days. UCR-GA1, however, is an early-maturing pigeon pea variety adapted to summer production of fresh pods for shelling and dry grain in the Central Valley of California and is ready for harvest 130 to 140 days after sowing. Currently a 2010 replicated trial of seven related selections is being conducted at Kearney, and we anticipate bulking seed from the best selection to make up the foundation seed of this variety.

Objective 2. Strengthen cowpea seed production and delivery systems

In Burkina Faso. To satisfy the demand for certified seed production, breeder seed of ten improved cowpea varieties was produced at the northern location of Pobe-Mengao during the 2008 season. At least 100 kg of seeds of each entry were obtained. One hectare of foundation seed for each of four

varieties was produced at Saria and Pobe- Mengao. A total of 2.5 MT of seeds were produced and sold to the certified seed producers. Money obtained by selling the foundation seed was used for supporting 2009 seed production activities in attempts to establish a self-sustaining plant seed production and delivery system. Breeder seeds produced last season allow us to grow 15 ha of foundation seed with the CRSP funds and 145 ha of foundation seed by INERA funds during the current reporting period. The quantity of seed produced will allow a doubling of the quantity of certified seed in 2011.

In Senegal. Two ha each of Melakh and Yacine and one ha of ISRA-2065 foundation seed was produced at the ISRA Bambey station. It is expected that at least 100 kg of each variety will be made available to the NGO. In the Thilmakha area, foundation seeds were distributed to two farmers for production of one ha of Melakh and one ha of Yacine certified seeds during the 2010 season. Certified seed production was also conducted in collaboration with a farmers' union (UGPM) in Mekhe with 10 ha of Melakh and Yacine each. Additionally 11 ha of Melakh and Yacine seeds were produced by the Millennium Village Project, which has 1343 members. Training of farmers during the 2009 and 2010 seasons for seed production consisted of field selection, removal of off-types and diseased plants, and both harvest and post-harvest handling. Double bags will be provided to farmers for storage.

Networking and Linking With Shareholders

We are working closely with national and international cowpea breeders and other scientists, including Drs. Ousmane Boukar, Christian Fatokun, and Sata Muranaka, senior scientists and cowpea breeders at IITA; Dr. Mohammed Ishiyaku of the IAR in Nigeria; Rogerio Chiulele at Eduardo Mondlane University in Maputo, Mozambique; Michael Timko at the University of Virginia; and Larry Murdock at Purdue University. We are working closely with the California Dry Bean Advisory Board and its Blackeye Council on research priorities of the industry. We are working with Inland Empire Foods, an important legume processor based in Riverside, on developing Akara (or bean tots) for inclusion in the California school program, and with another major U.S. manufacturer on utilizing several products that our varieties are well suited to. We have provided Dr. Julie Lauren of the Dry Grain Pulses CRSP project with advice about and seed of 35 cowpea varieties for her project in Kenya, and Dr. Barry Pittendrigh of the Dry Grain Pulses CRSP project with cowpea lines for his insect management project. We are also working with Dr. Jim Beaver at the University of Puerto Rico on training a CRSP student from Angola. Under the CGIAR-GCP-funded project Tropical Legumes 1, we are leading the cowpea improvement objective and interact with a large international network of tropical legumes researchers.

In Burkina Faso, we had been working with AFRICARE, a NGO financed by USAID to ensure food security. The collaborative work aimed to develop new Striga-resistant varieties adapted to intercropping. A collaboration with LVIA, an NGO financed by the EU and Italy, which aimed to train farmers for cowpea certified seed production and conservation, was also developed. However, during the current period, both AFRICARE and LVIA have ceased activities in Burkina Faso. With Association FERT, a French NGO whose aim is to improve cowpea production in the northern part of the country, we have continued on-farm tests of improved varieties and are helping them produce certified seed. Linkages have also been made with five farmer organizations: Song Taaba at Donsin near Ouagadougou; Six S at Pobe Mengao; Producteurs de Semences de Diouroum; Producteurs de Semences at Pobe Mengao; and Producteurs Semenciers Songd Woaga at Saria. Collaboration was also started with a seed producer association, Venegre, and a seed entrepreneur, Famille Kabre.

In Senegal, collaboration was established with the extension service ANCAR in the Kaolack and Thiès regions and with the PADER project of EWA in the southern region of Sedhiou for certified seed production of the advanced breeding line ISRA-2065. The Millennium project and ANCAR-Thiès were involved in seed production in the Louga, Mekhe and Touba Toul regions. In 2009, the Kirkhouse Trust began supporting activities on marker-assisted backcrossing for Striga resistance by providing $20,000 annually for three years.

Leveraged Funds

The University of California Riverside cowpea breeding program team has leveraged more than $3.4 million in external research funding in part due to the assistance provided by the Dry Grain Pulses CRSP.

Publications

Agbicodo, E.M., C.A. Fatokun, R. Bandyopadhyay, K. Wydra, N.N. Diop, W. Muchero, J.D. Ehlers, P.A. Roberts, T.J. Close, R.G.F. Visser, and C.G. van der Linden. Identification of markers associated with bacterial blight resistance loci in cowpea [*Vigna unguiculata* (L.) Walp.]. 2010. *Euphytica*. DOI: 10.1007/s10681-010-0164-5.

Das, S., D.A. DeMason, J.D. Ehlers, T.J. Close, and P.A. Roberts. 2010. Transcriptional profiling of root-knot nematode induced feeding sites in cowpea (*Vigna unguiculata* L. Walp.) using a soybean genome array. *BMC Genomics* 2010, 11:480. doi:10.1186/14712164-11-480.

Salem, N.M., J.D. Ehlers, P.A. Roberts and J.C.K. Ng. 2010. Biological and molecular diagnosis of seed-borne viruses in cowpea germplasm of geographically diverse sub Saharan origins. *Plant Pathology* 59:773-784.

Biological Foundations for Management of Field Insect Pests of Cowpea in Africa

PI-UIUC-1

Principle Investigators

Barry Pittendrigh, University of Illinois at Urbana–Champaign, USA

Ibrahim Baoua, INRAN, Niger

Clèmentine Dabirè, INERA, Burkina Faso

Collaborating Scientists

Mohammad Ishiyaku, IAR, Nigeria

Jeremy McNeil, UWO, Canada

David Onstad, UIUC, USA

Brad Coates, University of Iowa/ USDA, USA

Larry Murdock, Purdue, USA

William Muir, Purdue, USA

Joseph Huesing, Monsanto, USA

Malick Ba, INERA, Burkina Faso

Julia Bello, UIUC, USA

Manuelle Tamo, IITA, Benin

Mamadou N'Diaye, IER

Mali Madhu Viswanathan , UIUC, USA

Abstract of Research and Outreach Achievements

Our project is focused on immediate, tangible, cost-effective, and scalable integrated pest management (IPM) solutions for the largest biotic constraint on cowpea production in West Africa—six species of pest insects that attack cowpeas in the field. Pesticides are (or are fast becoming) a nonoption for many farmers and transgenic cowpeas; if/when they become available, they will only control one of the six major pest species of cowpea. Thus, there is an urgent need to develop a comprehensive IPM strategy for the insect pests that attack cowpeas using diverse control strategies. Three major steps are needed to develop cost-effective IPM solutions: 1. determining when and where the insect pests are located, 2. developing and deploying cost-effective and environmentally benign strategies for controlling these pests, and 3. developing and deploying cost-effective and sustainable educational strategies to enable both educators and farmers to learn about and use these pest control strategies. We have made significant progress in FY10 in building all three of these steps to deliver IPM solutions to West African cowpea producers in Burkina Faso, Niger, Mali, and Nigeria.

To better define the insect populations, our group is developing a new paradigm for pest control—an integration of genomics tools for making integrated pest management decisions, an approach we have termed "Integrated Pest Management Omics" (IPM-Omics). We have created the necessary molecular tools to understand population dynamics and the movement patterns of the legume pod borer (*Maruca vitrata*) and are currently creating these tools for the other major pests of cowpea. These molecular tools have and will be used in conjunction with traditional field studies to define where the pest populations are originating during the dry season so we can best determine where to release the biological control agents we now have. We have also performed field studies on the effectiveness of bio-control agents on insect pest populations and increasing yield in the cowpea crop; the results have been highly positive.

Lastly, we are developing educational tools to deploy pest control strategies on a large scale and, potentially, in a cost-effective manner. We are spearheading:

1. cell-phone ready animations that can be used to train people in pest control strategies,

2. an online peer-review system for host county collaborators to share these educational materials, and

3. the development of working relationships with other organizations (e.g., Peace Corps) that will allow us to scale up on-the-ground farmer education of IPM-based pest control strategies.

Project Justification and Objectives

Arguably, the greatest biotic constraints on cowpea production are insect pests. There is currently a dire need for pest control strategies to improve the livelihoods of those who produce and consume cowpeas. In the following project report, we outline that the most logical long-term options for control of pests of cowpea will be a mixture of biological control agents, cultural practices, bio-pesticides, and classic host plant resistance.

In the long-term, pesticides are likely to become a less viable option for controlling pests on cowpea due to poor manufacturing processes. Host plant resistance traits and cultural practices will certainly help control a few pest species; however, they need to be complemented by other strategies. Transgenic Bt cowpea for the control of *M. vitrata* has been in development for almost two decades; however, it may still be some time before such varieties are in the hands of farmers. Physical approaches for insect control have been developed and are currently being deployed for the control of bruchids in stored cowpeas; and many host-country scientists have continued to promote the successful use of local plant extracts (e.g., neem), in conjunction with host plant resistance traits, to suppress pest populations. Although these approaches can be used to suppress the pest populations, they require the development of educational materials that can be easily deployed for use by a large number of farmers in a given region or regions. Bio-control agents have the advantage that some can simply be released to do their job (suppress pest populations over the long-term) without further human intervention, while others can be turned into cottage industries (e.g., viral sprays). These aforementioned approaches represent immediate, tangible, and cost-effective pest control solutions that can be placed in the hands of farmers for the control of insects that attack cowpeas in the field.

Our HC scientists and their institutions have had major successes with biological control agents for other crop pests (e.g., cassava and millet). We now have numerous biological control agents against pests of cowpeas and educational materials for promotion of other pest control strategies (e.g., cultural practices and plant extract sprays) ready for release and testing on a pilot-scale to set the stage for a large-scale deployment effort.

One of the challenges of releasing bio-control agents has been determining where to release these organisms for the greatest impact. The best place to release these agents is 1. where the insects are endemic (and hence can support the bio-control agent populations), and 2. in endemic populations that cause the most damage in cowpea fields. There is a need to monitor the insect populations and develop molecular markers to determine insect movement patterns and verify the success of the bio-control agent programs. The use of genomics tools to determine insect movement patterns with applications for integrated pest management is an emerging field, which we have termed "Integrated Pest Management-omics" (IPM-omics).

Objectives

1. To combine surveys of pest populations with genomic analysis tools to determine where best to release bio-control agents for *M. vitrata* to maximize the control of this pest

2. To develop the necessary expertise to extend these IPM-omics strategies to all other insect pests of cowpea

3. To develop the necessary capacity and institutional infrastructure, as well as farmer training, for the strategic release of biological control agents for the pests of cowpeas in West Africa.

Research and Outreach Approaches, Results, and Achievements

Objective 1: *Light Trapping of Maruca and Microsatellite Markers.* Light trapping continued to occur over the past 12 months, in keeping with the previous 18 months, at the existing locations: 1. in Niger, the current locations are Maradi, Kornaka, and Gaya; 2. in Nigeria, the existing locations are Zaria, Kadawa, and Minjbir; 3. in Burkina Faso, the existing locations are Farako-ba, Kamboinsé, Fada N'Gourma and Dori. Adults were monitored and collected from the light traps on a daily basis and were sent to UIUC for molecular analyses.

The use of genomics tools to determine insect movement patterns with applications for integrated pest management is an emerging field . . .

Our field and molecular data currently support the hypothesis that *M. vitrata* move in a northerly pattern from an endemic zone during the wet season, surviving in the southern endemic zone during the dry season. However, we have observed the endemic zone in Burkina Faso to be farther north than previously expected. Our molecular data also suggests a fairly direct south to north movement pattern of *M. vitrata* in the rainy season. Bio-control agents will need to be released in Southern Burkina Faso (in the Bobo-Dioulasso area), Northern Ghana, Togo, and Benin. Additionally, we have also demonstrated that M. vitrata is an important pest of cowpea in Southern to mid-Burkina Faso but not in northern Burkina Faso. Thus, control efforts for this pest should be concentrated in the south and middle of the country.

This activity has allowed us to 1. build institutional infrastructures to monitor *M. vitrata* using light traps, 2. develop multiple standard and novel molecular approaches for studying *M. vitrata* population dynamics, 3. use these genomics tools for insect management decisions for the next phase of our project, and 4. lay the foundation for the development of insect resistance management plans for the deployment of host plant resistant varieties of cowpeas that can be used to control of *M. vitrata*.

Our group is now using what we have learned from our combined light trapping and genomics data of *M. vitrata* populations to determine how to cost-effectively deploy insect control strategies for this pest of cowpeas (e.g., biological control agents).

Molecular Tools Development – A series of genomics tools has been developed for use in more effective integrated pest management strategies for *M. vitrata*. The tools are as follows:

1. We have used a new large-scale sequencing technology (454 sequencing) combined with novel bioinformatics approaches to rapidly discover microsatellites that can be used to study *M. vitrata* populations from across West Africa. This microsatellite identification can be used for other Lepidopterous pests.

2. We have used 454 sequencing technology to (a) sequence the complete mitochondrial genome of *M. vitrata*, (b) determine the exact locations in the mitochondrial genome that will and

will not vary from insects found around the world, and (c) determine which genes vary locally and regionally (in West Africa) and across the planet. We can now characterize *M. vitrata* populations from distinct locations in West Africa to determine their movement patterns.

3. We have used 454 sequencing technology to determine single nucleotide polymorphisms (SNPs) across a great diversity (hundreds) of *M. vitrata* nuclear genes to determine (a) the exact locations in these gene that will and will not typically vary from insects found around the world and (b) which components of the genes vary locally, regionally, or across the planet. We have used these tools (along with Sequenom® array technologies) coupled with our field data to gain critical insights into movement patterns of *M. vitrata* populations in West Africa.

4. We have used the above molecular tools to (a) determine that *M. vitrata* is actually two separate species of insects and (b) determine important information on the migratory patterns of this pest in West Africa. We now have a clearer idea of where biological control agents need to be released to have the greatest impact on *M. vitrata* populations.

5. We have developed diagnostic PCR-based assays for other researchers to further test details of *M. vitrata* populations, which will allow African host country institutions with basic molecular biology equipment to easily characterize M. vitrata populations.

6. We have developed a computational model based on our datasets that will be critical for risk assessment associated with decisions regarding the potential release of transgenic Bt cowpea in West Africa.

7. All of the molecular tools we have developed, along with their applications for insect control, can now be applied to the other pest insects that attack cowpea. This past year we began the effort of applying these tools to the sequencing of two of the bio-control agents (*Apanteles taragamae* and *Ceranisus femoratus*) that we will release. We have also collected insects from all the other pest species to perform sequencing of these populations in FY11 to perform the same type of studies as we have done with *M. vitrata*. We now have the capacity to extend these approaches to all of the pest insects of cowpea.

Objective 2: *Insect pests on cultivated cowpeas*
This activity will provide the basis for a better understanding of pest insects on cowpeas within the host countries and will allow for cross-training in pest insect biology across the three host countries. This work will lay the basis for the development of an IRM plan for Bt cowpea and potentially provide the basis for other IPM-based pest control strategies for both *Maruca* and other pest insects of cowpea. We will also test the impact of viral and neem sprays on cultivated cowpea crops to determine if these approaches can be used to 1. reduce pest attack and 2. increase yield.

The major pests of cowpea in the field in West Africa include the legume pod borer, the coreid pod sucking-bugs, the groundnut aphid, and thrips. We studied the presence and detailed life-history of the five major pests of cowpea. We also tested viral sprays (against *M. vitrata*) and neem sprays (against all the pests) on the cowpea crops. We have been able to ascertain which pest insects represent the greatest problems (and at what time interval) in northern Nigeria, Niger, and Burkina Faso.

We have also performed field experiments where 1. we have tested pest tolerant strains of cowpeas on their own and in combination with neem sprays and 2. tested viral sprays to control M. vitrata. Both strategies were successful in reducing pest numbers and increasing yield (comparable to that of pesticide sprays).

These experiments have also helped us determine in which regions certain pest insects impact cowpea crops; this information will be important in determining where to deploy certain biological control agents for given pest insects where there is little need for such control measures.

Separate experiments were also performed to evaluate varieties of cowpeas tolerant to thrips and pod-sucking bugs. Our initial experiments (summer 2009) showed positive results for these varieties being more tolerant to insect attack; we repeated these field experiments in summer 2010 with similar results. These varieties are being used in our farmer field schools and other extension programs for evaluations by farmers of these varieties.

We have made large-scale collections of insects from these experiments to understand the nature of these pest populations and make informed decisions on the best places and times to release biological control agents.

The findings of these studies can be summarized as follows:

1. Major pest problems by region have been defined, and we now have three seasons of base-line data on the pest levels of insect populations on cowpeas in test plots.

2. Viral sprays dramatically reduced *M. vitrata* populations and increased yield in the test plots (26–34 percent increased levels of yield)

3. Neem sprays were effective in decreasing pest populations, increasing yield, while neem sprays coupled with host plant resistant strains were the most effective in reducing the pest populations.

The implications for developing a pest control strategy are as follows:

1. We have defined which regions we should focus the deployment of specific bio-control agents to control specific pest species for the long-term.

2. Viral sprays represent a new option for the control of M. vitrata

3. Neem sprays were effective, especially in combination with host plant resistant varieties, and have been used to train farmers in farmer field schools.

Objective 3: *Survey Wild Alternative host plants (in and off season)*
This activity will help us determine the location of the pest populations both during and outside the growing season.

A series of scouting trips in Niger, Nigeria, Benin, and Burkina Faso over the last 18 months have already provided information on where biological control agents for *M. vitrata* need to be released in northern Nigeria, Niger, and Burkina Faso. The two parasitoids useful in control of *M. vitrata* include the Hymenopteran parasitoids *Apanteles taragamae* and *Nemorilla maculosa*. As part of our Pulse CRSP Technology Dissemination Project, we are now in a position to release these parasitoids to maximize their potential impact on *M. vitrata* populations.

Implications for pest control strategy
Our results support the hypothesis that pod sucking bugs, thrips, and aphids live in the dry season in local areas where cowpeas are grown during the wet season. If these results are supported by molecular data, that the pest populations are endemic, then bio-control agent releases locally should support local pest populations over the long term.

Objective 4: *Development of Infrastructure for Release of Information to Extension Services, NGOs, and to Cowpea Farmers as well as Short-term and Long-term Training*

The goal of this program component is to develop a long-term capacity for the large-scale release of IPM strategies for Mali, Burkina Faso, Niger, and northern Nigeria, which includes 1. an institutional human resources infrastructure building, 2. partnerships with collaborative groups that will help us deploy these approaches on a larger scale, and 3. educational tools and resources for training host country scientists, extension educators, and farmers in the most effective pest control strategies.

We have used Farmer field schools (FFSs) to educate farmers about the pests of cowpeas, so they can assess, disseminate, and release improved methods for pest control (and overall production) in cowpeas.

To achieve these objectives:

1. We have performed scientist training, graduate student training, and intra- and inter-institutional technician training.

2. IITA has developed eight videos necessary for technician and scientist training on the pests of cowpeas, including identification of the pests in the field and rearing of the pests and their bio-control agents.

3. We have trained host country scientists and technicians on highly cost-effective strategies for rearing M. vitrata and the production of bio-control agents for release.

4. We have partnered with other organizations to deliver pest control strategies to farmers.

5. We have developed an online information sharing system of pest control strategies that will be used by our project to share materials within our group and with the rest of the world.

6. We have begun developing a series of animations (in local languages) that can be deployed using cell phones. We have developed videos for hermetic sealing of cowpeas for storage, solar treating of cowpeas, and proper preparation and use of Neem sprays. The first two videos were released in the beginning of FY11 and have been translated into multiple local languages. We have shared our videos with other Pulse–CRSP researchers.

Farmer Field Schools.
We have used Farmer field schools (FFSs) to educate farmers about the pests of cowpeas, so they can assess, disseminate, and release improved methods for pest control (and overall production) in cowpeas. FFSs represent multi-month half-day a week training sessions with a minimum of 20 farmers per village (10 men and 10 women). We performed a minimum of two farmer field schools in each of the host countries—Nigeria, Niger, Burkina Faso, and Mali. MP3 players and animations on cell phones were also distributed in villages to explore potential education.

As part of the farmer field schools, the farmers directly set up test plots with different technologies for cowpea production (host plant resistant lines, neem sprays, and viral sprays), assessed insect attack in detail along with the impact of other production technologies, and made decisions on the outcomes of these experiments. Technologies deployed in the farm field schools involved:

1. insect/pest tolerant varieties of cowpeas (more than five new varieties tested)
2. local biological/botanical sprays (three technologies tested)
3. early, medium, and late flowering varieties
4. a diversity of fertilizer strategies (manure and fertilizer combinations)
5. intercropping approaches
6. hermetic storage of cowpeas
7. soil preparation and planting density testing
8. how to minimize the use of traditional pesticide sprays in areas where farmers typically spray their cowpea crops
9. discussions on the use of viral sprays/biological control agents to control M. vitrata (to set the stage for their use in FY11 and FY12)

Feedback from these FFSs has allowed us to 1. identify which pest problems are the greatest concern in various regions of each country and 2. give the farmers the ability to identify early on which pest problems may be occurring so that they can take logical measures to minimize the pest populations.

To increase the impact of our program, we have held one-day sessions where other farmers, production groups, and people from other villages can interact with the FFSs to see the impacts of the various pest control strategies (and other technological improvements) on cowpea production. We have also distributed improved seed varieties to other farmer organizations for them to assess, multiply, and encourage the use of these seeds in their programs. We are currently producing printed and electronic media that can be used for deployment of technologies to assist in cowpea production, such that future Peace Corp volunteers can continue to integrate improved technologies into their village-level programs.

As part of the FFSs we have also been focused on determining the needs and roles of women in various aspects of cowpea production, particularly, how to increase the impact of FFSs on women in some regions connected to the current CRSP project. We are also working on our extension strategies as they relate to low literate learners.

Networking and Linkages With Shareholders

Dr. Pittendrigh has visited the USAID missions in Mali and Nigeria during the current CRSP grant. Dr. Tamò is continuing to work with collaborators in Ghana. In Benin, efforts are underway to work with the biggest federation of agro-ecological farmers (Federation Agro-ecologique du Benin) to promote bio-control agents and bio-pesticides in the context of their organic production approach. In Niger, our program is partnered with Peace Corps for the development of joint farmer field schools.

Leveraged Funds

Dr. Pittendrigh and his co-principal investigators have successfully leveraged approximately $500,000 in external funding in FY10 for research and outreach projects related to insect pest biology and management in cowpeas in part due to the assistance received from the Dry Grain Pulses CRSP.

Publications

Bello-Bravo, J., Diaz, R., Venugopal, S., Viswanathan, M., and B. R. Pittendrigh. 2010. Expanding the impact of practical scientific concepts for low-literate learners through an inclusive and participatory virtual knowledge ecosystem. *Journal of the World Universities Forum* 3(4):147–164.

Dannon, E., Tamò, M., Huis, A., Dicke, M., 2010. Functional response and life history parameters of *Apanteles taragamae*, a larval parasitoid of *Maruca vitrata, BioControl*, 55. 363–378

Dannon, E., Tamò, M., Huis, A., Dicke, M., 2010. Effects of volatiles from *Maruca vitrata* larvae and caterpillar-infested flowers of their host plant *Vigna unguiculata* on the foraging behavior of the parasitoid *Apanteles taragamae*. *J Chem Ecol*. 2010 Oct; 36(10):1083–91. Epub 2010 Sep 15.

Margam, V.M., Coates, B.S., Ba, M.N., Sun, W., Binso-Dabire, C.L., Baoua, I., Ishiyaku, M.F., Shukle, J.T., Hellmich, R.L., Covas, F.G., Ramasamy, S., Armstrong, J., B. R. Pittendrigh, & Murdock, L.L. 2010. Geographic distribution of phylogenetically-distinct legume pod borer, *Maruca vitrata* (*Lepidoptera: Pyraloidea: Crambidae*). *Molecular Biology Reports*. Online First Release.

Margam, V.M., Baoua, I., Ba, N.M., Ishiyaku, M.F., Huesing, J.E., Pittendrigh, B.R., & Murdock, L.L. 2010. Wild host plants of legume pod borer *Maruca vitrata* (*Lepidoptera: Pyraloidea: Crambidae*) in southern Niger and northern Nigeria. *International Journal of Tropical Insect Science* 30(2): 108–114.

Development, Testing and Dissemination of Genetically Improved Bean Cultivars for Central America, the Caribbean and Angola

PI-UPR-1

Principle Investigators

James Beaver (Lead PI), University of Puerto Rico, Mayaguez, Puerto Rico

Juan Carlos Rosas, Escuela Agricola Panamericana-Zamorano, Honduras

Emmanuel Prophete, National Seed Program, CRDA, Ministry of Agriculture, Haiti

Antonio Chicapa Dovala, Instituto de Investigacao Agronomica (IIA), Angola

Collaborating Scientists

Timothy Porch, USDA-ARS Tropical Agriculture Research Station, Mayaguez, Puerto Rico

Consuelo Estevez, University of Puerto Rico, Mayaguez, Puerto Rico

Abstract of Research and Outreach Achievements

Significant progress was made toward research and training objectives. ICTAZAM, a small black bean cultivar, with BGYMV and BCMV resistance and web blight tolerance, was released in Guatemala by ICTA. ICTA Sayaxche, a disease resistant, high yielding black bean cultivar developed by EAP and ICTA researchers with support of the Dry Grain Pulses–CRSP project, is a candidate for release in Guatemala. The BGYMV- and BCMV-resistant, high yielding small red cultivar INTA Matagalpa (released in Honduras as DEHORO) will be released in Nicaragua by INTA. DEHORO and Amadeus 77, are the principal bean cultivars being disseminated by governmental seed programs in Honduras and El Salvador, which reach more than 120,000 farmers annually. The BGYMV- and BCMV-resistant small white seeded, cultivar Surú was released in Costa Rica. A significant quantity of the black bean cultivars Aifi Wuriti and Arroyo Loro Negro were multiplied by the National Seed Service in Haiti. This seed was used to establish demonstration plots in the fields of 300 cooperating farmers in the Vallée de Jacmel area in southeastern Haiti. The Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF) formally released DPC-40. This BGYMV-, BCMNV-, and BCMV-resistant black bean variety was developed in collaboration with the University of Nebraska and the University of Puerto Rico with support from the Bean/Cowpea CRSP. The bean grower association in the San Juan de la Maguana Valley sold FAO 100 tons of seed of DPC-40 and Arroyo Loro Negro to distribute to bean producers in Haiti. The multiple disease resistant light red kidney bean cultivar Badillo and the heat-tolerant gemplasm lines TARS-HT1 and TARS-HT2 were developed and jointly released by the University of Puerto Rico and the USDA-ARS Tropical Agriculture Research Station.

More than 50 small red and black bean elite breeding line nurseries (VIDAC) and (ECAR), 40 promising breeding line evaluation trials (COVAMIN, PASEBAF), and more than 400 on-farm cultivar validation trials (Aifi Wuriti, ICTAZAM, INTA Matagalpa, MER2226-41) were conducted in collaboration with National Bean Programs, NGO, and technical personnel and farmer groups in Central America and the Caribbean (CA/CInbred backcross populations for developing small red and black bean cultivars that combine BGYMV-, BCMV-, and BCNMV-resistance for Central America) were generated and advanced to early generations. Marker-assisted selection was used to insure that small red and black bean varieties have BGYMV- and BCMV-resistance genes. Populations were developed from crosses between commercial seed types used in Angola and sources of resistance to BCMV, CBB, and ALS resistance. Marker-assisted selection has been used for selection of CBB and BCMV resistance and phenotypic selection for ALS resistance. Yellow bean cultivars from Mexico were crossed with red mottled bean breeding lines that have resistance to BGYMV and BCMV and common bacterial blight. Bean breeding lines from Oregon State University had high levels of resistance to the bean weevil. Bean lines with greater nodulation scores, root, shoot, and total dry matter accumulation under low N conditions were identified in greenhouse trials conducted at Zamorano. Experiments were conducted in Honduras using the soil cylinder technique containing a substrate low in N to study the response to inoculation with *Rhizobium* strains CIAT 899 (*R. tropici*) and CIAT 632 (*R. etli*) and to identify potential parents for a recurrent selection program for high nodule number, early nodulation, and N2 fixation. Additional BNF studies in Honduras include testing the response of 50 inbred-backcross (IB) lines to inoculation with strains CIAT 899 and CIAT 632 under low fertility conditions.

In field trials planted at Isabela, Puerto Rico, over a two-year period, the black bean line PR0443-151 and the small red lines VAX 3 and IBC 309-23 produced superior seed yields and were found to be efficient in the acquisition and use of N. Field experiments were conducted at two locations in Puerto Rico to test the effectiveness of the commercial inoculant Nodulator (Becker Underwood). *Bacillus subtilis strain MBI 600 Integral*™ was included as a seed treatment to control root rots. In Isabela, nodulation scores were significantly different among treatments. Plant biomass was greater with fertilization (NPK). *Bacillus subtilis* seed treatment was effective in increasing plant biomass, nodulation, and seed yield probably due to reduction of root rot. Because the putative RAPD markers for ashy stem blight were proven to be ineffective, recombinant inbred lines (RILs) from crosses between BAT 477 and susceptible bean lines were evaluated for the development of novel markers. A detached leaf technique for *Macrophomina phaseolina* evaluation has been implemented for screening the BAT 477 x DOR 364 RIL population. Significant differences were found between RILs in the population, and some lines were identified in which seed yield and detached leaf score corresponded. Morphological and agronomic traits of Lima bean landrace varieties from Puerto Rico were evaluated. We identified significant differences among varieties for seed type, leaf and pod type, days to flowering, seed yield, and concentration of HCN in the leaves and seed. PL-08-14 was the only landrace variety that had early flowering in Puerto Rico (51 DAP) and Honduras (71 DAP) and a seed HCN concentration < 100 ppm in the seed. The diversity of Angolan cowpea germplasm, in relation to a diverse worldwide collection, was evaluated through phenotypic characterization in a field trial planted at Isabela, Puerto Rico. The initial seed elemental composition results indicate some unique nutritional characteristics of Angolan germplasm, including high protein and iron content.

Project Justification and Objectives

Common bean (*Phaseolus vulgaris* L.) is an important source of protein for low income families in Central America, the Caribbean, and Angola. Increased or more stable bean yield can improve the diet and provide a reliable source of income for small-scale farm families in these countries. An increased supply of beans should also benefit the urban consumer of beans.

Objectives

1. Development, release, and dissemination of improved bean cultivars for Central America, the Caribbean, and Angola.

2. Selection of beans for adaptation to low N soils.

3. Develop molecular markers for disease resistance genes.

4. Evaluation of other dry pulse crops for Central America and the Caribbean.

Research and Outreach Approaches, Results, and Achievements

Objective 1. Development, release, and dissemination of improved bean varieties for Central America, the Caribbean, and Angola.

Development of breeding populations. Several different small red, black, and Andean bean breeding populations were developed and evaluated during the past year. The overall goal is to combine resistance to diseases with drought and low fertility tolerance in improved cultivars and breeding lines. This should lead to the release of improved small red, black, and Andean bean cultivars with enhanced adaptation and greater consumer acceptance. Some of these populations were developed for greater adaptation to the highlands of Honduras, Guatemala, and Haiti, while others for the lowlands of all Central American countries and Haiti. During the past year, F1 populations were developed and F2 plants were evaluated and selected for highly heritable traits. Early generation populations have been developed at the University of Puerto Rico from crosses among sources of disease (BGYMV, BCMNV, common blight, rust and web blight), pest (leafhopper and bruchid) resistance, and tolerance to low N soils. During the past year, individual plants were selected in F_3 and F_4 generations based on agronomic characteristics and seed type (black, red mottled, and yellow).

Inbred backcross populations for developing small red and black bean cultivars that combine BGYMV, BCMV, and BCMNV resistance for CA/C were generated and advanced to early generations using the XRAV40-4 black bean cultivar and the small red breeding line PR9825-49-4 as BCMNV resistance sources. The availability of BCMNV-resistant bean cultivars for Central American is vital to deal with the potential spread of this virus that has caused severe reductions in bean production in the Caribbean. In addition, the black bean lines under development should be useful for bean production in Haiti and other Caribbean countries, where resistance to BCMNV in combination with other disease resistance genes and adaptation to production constraints, such as limited rainfall and low soil fertility, are necessary.

Seed of seven bean landraces were collected in Angola. As a part of her M.S. thesis research at the UPR, Monica Martin developed populations based on crosses between commercial seed types used in Angola (medium-sized yellow, green, and white types; and large seeded cranberry and kidney types) with sources of resistance to BCMV, BCMNV, CBB, and ALS resistance. Individual plant selections were made in the F_2 generation, and F_3 seed will be tested in the greenhouse for disease resistance. During the upcoming year, F_5 breeding lines will be sent in 2011 for field testing.

The yellow bean is a preferred seed type in Haiti and Angola. These yellow bean lines were crossed with red mottled bean breeding lines that have resistance to BGYMV, BCMV, and common bacterial blight. Approximately 100 F_5 lines were selected based on seed type, adaptation, and agronomic characteristics. The lines will be screened in the greenhouse and with molecular markers to identify lines with BGYMV- and BCMV-resistance.

Regional performance trials. More than 50 small red and black bean breeding line VIDAC nurseries and ECAR trials were distributed to collaborators from the National Bean Programs (NBP) from Central America and the Caribbean. Ten ERMUS trials, including web blight resistant lines from the first and second cycle of recurrent selection were distributed to NBP in CA/C and farmer research committees (CIAL) in Honduras. Most of the web blight resistant lines in the ERMUS trial were superior to the moderately resistant (Talamanca and VAX 6) and susceptible (Tio Canela 75) checks and were also resistant to BGYMV and BCMV, and have good agronomic adaptation and desirable commercial red and black seed types.

In addition, more than 40 elite line evaluation trials (COVAMIN, PASEBAF) and more than 400 on-farm cultivar validation trials (Aifi Wuriti, ICTAZAM, INTA Matagalpa, MER2226-41) were conducted in collaboration with researchers from NBP, NGOs, and farmer groups from Central America and the Caribbean, resulting in the identification of several promising materials for in-country testing by the NBP of the

CA/C bean network and the potential release in 2011 of at least one cultivar in Guatemala, Nicaragua, and El Salvador.

Seed for regional performance trials were prepared at the University of Puerto Rico and sent to Haiti, Angola, and Rwanda. Entries in the trials included the differentials for rust, angular leaf spot, and anthracnose, and improved bean breeding lines from Michigan State University, the University of Puerto Rico, USDA-ARS Tropical Agriculture Research Station, Zamorano, and INIAP. Information from these trials will be valuable to identify the most important biotic and abiotic constraints and to select bean lines that can serve as parents in a breeding program for Angola. Field trials were planted in Angola in October 2008, August and October 2009, and 2010. Results from these trials identified bean breeding lines with different seed types that were well adapted, had good yield potential, and were resistant to disease. The red mottled line PR9745-232 was the top yielding red mottled line in trials planted in Puerto Rico, Haiti, and Angola.

On-farm validation of promising breeding lines. On-farm validation trials were conducted in Nicaragua and Honduras in collaboration with the National Bean Research programs, Local Agricultural Research Committees (CIAL), NGOs, and other extension organizations. The PASEBAF validation trial included drought, low fertility tolerant lines developed with support from the Bean/Cowpea CRSP, and the Red SICTA. The Agrosalud (COVAMIN) trial included small red lines with greater mineral content (iron and zinc) developed in collaboration with CIAT and INTA/Nicaragua.

Release of cultivars and seed multiplication. ICTAZAM, a small black bean cultivar, with BGYMV- and BCMV-resistance and web blight tolerance, was released in Guatemala by ICTA researchers in collaboration with the EAP and UPR. This variety was developed at Zamorano and tested during the last four years in Guatemala as the experimental line MHN 322-9. This improved variety is currently being disseminated to farmers in the main bean production regions in collaboration with ICTA researchers, the World Food Program, and farmer organizations. ICTAZAM will be included in the Feed the Future– USAID Rapid technology dissemination project being implemented by the Dry Grain Pulses–CRSP (DGP–CRSP) in CA/C. ICTA Sayaxche, a disease-resistant, high yielding black bean cultivar developed by EAP and ICTA researchers with support of the DGP–CRSP project, is a candidate for release in Guatemala. Seed for dissemination was increased in the Peten region (more than 30 percent of the national bean production) and distributed to farmers from that region and other parts of the country.

The black bean cultivar Aifi Wuriti, was introduced for testing in the semiarid southeastern region of Guatemala in collaboration with World Hope Organization. In response to the excellent acceptance by bean producers, small packages of seed were distributed during 2010 to a larger group of farmers from this region in collaboration with this NGO. Aifi Wuriti has early maturity and resistance to BGYMV. A significant amount (12 MT) of Aifi Wuriti and Arroyo Loro Negro were multiplied by the National Seed Service in Haiti.

The BGYMV- and BCMV-resistant, high yielding small red cultivar INTA Matagalpa will be released in Nicaragua by INTA researchers with support from the DGP–CRSP.

The small white-seeded, BGYMV and BCMV resistant cultivar Surú, derived from the cross PAN 68/Bribri, was released in Costa Rica in December 2009 in collaboration with the National Bean Program.

The red mottled line PR9745-232 was the top yielding red mottled line in trials planted in Puerto Rico, Haiti, and Angola.

In February 2010, the Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF) formally released DPC-40. This black bean variety was developed in collaboration with the University of Nebraska and the University of Puerto Rico with support from the Dry Grain Pulses CRSP.

The University of Puerto Rico and the USDA-ARS Tropical Agriculture Research Station released the high-yielding, light red kidney bean cultivar Badillo that has resistance to common bacterial blight and BCMV. Badillo should increase the yield of marketable beans in Puerto Rico and other Caribbean countries that produce light red kidney beans.

The USDA-ARS, University of Puerto Rico, Cornell University, and the University of Tennessee released TARS HT-1 and TARS HT-2, heat tolerant dark red and light red kidney beans with tolerance to high temperature stress in both temperate and humid tropical environments.

The pink bean line PR0401-259 and the black line PR0650-31 are under consideration for release as improved germplasm. Both lines have the I locus conferring resistance to BCMV and high levels of resistance to common bacterial blight (CBB) and moderate levels of resistance to web blight. PR0401-259 also has

the bgm gene for resistance to BGYMV. PR0401-259 and PR0650-31 should serve as useful sources of resistance where CBB and web blight are significant diseases.

The University of Puerto Rico has developed red mottled bean lines that combine resistance to BGYMV, BCMNV, BCMV, and common bacterial blight.

The white bean breeding line PR0634-13 is under consideration for release in collaboration with the University of Nebraska and IDIAF as Beniquez. This cultivar has resistance to BCMV, BCMNV, and BGYMV. The release of Beniquez will provide protection against the possible emergence of BCMNV in Puerto Rico. This virus already causes significant losses in the Dominican Republic and Haiti.

Objective 2: Selection of beans for adaptation to low N soils.

GExperiments were conducted in Honduras using the soil cylinder technique containing a soil: sand (1:2) substrate low in N to study the response of selected genotypes to inoculation with Rhizobium strains CIAT 899 (R. tropici) and CIAT 632 (R. etli) and to identify potential parents for a recurrent selection program for high nodulation and N2 fixation. Additional BNF studies in Honduras included testing the response of 50 inbred-backcross (IB) lines to inoculation with strains CIAT 899 and CIAT 632 under low fertility conditions.

Thirty-three bean lines were selected from an initial screening of 228 breeding lines from Zamorano and the University of Puerto Rico conducted by Haitian graduate student Ronald Dorcinvil. The varieties Morales and Verano from Puerto Rico and Salagnac 90 from Haiti were used in the trials as checks. Values of N utilization efficiency (NUE) were calculated as the ratio of seed yield (kg/ha) and extractable NO_3 in the soil. In trials planted at Isabela, Puerto Rico, over a two-year period, the mean seed yields of the black bean line PR0443-151 and the small red lines VAX 3 and IBC 309-23 ranked no lower than ninth in the N plots. The NUE values of these lines were > 30 over both years. Spring cereal lines with NUE scores ≥ 35 were considered efficient in nutrient acquisition.

Treatments	Nodulation (1-9)	Shoot dry wt (g/3 plants)	Root dry wt. (g/3 plants)	Seed yield kg/ha
Uninoculated control	9.0 a	2.65 b	1.11 a	651 bc
N	9.0 a	2.10 b	0.83 a	879 ab
NPK	9.0 a	4.59 a	1.35 a	828 ab
Nodulator (*Rhizobium leguminosarum*)	6.5 b	4.69 ab	1.42 a	710 abc
PK + Nodulator	6.5 b	4.70 a	1.52 a	484 c
Integral (*Bacillus subtilis*)	8.5 a	2.82 ab	0.85 a	933 a
Nodulator + Integral	6.0 b	2.90 ab	1.59 a	884 ab
PK	9.0 a	2.44 b	1.00 a	505 c

Table 11. Response of the bean cultivar Verano to inoculation with Nodulator and Integral (*Bacillus subtilis*) seed treatments in a trial conducted in 2010 at Isabela, PR.

Treatments	Nodulation (1-9)	Shoot dry wt (g/3 plants)	Root dry wt. (g/3 plants)	Seed yield (kg/ha)
Uninoculated control	9.0 a	2.54 b	0.95 b	305 d
Nitrogen	9.0 a	4.78 a	1.52 a	525 ab
NPK	9.0 a	4.40 a	1.52 a	596 ab
Nodulator (*Rhizobium leguminosarum*)	5.0 d	4.7 a	1.72 a	510 bc
½ NPK + Nodulator	6.0 c	4.52 a	1.55 a	663 a
Integral (*Bacillus subtilis*)	5.0 a	4.40 a	1.63 a	529 ab
Nodulator + Integral	7.0 b	5.09 a	1.76 a	652 ab
PK	8.5 a	2.44 b	1.18 b	450 cd

Table 12. Response of the bean cultivar Verano to inoculation with Nodulator and Integral (*Bacillus subtilis*) seed treatments in a trial conducted in 2010 at Juana Diaz, PR.

Populations were developed using PR0443-151 as a parent to develop breeding lines that combine adaptation to low N soils with resistance to BCMV or BGYMV. Results from the thesis research of UPR graduate student Luis Ruiz suggest that it is possible to develop disease resistant breeding lines that are better adapted to low N soils.

Field experiments were conducted at two locations in Puerto Rico to test the effectiveness of the commercial inoculant Nodulator (Becker Underwood). Treatments were applied at planting in Isabela (Oxisol) and Juana Diaz (Vertisol), Puerto Rico, in February and March 2010 (Tables 11 & 12).

In Isabela, nodulation scores were significantly different among the inoculated treatments and the noninoculated treatments with or without fertilizer. Plant biomass was greater with fertilization (NPK). Response to inoculation was observed with Nodulator when combined with Integral, indicating a synergistic effect (Table 11). However, the highest seed yields were obtained with Integral alone. In conclusion, there was response to inoculation with Nodulator when combined with Integral. However, the highest seed yields were recorded with Integral alone, probably due to control of root rots. The NPK and N treatments increased yields when compared to PK and PK + Nodulator (Table 12).

In Juana Diaz, a starter fertilizer treatment with inoculation was included because of low nitrogen in the soil. Inoculation with Nodulator plus application of a starter of NPK significantly increased seed yield. Inoculation with Nodulator alone was not effective unless combined with Integral or with starter fertilizer.

Plant biomass was significantly lower for the untreated control and the PK treatment.

Given the similarities in climate, seed type, and biotic constraints, the bean research programs in Ecuador and Angola should strengthen collaboration.

Objective 3: Develop molecular markers for disease resistance genes.

The RAPD markers previously reported to be linked to genes for charcoal rot were screened with a set of susceptible and resistant genotypes. Seven susceptible genotypes.

Because the putative RAPD markers were proven to be ineffective, recombinant inbred lines (RILs) from crosses between BAT 477 and susceptible bean lines were pursued for the development of novel markers. Seed of RILs from the cross DOR 364 x BAT 477 were obtained from CIAT by Dr. Tim Porch. In September 2008, 2009, and 2010, these lines were planted at Isabela, Puerto Rico, in a replicated field trial that was inoculated with the pathogen. The disease reactions of the RILs will be used to initiate the search for molecular markers for resistance to ashy stem blight.

A detached leaf technique for *Macrophomina phaseolina* evaluation has been implemented for screening the BAT 477 x DOR 364 RIL population. Significant differences were found between RILs in the population and some lines were identified in which seed yield and detached leaf score corresponded (Table 13).

RIL/Genotype	Laboratory - 2010		Field - 2009	
	Detached leaf score (1-9)		Seed yield (hg/ha)	
	Average	Rank	Yield	Rank
0851-87	1.5	4	2340	3
0851-92	2.3	7	2181	4
0851-100	2.5	8	2479	2
BAT 477	4.0	15	2047	8
DOR 364	4.0	16	1762	17
0851-72	5.4	34	1360	34
XAN 176	5.8	36	2157	6
0851-5	5.9	37	413	53
ICA Pijao	6.2	42	1580	24
0851-57	7.0	46	976	49
0851-60	7.8	47	1400	31

Table 13. Detached leaf and yield response of lines from BAT 477 x DOR 364 RIL population to M. phaseolina inoculation.

Field trials are being conducted for a third year with the BAT 477 x DOR 364 RIL population. The trial was inoculated with *M. phaseolina* before flowering using liquid inoculum and backpack sprayers. QTL analysis will be completed based on the phenotypic scoring of the lines (1-9 scale) and based on yield and plant survival using the data from the multiple field trials.

Objective 4: Evaluation of other dry pulse crops for Central America and the Caribbean.

Morphological and agronomic traits of Lima bean landrace varieties from Puerto Rico were evaluated and compared with the Sieva and Christmas Lima bean varieties from Seed Savers Exchange. Days to flowering of the landrace varieties ranged in Puerto Rico from 46 to 100 days after planting (DAP). When planted in Honduras in June, four landraces flowered less than 60 days after planting, suggesting that these varieties could be planted in the tropics throughout the year. PL-08-1 and PL-08-2 were the highest-yielding lines in Puerto Rico and Honduras.

The University of Puerto Rico received seed of 10 Lima bean landraces from Haiti and 24 Lima bean landraces from the Dominican Republic. One or two of the most promising lines may be considered for release as cultivars.

As part of the M.S. thesis research of Antonio David, the diversity of Angolan cowpea germplasm in relation to a diverse worldwide collection was evaluated through phenotypic characterization in a field trial planted at Isabela, Puerto Rico, in March 2010. The initial seed elemental composition results indicate some unique nutritional characteristics of Angolan germplasm, including high protein and iron content.

Networking With Stakeholders

Cultivars developed in collaboration with CIAT and National Bean Programs (NBP) were purified for the presence of the SR2 (bgm gene), SW12 (major QTL), and SW13 (I gene) markers for resistance to BGYMV and BCMV. In addition, individual plants identified to have the previously described SCAR markers were characterized with more than 10 other markers associated with resistance to CBB, anthracnose, rust, and ALS. This marker-assisted selection included the small red cultivars INTA Zamorano, INTA Ferroso and INTA Sequía recently released in Nicaragua under the CIAT/INTA/Zamorano collaboration.

The participants in the CA/C bean research workshop expressed support for the recruitment and training of young researchers to strengthen the scientific and technical capacities of national as well as regional bean research programs. This project, in collaboration with the Michigan State University

(PI-MSU-1) project, prepared a set of regional nurseries that were planted in Angola and Rwanda. The nurseries included elite breeding lines from Michigan State University, the University of Puerto Rico, USDA-ARS, Zamorano, and INIAP. Given the similarities in climate, seed type, and biotic constraints, the bean research programs in Ecuador and Angola should strengthen collaboration.

The UPR bean breeding program collaborated with Dr. Graciela Godoy-Lutz, Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF) plant pathologist, in the preparation of a proposal entitled *Evaluación, multiplicación y adopción de líneas avanzadas de habichuela con resistencia a limitantes bióticas desarrolladas en el proyecto Bean/Cowpea CRSP* that was submitted and approved by the Consejo Nacional de Investigaciones Agropecuarios y Forestales (CONIAF). Although the project will not provide any additional funding for research in Puerto Rico, it will provide an opportunity to continue to test the most promising lines from our breeding program in the Dominican Republic. This collaboration should result in the release of disease resistant black and red mottled bean cultivars.

Leveraged Funds

Scientists involved in this project have effectively used Dry Grain Pulses–CRSP support and institutional linkages to leverage more than $415,000 in external funding in 2010 to achieve objectives related to this project.

Publications

Beaver JS, Porch TG, Zapata M. 2010. Registration of “Badillo” Light Red Kidney Bean. *Journal Plant Registrations* 4:1–4.

Dorcinvil R, Sotomayor-Ramírez D, Beaver JS. 2010. Agronomic performance of common bean (*Phaseolus vulgaris* L.) lines in an Oxisol. *Field Crops Research*. 118:264–272.

Godoy-Lutz G, Beaver JS, Rosas JC, Steadman JR. 2010. Web blight research techniques posted on the web site of the Bean Improvement Cooperative. http://www.css.msu.edu/bic/PDF/Web_Blight.pdf

Guachambala MS and Rosas JC. 2010. Caracterización molecular de accesiones cultivadas y silvestres de frijol común de Honduras. *Agronomía Mesoamericana* 21(1):1–10.

Henry A, Rosas, JC, Beaver JS, Lynch JP. 2010. Multiple stress response and belowground competition in multilines of common bean (*Phaseolus vulgaris L.*). *Field Crops Research* 117:209–218.

Porch TG, Smith JR, Beaver JS, Griffiths PD, Canaday CH. 2010. TARS-HT1 and TARS-HT2 Heat-tolerant Dry Bean Germplasm. *HortScience* 45:1278–1280.

Ruiz L, Beaver JS, Rosas JC, Ernest E. 2010. Evaluation of Lima bean landraces from Puerto Rico. *Annual Rep. of the Bean Improvement Coop.* 53:72–73.

Rosas JC, Guachambala MS, Ramos RA. 2010. Guía ilustrada para la Descripción de las Características de Variedades de Frijol Común. EAP, Zamorano, Honduras, 22p.

Rosas JC, Araya R, Ortega I. 2009. Variedades de Frijol Rojo obtenidas por Fitomejoramiento Participativo en Honduras y Nicaragua. Est. Exp. Agr. Fabio Baudrit Moreno, Heredia, Costa Rica, 40p.

Enhancing Biological Nitrogen Fixation (BNF) of Leguminous Crops Grown on Degraded Soils in Uganda, Rwanda, and Tanzania

PIII-ISU-2

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

Mark E. Westgate, Iowa State University, USA

Collaborating Host Country and U.S. PIs and Institutions

John Steven Tenywa, Makerere University, Uganda

Lynne Carpenter-Boggs, Washington State University, USA

Karen Cichy, USDA-ARS, USA

James D. Kelly, Michigan State University, USA

Phillip Miklas, USDA-ARS, USA

Henry Kizito Musoke, Volunteer Efforts for Developmental Concerns, Uganda

Susan Mchimbi-Msolla, Sokoine University of Agriculture, Tanzania

Augustine Musoni, Institit des Sciences Agronomiques du Rwanda (ISAR), Rwanda

Daniel Krohn, Becker Underwood Inc., USA

Hamisi Tindwa, Sokoine University of Agriculture, Tanzania

Michael Ugen, National Crops Research Institute, Uganda

Peg Armstrong-Gustafson, Amson Technology l.c., USA

Abstract of Research and Outreach Achievements

Loss of soil fertility is recognized as the most important constraint to food security in sub-Saharan Africa. Enhancing the natural capacity of legume crops, such as common beans, for biological nitrogen fixation (BNF) has been shown to help overcome this constraint, but an optimum combination of variety, inoculant, and crop management has not been established. To this end, this CRSP program will identify production systems that enhance BNF, develop germplasm that benefits most from symbiotic inoculation, and aggressively share this new information with smallholder farmers in sub-Saharan Africa whose health and well-being depend heavily on legume production.

This first report encompasses research achievements since the program was formally initiated in August 2010. Although the program was intended to begin January 1 of this year, funding allocation to the lead U.S. institution was delayed and subcontracts to partner and host country institutions were finalized only in August and September. While U.S. institutions initiated some aspects of the program objectives prior to funding, the host country partners began the first field trials with the second planting season in September. As a result, this report describes the preliminary investigations initiated this summer at U.S. institutions and the design of field trials and initial collection at the host country research sites.

Although the project activities have been underway for only two to three months, all the six-month benchmarks outlined for Objectives 1 and 2 in the revised FY10 workplan have been accomplished. These include:

- Identifying the genotypes and research demonstration sites to be examined at HC institutions
- Quantifying the soil's physical and chemical characteristics at all test sites
- Obtaining experimental and adapted common bean germplasm for genetic marker analyses
- Increasing seed of existing mapping populations for QTL analysis

All HC institutions have identified graduate students or undergraduate interns and have initiated their research activities. Students from partner countries have begun their graduate study or are slated to begin study in January 2011 at U.S. institutions.

This project is in its earliest stages with the first field trials just reaching flowering and first major sampling activities. Harvest is anticipated in early December, which will provide initial results to evaluate the potential impact of advanced inoculant technologies on BNF. Initial field evaluation of bean germplasm for genetic marker analyses also have yet to be analyzed and need to be repeated under controlled conditions. Planning is underway for a workshop to bring together all BNF-CRSP program PIs to develop synergies among these complementary programs.

Project Justification and Objectives

Loss of soil fertility is the most important constraint to food security in sub-Saharan Africa. Low levels of nitrogen and phosphorous are the primary fertility constraints. Because soils are becoming increasingly degraded, an affordable means of improving soil fertility and productivity of nitrogen-accumulating crops is critical. Numerous studies have shown the potential for improving legume productivity by enhancing nodulation through proper use of biological inoculants, yet field trials have provided mixed results. Potential reasons for failure include poor quality of inoculants, failure to compete with local rhizobia, inhibition by indigenous microbial flora, or failure of the inoculants to survive in low pH and droughty soils.

Modern inoculant formulations designed to deliver a synergistic suite of biological and chemical enhancements for biological nitrogen fixation under stressful soil conditions have been made available to our collaborative research project by Becker Underwood, Inc., whose BioStacked® inoculant technologies for legume crops consist of well stabilized *Rhizobium* bacteria, a biological fungicide, plant growth promoting rhizobacteria, and other biologically derived proprietary biostimulant technologies that promote plant growth and overall plant health. These stacked inoculants decrease chemical fertilizer use in crop rotations, increase legume yields, suppress root diseases, and improve rhizosphere conditions for root growth. They are suitable for use on a variety of legume crops, such as soybean, common bean, cowpea, and pigeon pea. We anticipate they will be particularly effective under degraded soil conditions encountered on smallholder farms in Uganda, Rwanda, and Tanzania.

To optimize BNF, it is essential to identify germplasm with the greatest capacity for this trait. Although common bean has the potential for BNF, it is reported to have the lowest percent N2 derived from N fixation among legumes. Genetic variation for BNF has been reported and lines with superior BNF have been identified. Superior BNF lines, such as Puebla 152 and BAT 477 have been used as parents in crosses to generate populations for genetic studies and breeding for improved BNF. Few breeding lines with improved BNF, however, have been developed. Low heritability estimates for BNF and related traits indicate that BNF traits are quantitatively inherited and influenced by environment. The optimal selection environment for BNF is under low soil N since application of nitrogen fertilizer reduces N fixation capacity. Marker-assisted selection under such conditions is highly sought after as a means to facilitate breeding for improved BNF because of its low heritability.

There have been few molecular mapping studies conducted for BNF in legumes, but there are many available recombinant inbred mapping populations within the bean breeding community that are ideal for a BNF–QTL study. Molecular mapping in combination with germplasm screening and marker assisted selection (MAS) would be a powerful way to improve locally adapted germplasm for BNF in a host country. Recombinant inbred populations are ideal for tagging and mapping genes that influence quantitative traits (QTLs). These populations provide segregating inbred lines that can be replicated over space and time and maintained for many years, which is ideal for characterizing traits conditioned by many genes and influenced by the environment. Few QTLs associated with BNF have been identified to date, and those identified have not been validated. Therefore, identification and subsequent validation of QTL-conditioning-enhanced BNF would represent a major contribution to the scientific community and represent a major step toward generating capacity for marker-assisted selection for BNF.

Our CRSP program objectives address the need to identify production systems that enhance BNF, develop germplasm that benefits most from symbiotic inoculation, and aggressively share this new information with small landholder farmers in sub-Saharan Africa whose health and well-being depend heavily on legume production.

Objectives

1. Improve BNF and seed yields of common beans significantly using superior seed inoculants, such as Becker Underwood's BioStacked® inoculant, through farmer-based experimentation and adoption of innovative production techniques.

2. Examine the inheritance of genetic and environmental variation in BNF in common bean and identify molecular markers associated with QTL conditioning for enhanced BNF.

3. Improve the productivity, profitability, and sustainability of agricultural systems on degraded soils through effective dissemination of new information and technologies to smallholder farmers through on-farm demonstrations, mass media, field schools, and local forums.

4. Institutional Capacity Building: Purchase computers and other technical equipment.

Research and Outreach Approaches, Results, and Achievements

Objective 1: Improve BNF and seed yields of common beans significantly using superior seed inoculants, such as Becker Underwood's BioStacked® inoculant, through farmer-based experimentation and adoption of innovative production techniques.

1a. Evaluate effectiveness of biologically stacked inoculants on local and improved germplasm.

- Six-month benchmark: Identify genotypes and research demonstration sites at HC institutions

Trial sites on research stations have been established in Uganda, Rwanda, and Tanzania. Similar protocols were followed in all three host countries (HCs) based on collaborative discussions among HC PIs. Varieties and specific field designs vary based on local adaptation and production preferences.

3x5 m^2	1	2	3	4	5	6	7	8
	$V_1R_0P_0$	$V_1R_NP_+$	$V_1R_0P_0$	$V_1R_NP_0$	$V_1R_UP_0$	$V_1R_MP_+$	$V_1R_MP_0$	$V_1R_UP_+$
1	$V_1R_0P_+$	$V_1R_UP_0$	$V_1R_NP_0$	$V_1R_NP_0$	$V_1R_NP_+$	$V_1R_MP_+$	$V_1R_0P_0$	$V_1R_UP_+$
	$V_1R_0P_+$	$V_1R_UP_0$	$V_1R_UP_+$	$V_1R_MP_+$	$V_1R_MP_0$	$V_1R_NP_+$	$V_1R_MP_0$	$V_1R_0P_+$
	$V_2R_UP_0$	$V_2R_NP_0$	$V_2R_0P_0$	$V_2R_NP_0$	$V_2R_0P_+$	$V_2R_MP_+$	$V_2R_MP_0$	$V_2R_MP_0$
2	$V_2R_0P_+$	$V_2R_NP_+$	$V_2R_NP_+$	$V_2R_MP_+$	$V_2R_NP_0$	$V_2R_UP_+$	$V_2R_NP_+$	$V_2R_0P_+$
	$V_2R_UP_0$	$V_2R_MP_0$	$V_2R_MP_+$	$V_2R_UP_0$	$V_2R_0P_+$	$V_2R_UP_+$	$V_2R_0P_0$	$V_2R_UP_+$
	$V_3R_MP_0$	$V_3R_0P_0$	$V_3R_NP_+$	$V_3R_UP_0$	$V_3R_MP_0$	$V_3R_UP_+$	$V_3R_MP_+$	$V_3R_UP_0$
3	$V_3R_UP_+$	$V_3R_MP_+$	$V_3R_UP_+$	$V_3R_NP_+$	$V_3R_MP_+$	$V_3R_0P_0$	$V_3R_0P_0$	$V_3R_NP_+$
	$V_3R_NP_0$	$V_3R_0P_+$	$V_3R_0P_+$	$V_3R_NP_0$	$V_3R_0P_+$	$V_3R_NP_0$	$V_3R_UP_0$	$V_3R_MP_0$

Figure 1. General field map for one replicate of the inoculant evaluation trials. R0 = No Rhizobium strain Inoculated, RM = Rhizobium strain from Makerere University Bio-fix, RN = Rhizobium strain from Nairobi Bio-N-fix, RU = Rhizobium strain from Underwood BioStacked®, P0 = No phosphorus fertilizer applied, P+ = Phosphorus fertilizer (TSP) applied at 40 kg P ha-1. Varieties V1-3 varied by location.

Germplasm

In Uganda, there are three common bean varieties with market preference: K 132, Kanyebwa (local cultivar), and K131 (V1, V2, V3, respectively). Kachwekano was selected for climbing bean and three varieties, namely NABE10C, NABE12C, and a local cultivar (V1, V2 and V3 respectively), were selected and planted under the same treatments. Figure 1 shows the general outline of the field study.

In Tanzania at SUA, 20 local and improved germplasm lines for the experiments have been collected from National Agricultural Research (NAR) Institutes and CIAT for evaluating the effectiveness of the inoculants (both local and the Becker Underwood's BioStacked® inoculant). Seeds are now being increased at the station (SUA) to obtain adequate seed for planting.

In Rwanda, two improved climbing bean varieties, ISAR-CB-105 and ISAR-CB-107 (Type IV), and two bush, ISAR-SCB-102 (Type IIA) and RWR 1668 (Type I), were selected among the newly released bean varieties in Rwanda (Table 1) for their adaptability in the low altitude zones of eastern Rwanda and their culinary and marketable attributes that were appreciated by farmers during the variety selection trials.

Field sites

In all cases, field research and demonstration sites are on national or university research stations to ensure control of field operations and uniformity of treatment applications.

In Uganda, field sites are located in three agroecological zones identified in cooperation with Dr. Tenywa and two master's students from Makerere University in central Uganda at Namulonge (NaCRRI) and southwestern Uganda at Mbarara

Variety	Plant type	Market class	Maturity (M)	Mean (t/ha)	Yield	Special attributes
ISAR-CB-105	IVA	Calima/mottled	3.0	3.0		Heat & drought tolerant; extra early; rust &CBB resistant, marketable
ISAR-CB-107	IVA	Calima/mottled	3.0	3.5		Heat & drought tolerant; extra early; BMV, rust resistant, marketable and taste
ISAR-SCB-102	IIA	Small red	2.5	2.5		Drought resistant, marketable, taste
RWR 1668	I	Kidney	2.5	2.0		Multiple resistance, marketable and culinary

Table 1. High yielding climbing and bush beans varieties selected for the bionitrogen fixation trial in Nyagatare district (1200 – 1500 masl) of Rwanda in 2010.

ZARDI and Kachwekano ZRDI research stations. Treatments include three rhizobia types sourced from the USA (Becker Underwood) and from the University of Nairobi and the University of Makerere.

In Rwanda, two sites were selected at ISAR Nyagatare research station and at the farmers' field in Nyakigando sector of Nyagatare district. The Nyakigando site was selected for research as well as demonstration and training purposes for farmers' cooperatives and other farmers in the area.

In Tanzania, the field sites are located at the research stations at Morogoro, Mbeya, and Arusha.

Additional field management details

At the NaCCRI stations, phosphorus—being the most constraining nutrient in the soils of east Africa and yet very crucial to effective BNF—was considered as a treatment (0 and 40 kg P ha-1) to evaluate to what extent the imported rhizobia can withstand the limited P supply in the soil. The factorial combinations culminated into a total of 72 treatment plots.

At ISAR, four varieties (V1, V2, V3, and V4) x rhizobia (Ru, Rn with or without Ro) x P fertilizer at two levels (with and without) were applied in all combinations to give a total of 24 treatments.

1b. Quantify genotype by environment interactions and constraints to enhancing BNF of inoculated plants.

- Six-month benchmark: Quantify soils' physical and chemical characteristics at all test sites

Soil samples for all three sites for which physical analysis has already been carried out were collected for chemical analysis. Additional soil samples will be collected for DNA extraction, and further analysis is scheduled when plants reach flowering, which will coincide with biomass sampling and assessments of nodule number and activity. Standard weather data will be collected throughout the growing season.

Data on crop development related to N2 fixation to be collected at flowering: Nodulation potential at 10 – 20 percent flowering, number of effective nodules (based on legheamoglobin pigment status), leaf area index (LAI) at flowering, visual chlorotic symptoms (green vs. yellowness), vegetative biomass, total plant N, and petiole ureide concentration.

Harvesting for grain yield and total plant N is anticipated two months after planting dates for each site.

Harvest data will include final seed weight, pod number, seed number, seed size, and seed nitrogen content.

Objective 2: Examine the inheritance of genetic and environmental variation in BNF in common bean, and identify molecular markers associated with QTL conditioning for enhanced BNF.

2a. Identify parental materials for inheritance studies of BNF.

- Six-month benchmark: Obtained experimental and adapted common bean germplasm

Michigan State University: Parental materials for inheritance studies were identified based on previous knowledge of BNF capacity. One line, Puebla 152, was identified as BNF efficient and an RIL population exists with Eagle (snap bean) as the other parent. Additional genotypes were planted that are parents of other available RIL populations. Ninety-two genotypes were planted in low nitrogen (25 lbs/acre) in Frankenmuth, Michigan, including Eagle, Puebla 152, 72 Eagle x Puebla RILs, a no nod mutant, and 17 additional genotypes under two treatments: plus Becker Underwood Nodulator inoculant and no inoculant.

2b. Phenotype existing mapping populations for BNF response, populate with molecular markers, and conduct QTL analysis.

- Six-month benchmark: Increased seed of existing mapping populations for QTL analysis

At Washington State University, a BNF experiment was conducted in the field in Washington in 2010 at two separate locations, Prosser and Paterson. The objective was to survey bean genotypes for biological nitrogen response under low soil N conditions. There were three treatments: 1. NT=no nitrogen or rhizobium inoculum, 2. BS=Biostacked rhizobium inoculum only, and 3. N=75 lbs of additional N only in the form of urea (46-0-0).

The Prosser trial site is a Warden Silt Loam and is used for selecting bean lines under multiple stresses (low fertility, soil compaction, drought, and root rot diseases). The Paterson trial site is a Quincy Sand. Low residual N (25lbs/A) was confirmed for this trial prior to planting. The same set of genotypes plus five more (28 total) was tested in Paterson. Soil total, available, and mineralizable N will be analyzed. Plant %N and 15/14N ratio will be analyzed. This information plus yield data will be used to quantify the proportions and total amounts of BNF by these genotypes and treatments.

The non-nodulating genotypic check R99 had 43 percent more seed yield in the N (3460 kgha-1) than the NT (1966 kgha-1), which suggests that response to supplemental N in the absence of nodulation was detectable in this field trial. Across all the genotypes tested, however, there was no significant difference between NT and N treatments, suggesting that most of the genotypes included in the study are quite efficient for BNF. There was a significant effect for the BS inoculant treatment, which unexpectedly resulted in 7 percent and 8 percent less yield than the NT and N treatments, respectively.

Procedures to analyze nodule and soil rhizobia will primarily use full community pyrosequencing of nifH, nifD, and (for nodules) 16SrDNA genes. Where individual treatments are of particular interest for very high BNF, individual strains will be isolated from nodules for pure culture.

Preliminary greenhouse trials were undertaken between July and October to optimize growth conditions for P. vulgaris in the WSU–Pullman greenhouse facilities. A perlite–vermiculite mixture was found to reduce seedling growth but increase nodulation and final biomass as compared to perlite alone. Inoculated plants supplied Hoagland solution (N-free recipe after week two) twice weekly produced more biomass and nodules than plants fertilized once weekly. Fifty lines, including the 28 genotypes tested in the field, and 23 additional lines were sent to Pullman for analysis of BNF response in the greenhouse. The greenhouse studies will commence in early November 2010.

QTL analyses: An existing RIL population (Eagle/Pueblo-152) was increased in the greenhouse for 2011 field planting, but lack of adaptation of the parents for this population in 2010 Washington field trials indicated that this population may only be useful for greenhouse examination of BNF response.

Michigan State University: Plant samples of the BNF trial were taken at mid-pod fill for each genotype/treatment/rep. These samples are being analyzed for N15 via natural abundance analysis and results are expected in December 2010. Nitrogen from fixation will be estimated relative to the nitrogen accumulated by a non-nodulating bean line included as a control in the experiment.

SSR screening was conducted on Eagle and Puebla 152 to identify polymorphic markers. The BNF trial, including Eagle x Puebla RILs and an additional 18 lines, was harvested in October 2010. The Eagle x Puebla population did not do well in the field in Michigan, with many lines maturing very late and without desirable growth.

Objective 3: Improve the productivity, profitability, and sustainability of agricultural systems on degraded soils through effective dissemination of new information and technologies to smallholder farmers through on-farm demonstrations, mass media, field schools, and local forums.

3a. Improve farmer awareness of inoculation technologies.

3b. Conduct on-farm demonstrations comparing inoculant strategies.

3c. Strengthen farmers' collective capabilities to purchase inoculants and incorporate them into a profitable and sustainable system for small landholders.

• No funding allocated or benchmarks for this period.

On-station research and demonstration trials have been initiated in which the benefits of inoculants on the different varieties are being compared. These sites will serve as initial demonstrations for farmer field days. Initial contacts were made with the collaborating farmers that offered their fields for experimentation and demonstration. Training sessions followed by site visits and field days will be organized during this growing season.

PI Westgate met with the Chair of PELUM (Participatory Ecological Land Use Management) Uganda and Communications Coordinator for VEDCO, Agnes Kirabo, to initiate outreach activities with participating farmer organizations in PELUM Uganda, PELUM Kenya, PELUM Tanzania, and PELUM Rwanda. A strategy meeting among PELUM country coordinators to initiate dissemination activities is scheduled for November 2010.

Objective 4: Institutional Capacity Building: Purchase computers and other technology materials for educational and research use.

Three laptops (Dell) and one printer HP LaserJet P1006 were purchased by Makerere University for a total cost of U.S. $5,369 through the procurement system of the university. This equipment is being shared by two graduate students and the PI (Tenywa) at Makerere University.

Networking and Linkages with Stakeholders

Germplasm was obtained from the NARs in Tanzania and from CIAT.

Dr. Tenywa travelled to Rwanda in September 2010 to discuss project activities with Dr. Augustine Musoni. Both travelled to Nyagatare where the then-proposed site was evaluated for suitability for BNF demonstrations. Soil sampling was conducted, and the study design and treatments adopted for the NaCRRI sites were also considered for the Rwanda sites to permit regional comparisons.

A Material Transfer Agreement was established between ISU and CIAT Columbia to obtain germplasm with potential application to this project.

Plans to conduct a workshop among BNF–CRSP PIs directing Phase II and Phase III projects is currently being planned for early in FY11.

Pulse Value Chain Initiative;— Zambia (PVCI-Z)

PIII-KSU-1

Principle Investigator

Vincent Amanor-Boadu, Kansas State University, USA

Collaborating Scientists

Gelson Tembo, University of Zambia, Zambia

Mukwiti Mwiinga, University of Zambia, Zambia

Prisilla Hamukwala, University of Zambia, Zambia

Rebecca Lubinda, University of Zambia, Zambia

Tim Dalton, Kansas State University, Zambia

Allen Featherstone, Kansas State University, Zambia

Mahmud Yesuf, Kansas State University, Zambia

Abstract of Research Achievements and Impacts

This project is just about to start. Therefore, we have no research achievements to report. However, we have completed the U.S. institution project planning and the lead PI is going to Zambia from September 22 to October 5 to begin the host country institution project planning.

Category I Objectives

1. Identify the different supply chains used by the Zambian pulse industry and describe the characteristics of those using them at the different loci of the supply chains.
2. Identify and estimate the effects of stakeholder characteristics on producers' supply chain participation decisions.
3. Describe and estimate the pecuniary and nonpecuniary value for different supply chain participants.
4. Identify the institutional and policy issues influencing value creation and determine if any differences exist by crop, location, gender, and stage of the chain.
5. Based on the results from the foregoing, develop and deliver education and outreach programs targeting specific stakeholders and provide policy recommendations to facilitate solutions.

Research and Outreach Approaches, Results, and Achievements

Objective 1: Identify the different supply chains used by the Zambian pulse industry and describe the characteristics of those using them at the different loci of the supply chains.

The approach to achieving this objective (and others) includes developing a common appreciation of the project and engaging both PIs and students. Because our project was just approved at the end of August 2010, we have only completed the strategic planning of the U.S. PIs and set up a planning session in Zambia from September 22 to October 5, 2010, to initiate the development of the project's survey instruments.

In the short weeks since signing our contract, we have completed recruiting the six undergraduate students and one of three MS students. We have also identified six candidates for the MAB program and will be conducting interviews when the lead PI arrives in Zambia to facilitate their recruitment and enrollment for the January 2011 class.

Due to this project being at its very beginning, there is nothing more specific to report on the remaining objectives as of this report (September 2010).

Category II Objectives

1. Work with specific industry stakeholders to pilot different governance systems to identify the factors and participant characteristics influencing performance.
2. Use the results of the experiment to develop outreach programs, program advocates, and program advisory support systems to help producers and their partners develop appropriate governance systems to improve their economic well-being.
3. Capacity Building

Objectives 1 and 2

There are no details to report on Category II Objectives one and two at this time, due to the project being at its very beginning.

Objective 3: Capacity Building

We have recruited six (of six) undergraduate students, one (of three) MS students, and none (of three) MAB students.

Improving Nutritional Status and CD4 Counts in HIV-Infected Children Through Nutritional Support

PIII-MSU-3

Principle Investigators

Maurice R. Bennink, Michigan State University, USA

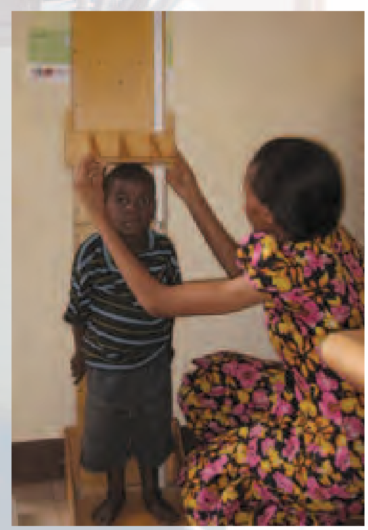
Theobald Mosha, Sokoine University of Agriculture, Tanzania

Collaborating Scientists

Henry Laswai, Sokoine University of Agriculture, Tanzania

Elizabeth Ryan, Colorado State University, USA

Reuben Kadigi, Sokoine University of Agriculture, Tanzania



Abstract of Research Achievements and Impacts

A randomized, prospective, community-based trial is being conducted to determine if HIV-infected, HAARV-naïve, 2- to 15-year-old children and adolescents eating a bean–maize or cowpea–maize supplement will maintain a higher CD4 percent than HIV-infected, HAAR-naïve, 2- to 15-year-old children and adolescents eating a fish–maize supplement. The food supplements are similar in nutrient and energy content, with only the major source of protein (bean, cowpea, or fish) differing among the three study groups. The study is being conducted at two rural sites in Tanzania—the Turani and the Rombo areas—and 270 children and adolescents are enrolled at each site. A local supervising and monitoring group has been formed and trained for each research site. A laboratory at Sokoine University of Agriculture (SUA) in Tanzania has been equipped to analyze biohazardous samples (HIV infected blood) and a two-months' supply of individual supplement packages (approximately 30,000 packages) have been prepared. Dried blood spots will be prepared for each blood sample and these blood spots will be shipped to the United States. Protocols for eluting and analyzing viral RNA, ribosomal 16s RNA, and various proteins from dried blood spots have been standardized. Viral RNA will be monitored to determine if dietary treatment affects the innate ability to suppress the human immune virus. Ribosomal 16s RNA is an indicator of bacterial products in blood and will reflect bacterial translocation from the gut. The proteins being analyzed (C-reactive protein, soluble tumor necrosis factor receptor p55, and interferon-γ) are markers of inflammation. These assessments will be performed to monitor HIV status and to evaluate hypotheses regarding treatment effectiveness. A cost comparison of the precooked supplements versus home prepared foods with the same ingredients versus antiretroviral drug treatment has been initiated. The baseline blood data and commencement of supplement feeding will occur in the beginning of FY11 and conclude at the end of FY12.

Project Justification and Objectives

The overall goal of the research is to determine if eating beans or cowpeas will improve the immune status of HIV-positive children who are not being treated with antiretroviral drugs. The global theme addressed by this research is "to increase the utilization of bean and cowpea grain, food products, and ingredients so as to expand market opportunities and improve community health and nutrition" and the topical area that will be addressed is "Achieving Nutritional Security for Improved Health of Target Populations."

HIV has caused an estimated 25 million deaths worldwide in just 27 years, and there are approximately 33 million people in the world infected with HIV. Around 2 million children less than 15 years of age have HIV and 90 percent of the children living with—and dying from—HIV live in sub-Saharan Africa. Furthermore, about 140,000 of these children live in Tanzania. Most children living with HIV are infected during pregnancy, at birth, or via breastfeeding.

It is well-known that insufficient intake of macronutrients and some micronutrients leads to a decrease in immune function and an increase in infectious diseases. Infections, in turn, cause nutrient loss that quickly leads to greater malnutrition, and a vicious cycle is set in motion. Since the human immunodeficiency virus destroys CD4 cells (immune cells), opportunistic infections are common among those living with HIV. In addition, most young children (not infected with HIV) in resource poor countries are undernourished or have marginal nutrition status. Since the insults of malnutrition and HIV on the immune system are synergistic, it is not surprising that young children with HIV are 2.5 to 4 times more likely to die than their uninfected counterparts.

We previously showed that providing HIV+ children with a bean–maize supplement containing minerals and vitamins could reverse malnutrition, if present, and improve the immune system (increased CD4 counts) even though the children were not receiving highly active antiretroviral (HAARV) drugs. Since 50 percent of HIV+ people do not have access to HAARV drugs, this is an extremely important finding; consuming the bean-based supplement could be an important stop gap until more people are able to obtain HAARV drugs. Children receiving HAARV treatment also benefited from the bean-based supplement in a second study we have conducted. Thus, the bean-based supplement would also be beneficial to children who have access to HAARV medicine.

Cowpea is a widely consumed pulse in Africa, but there is no published data regarding the effect of feeding cowpeas to HIV+ children. If cowpea is also effective in improving nutritional and immunological status, consuming a bean-based or cowpea-based supplement could improve the lives of millions of HIV-infected people, which would also benefit the entire bean/cowpea value-added chain from farmers to consumers.

Objectives

1. Determine if HIV infected, HAARV naïve, 2- to 15-year-old children and adolescents eating a bean–maize or cowpea–maize supplement will maintain higher CD4 percent than HIV infected, HAARV naïve, 2- to 15-year-old children and adolescents eating a fish–maize supplement.

2. Determine the relative costs of three dietary treatments compared to HAARV drug treatment.

3. Capacity building at SUA.

Research and Outreach Approaches, Results, and Achievements

Objective 1: Determine if HIV infected, HAARV naïve, 2- to 15-year-old children and adolescents eating a bean–maize or cowpea–maize supplement will maintain higher CD4 percent than HIV infected, HAARV naïve, 2- to 15-year-old children and adolescents eating a fish–maize supplement.

Approaches and Methods

1. Assemble research team members in Tanzania (field supervisors, nurses, technicians).

2. Install blood cell counter (cytometer) and train technicians to use and maintain the instrument.

3. Enroll 270 subjects into the HIV study.

4. Train one Ph.D. and three M.S. students to assist in research.

5. Provide field practical training in community nutrition and health for 10 undergraduates.

6. Analyze 540 blood samples for CD4 and related lymphocytes.

Results and Outputs

The study sites are remote from SUA (Turani is approximately 100 km from SUA and not easily accessible due to a 45 km stretch of very poorly maintained dirt road, and Rombo is a rural area 550 km from SUA). Consequently, on-site, local research teams were assembled for each study site. The meetings suggest that each site can provide the required 270 subjects.

Approximately 30,000 individual packages of food supplement (daily servings for about two months) have been prepared. A laboratory capable of receiving, processing, and storing biohazardous materials was assembled at SUA. Except for the flow cell counter, all other pieces of equipment necessary for the study have been installed. The laboratory has been stocked with the necessary supplies and pieces of small equipment.

Three master's students completed their course work and received training to assist in the study and to gather data for their theses. This project allowed 11 undergraduate students to receive practical field training in community nutrition and health. (There is no cost to the project associated with the undergraduate training.)

Because there was a delay in receiving and installing the flow cytometer, no blood samples were collected since the CD4 counts have to be performed within hours of blood collection.

Protocols for eluting and analyzing viral RNA, ribosomal 16s RNA, and various proteins from dried blood spots have been standardized. Viral RNA will be monitored to determine if dietary treatment affects the innate ability to suppress the human immune virus. Ribosomal 16s RNA is an indicator of bacterial products in blood and will reflect bacterial translocation from the gut. The proteins being analyzed (C-reactive protein, soluble tumor necrosis factor receptor p55, and interferon-γ) are inflammatory markers. These assessments will be performed to monitor HIV status and to provide hypotheses regarding treatment effectiveness.

Objective 2: Determine the relative costs of three dietary treatments compared to HAARV drug treatment.

Approaches and Methods

1. Determine costs associated with cooking beans in a pot and preparing Ugali (corn-based local food).

2. Determine costs associated with preparation of the bean–maize supplement and thin porridge from the supplement.

3. Determine costs associated with preparation of the fish–maize supplement and thin porridge from the supplement.

4. Determine costs associated with HAARV drug treatment.

Results and Outputs
Wholesale and retail prices for the various antiretroviral treatments (ART) utilized in Tanzania were obtained from CTC/VCT areas, pharmacies, the ministry of health, medical stores, and pharmaceutical factories. Costs for raw ingredients for supplement preparation and distribution have been compiled. Determining energy usage and cost for preparing the various supplements and preparation of similar foods at the household level is technically more difficult and has not yet been completed.

Objective 3: Capacity building at SUA

Results and Outputs
One Ph.D. and three master's students received support and training for their respective research projects that are part of this research activity. The ability and capacity to conduct research related to HIV monitoring at SUA is a significant advancement. It is expected that other researchers at SUA will now be willing to engage in similar research activities that will increase the overall research capacity at SUA.

Institutional Capacity Building

Degree Training
One doctoral and three master's students are currently training at SUV with support from CRSP. All four of these students should complete their programs in August 2011 or August 2012.

Equipment purchased (costing >$5000) None. A $49,000 flow cytometer has been loaned to SUA for the project duration by the manufacturer (BD Dicton) with the provision that research reagents be purchased for determination of CD4 and other lymphocytes. The loan was possible in part due to prior arrangements between the Clinton Foundation and the manufacturer.

Networking and Linkages with Stakeholders

In June 2010, Drs. Mosha and Bennink visited the Tanzanian USAID Mission and the World Bank to inform them of the research activities being conducted and planned by this activity. The host country PIs provided advice and assistance to two agricultural firms/enterprises:

1. Tanzania Foods Limited—composite food producers for special groups

2. Tanzania Power Foods—producer of foods for children, hospitals, rehabilitation centers, and retail outlets

The host country PIs provided advice and assistance to three women's groups:

1. WAVUMO —a women's group fighting against HIV/AIDS

2. TUNAJALI "We care"—an NGO women's group that provides home-based care and counseling for HIV+ families

3. FARAJA TRUST FUN —A women's group dealing with women's and children's needs due to HIV infection.

Leveraged Funds

No direct leveraged funds were received. The Heinz Company Foundation supports two research projects with the PIs of this activity. The Heinz-supported projects are synergistic to this activity, but their support does not directly increase the capacity of this activity. The loan of the flow cytometer avoids the need to purchase one and is a huge savings for the project.

Scholarly Activities and Accomplishments

None; the project was officially approved January 2010 and revised in June to include cowpeas and an additional study site. There has not been sufficient time to achieve scholarly activities as of September 2010.

Increasing Utilization of Cowpeas to Promote Health and Food Security in Africa

PIII-TAMU-1

Principle Investigators

Joseph Awika (Lead PI), Texas A&M University, USA

John Shindano, University of Zambia, Zambia

Abdul Faraj, Egerton University, Kenya

Amanda Minnaar, University of Pretoria, South Africa

Collaborating Scientists

Susanne Talcott, Texas A&M University, USA

Lloyd Rooney, Texas A&M University, USA

Bir Bahadur Singh, Texas A&M University, USA

Chitundu Kasase, University of Zambia, Zambia

Kalaluka Lwanga Munyinda, University of Zambia, Zambia

Kennedy Muimui, Zambia Agriculture Research Institute (ZARI), Zambia

Prisca Tuitoek, Egerton University, Kenya

Gyebi Duodu, University of Pretoria, South Africa

Abstract of Research Achievements and Impacts

Cowpea is a drought tolerant crop that has a major potential as a nutrition and food security crop in Africa. Evidence indicates that legumes may contain compounds that have health benefits against chronic diseases like cancer and cardiovascular disease; however, the large diversity in cowpea makes it difficult to determine the varieties with the best potential to promote health. We screened 81 cowpea lines of diverse phenotypes from around the world for phenol content and composition, and antioxidant properties to allow for selection of lines that can be used to study the health-promoting potential of cowpea. Phenol content varied by a factor of more than 50 among the samples analyzed (minimum 0.3, maximum 17.0 mg/g, gallic acid equivalent [GAE]). Based on seed coat color, the white varieties had the lowest phenol content. The black, red, and light brown varieties had the highest phenol content. Tannin contents also varied widely, with the lowest values reported for the white cowpea varieties, and the highest values in the light brown varieties. Antioxidant activity followed the same trends as phenol content; the white cowpea varieties had the lowest antioxidant activity, whereas the black, red, and light brown varieties had the highest antioxidant activity. Phenol contents correlated significantly with antioxidant activity. The antioxidants and phenols were mostly concentrated in the seed coat. Additionally, the trends for phenol and antioxidant activity were consistent regardless of where the samples were grown, suggesting that seed coat color is a major indicator of potential health benefits of cowpea. From the screening data we have narrowed down our sample selection to the black, red, and light brown seed coat colors as the ones most likely to have the best health-promoting potential. These phenotypes will be used in more advanced chemical and biochemical studies. The selected lines will also be crossed with appropriate white cultivars to study the genetic inheritance of seed coat color and antioxidant properties. The HC PIs and technical personnel have been trained and are currently actively involved in generation of data contributing to the goal of this project. Appropriate equipment was also purchased to enable host country (HC) institutions to adequately contribute to project objectives.

Project Justification and Objectives

Poor families in sub-Saharan Africa suffer high rates of malnutrition, especially among children, and diet-related chronic diseases have become a common phenomenon among urban African populations. For example, a recent survey reported that stunting and overweight due to malnutrition co-existed and were rampant among school-age children in poor communities of Western Kenya, affecting up to 70 percent of the children. Moreover, evidence indicates that childhood malnutrition may lead to increased risk of chronic diseases, e.g., cancer in adulthood. In fact, nutrition-related chronic diseases are becoming increasingly common in Africa, especially in urban areas, thus putting a large strain on the limited health infrastructure and imposing economic burden among the poor. Research shows that regular consumption of dry beans and other legumes may reduce serum cholesterol, improve diabetic therapy, and provide metabolic benefits that aid in weight control as well as reduce the risk for coronary heart disease and cancer. Thus, in addition to alleviating protein malnutrition, grain pulses have the potential to contribute to chronic disease prevention.

In Africa, malnutrition is closely linked to food insecurity; thus, the most vulnerable groups are those in marginal rainfall rural areas and the urban poor. Cowpea is one of the most drought tolerant crops and has a big potential as a food security crop for many poor African subsistence farmers. Additionally, cowpea has high quality proteins that compare favorably with soybean proteins when substituted in diets at equivalent protein contents. A limited number of studies have also demonstrated that cowpeas have high antioxidant capacity and that the antioxidant properties may be improved by heat processing or fermentation. Recent evidence also suggests that whole cowpea is effective at binding cholesterol and lowering blood cholesterol in hamsters. However, information on how cowpea and its constituents may directly impact human health is lacking. How variations in cowpea genetics affect their composition of potentially beneficial compounds is also unknown. This makes it difficult to promote cowpea as a healthy grain which dampens its demand and utilization.

Constraints to consumption of cowpeas

The image of cowpea as a healthy food lags behind other commodities. Part of this is due to lack of scientific data on the health and nutritional benefits of cowpea. In many parts of East and Southern Africa, the common perception that beans, cowpeas, and other pulses are poor man's food has also been a major impediment to broader consumption of these grains. Thus, most cowpea use is still restricted to low income populations. This leads to weak demand and depressed economic value of the crop, which in turn leads to limited incentive to invest in an efficient cowpea production and utilization infrastructure. In the United States, lack of nutritional benefit information limits incentives to promote cowpea use as a mainstream part of any diet.

Project Rationale
Reliable scientific evidence is essential to make educated dietary recommendations on type of cowpea, level of consumption, and design of food processing strategies that maximize the beneficial effects. Such evidence would also provide a basis for genetic and agronomic improvement aimed at optimizing composition of beneficial compounds. It is a first step in transforming cowpea into a primary food to address malnutrition in poor populations and in promoting cowpea as a mainstream part of a healthy diet. This could, in turn, lead to an increased demand for cowpea and improvement in the economic well-being of producers and the overall health of consumers.

Objectives

1. Identify cowpea lines with high content of health-enhancing compounds and their relationship to seed color and other seed traits.

2. Establish how the phytochemical profiles of cowpeas affect bioactivity by measuring key markers/predictors of protection against chronic diseases.

3. Elucidate the mode of inheritance (heritability) of selected bioactive traits in cowpea and genetic association between physical and bioactive traits.

4. Establish strong linkages with host country (HC) policy makers and other stakeholders, and develop outreach strategies that will lead to long-term increase in cowpea consumption for health and food security.

Research and Outreach Approaches, Results, and Achievements

Objective 1: Identify cowpea lines with high content of health enhancing compounds and their relationship to seed color and other seed traits.

Seeds of improved varieties and land races of cowpea sourced from West Africa, East and Southern Africa, and diverse types found promising in U.S. collections were obtained and screened for bioactive compounds. A total of 81 cowpea lines of diverse phenotypes have been screened for bioactive composition. An additional 20 lines are being screened in Zambia and Kenya.

Gross phenolic composition. The following analyses were used for the screening: gross phenol content, anthocyanin pigments, and tannins content. To confirm location of the phenolic compounds, three representative samples were selected and separated into seed coat and cotyledon, milled into flour, and analyzed. Samples were grouped into six phenotypes based on seed coat color: black, red, light brown, brown, streaked, and white. Two representative samples within each phenotype were selected for use in detailed chemical characterization and biochemical assays.

Flavonoids profiling. Sample extracts were obtained and washed through a C-18 column to remove sugars and other nonflavonoid constituents.

Phenolic acid and phenolate esters. Free phenolic acids were measured in methanol extract whereas alkaline hydrolysis of residue was used to measure esterified phenolic acids. Reversed phase HPLC separation, with appropriate standards, was used to identify the compounds. The gross phenolics content of the 77 cowpea lines screened are summarized in Table 1.

When the samples were grouped based on seed coat color, significant patterns were observed. The white varieties generally had the lowest phenol content, with the higher value being observed in lines with a pigmented eye. The black, red, and light brown varieties had the highest level of phenols. The dark brown and streaked varieties had intermediate phenol content. The results were partly expected based on evidence from other food plants; the darker seeded varieties of most plant materials usually have higher phenol content than the nonpigmented varieties. However, one unexpected observation was that the high level of phenols in the light brown cowpea seeds, which were comparable to the black and red varieties, and significantly higher than the dark brown varieties. This data suggests that the types of phenols that are dominant in the light brown phenotype do not absorb visible light. It was also recently observed that a light brown cowpea variety yielded extracts that contained more phenols than a dark brown variety.

Tannins content of the cowpea lines generally followed the gross phenol content data (Table 1). The white varieties generally had very low levels of detectable tannins; the light brown cultivars had the highest tannin content.

As expected, anthocyanins were highest in the black cowpea varieties compared to the red and dark brown varieties. The rest of the phenotypes had trace levels of anthocyanins.

Seed coat color	Gross phenol content (mg/g, db)		Condensed tannin content (mg/g, db)		N
	Range	Mean	Range	Mean	
White	0.30 – 5.5	3.1 a	0.29 – 1.3	0.59 a	36
Light brown	5.7 – 16.5	12.0 c	8.8 – 12.3	10.4 d	21
Dark brown	5.2 – 9.0	6.8 b	1.9 – 6.7	3.6 b	8
Streaked	5.4 – 9.9	8.5 b	3.6 – 3.8	3.7 b	5
Red	10.1 – 14.2	11.9 c	4.8 – 7.8	7.3 c	5
Black	12.5 – 17.0	14.8 cd	6.3 - 9.0	7.7 c	3

Table 1. Phenol and tannin content of cowpea varieties grouped by seed coat color. (N represents the number of varieties analyzed within a phenotype. Coefficient of variability for phenol content determination was 3.1 percent and for condensed tannins was 4.4 percent. Values with same letters in a column are not significantly different ($p < 0.05$).)

In investigating phenolic composition of cowpea with the goal of identifying the lines with the best potential to promote health, it is important to confirm the location of the phenols within the seed to recommend processing strategies that would limit the loss of these compounds. A set of three samples were decorticated to separate the seed coat from the cotyledon and these fractions analyzed separately. As expected, the phenols were mostly concentrated in the seed coat (Table 2). The cotyledons contained less than two percent of the total phenols in the cowpea. The implication of this information on how cowpea is processed for food in parts of Africa is significant. In popular products like akara in West Africa, the seed coat is typically removed, which would mean that any health benefits contributed by the phenolics in the seed coat would be lost. As more data become available from this project, we will be able to advise on appropriate ways to preserve potential health benefits during cowpea processing.

Variety	Solvent used	
	Acidified DMF	***Acidified methanol***
	Seed coat	**Seed coat**
Glenda	25.85 d[2] (0.17)[3]	13.46 a (0.01)
Mae a tsilwane	33.41 e (0.41)	18.16 b (0.13)
Mogwe o kgotsheng	37.70 f (0.17)	21.84 c (0.01)
	Cotyledon	**Cotyledon**
Glenda	0.57 d (0.01)	0.29 b (0.02)
Mae a tsilwane	0.41 c (0.01)	0.09 a (0.01)
Mogwe o kgotsheng	0.39 c (0.01)	0.08 a (0.02)

Table 2. Phenolic content (g/100 g (dry weight basis) of extracts prepared from cowpea seed coats and cotyledons with acidified dimethyl formamide (DMF) and acidified methanol[1]

[1]Results are means of four determinations, on dry weight basis

[2]Mean values for seed coats and cotyledons in each row and column with the same letter are not significantly different at ($p < 0.01$)

[3]Standard deviation values are given in parentheses

A detailed analysis of the seed coat of selected varieties revealed that they contained significant quantities of phenolic acids, mostly in soluble esterified and bound forms. The hydroxycinnamates were generally more abundant than the hydroxybenxoates. The bound phenolic acids in the seed coats were mainly hydroxycinnamates. The flavonoid group of phenols was more abundant than the phenolic acids. Catechin was the most abundant flavonoid, while quercetin, naringenin, kaempferol and rutin were also present in significant quantities. Many of these compounds have been associated with various health benefits and it will be interesting to discover how their levels in cowpea influence biomarkers for health.

Objective 2: Establish how the phytochemical profiles of cowpeas affect bioactivity by measuring key markers/predictors of protection against chronic diseases.

Research and Outreach Approaches, Results, and Achievements

Hydroxyl/free radical scavenging properties. Protection against oxidative stress is an important component of chronic disease prevention. Rapid screening methods were used to determine antioxidant properties of the cowpea lines. Antioxidant capacity of cowpeas and their fractions were measured by two widely accepted methods that involve hydrogen atom transfer (HAT) and single electron transfer (SET) that have been shown to correlate with biological oxidative status measures. The ability of cowpea extract to protect fluorescein from free radical attack by AAPH was monitored for 90 min at 37°C using a fluorescence spectrophotometer.

As with the gross phenolics content, there was wide variability in the antioxidant activity of the cowpea lines (Figures 1 and 2). Antioxidant activity in the seeds ranged from 4.6 and 24.6 mmol TE/g to 111 and 282 mmol TE/g. This represents an 11- to 24-fold variation in antioxidant activity among the cowpea cultivars. Given that antioxidant activity is broadly accepted as a major indicator of health-promoting potential of natural products and foods, this data clearly demonstrates the importance of caution when selecting raw material for any studies aimed at elucidating the impact of legumes on health outcomes in animals and humans.

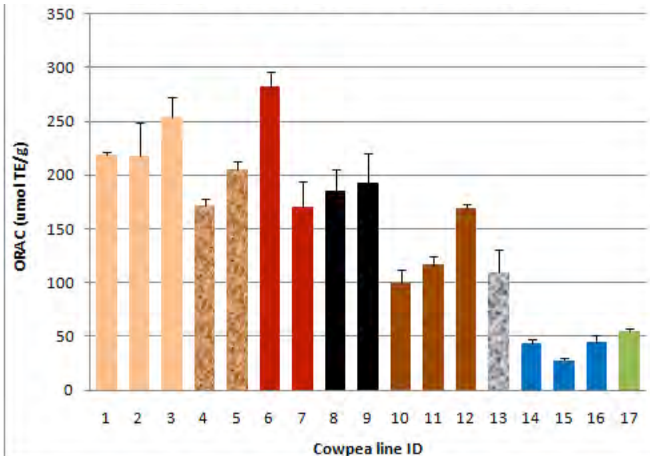


Figure 1: Antioxidant activity of 16 representative cowpea lines measured by the oxygen radical absorbance capacity (ORAC) method (values are on dry basis). Error bars are ±sd [see Table 4 for sample identification]

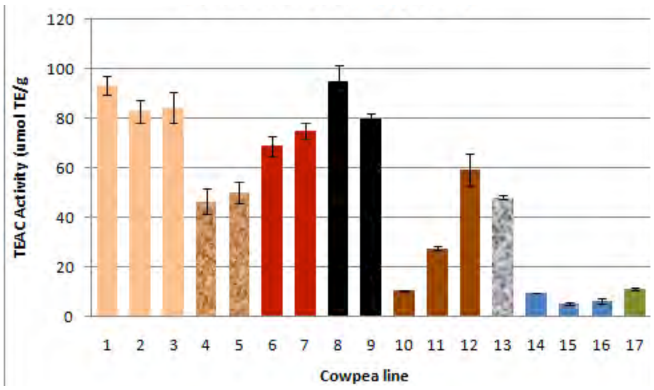


Figure 2. Antioxidant activity of 16 representative cowpea lines measured by the trolox equivalent antioxidant capacity (TEAC) method (values are on dry basis). Error bars are ±sd. (See Table 4 for sample identification)

Sample No.	Variety	Seed coat color
1	09FCV-E IT99K-407-8	Light brown
2	09FCV-M-UCR 799	Light brown, pink
3	09FCV-M-IT97K-556-6	Light brown, pinkish
4	09FCV-E YACINE	Light brown (golden)
5	09FCV-E IT85M-303	White, brown patches
6	09FCV-M-UCR 5272	Red
7	09FCV-E IT85F-867-5	Red, brownish
8	09FCV-E IT95K-1105-5	Black
9	IT99k-216-48-1	Black
10	09FCV-M FVX421-25	dark brown (golden)
11	09FCV-M-IT93K-693-2	dark brown (golden)
12	09FCV-M-UCR 1432	Chocolate brown
13	09FCV-M MOUNGE	Streaked
14	09FCV-E 5248	White, black eye
15	09FCV-E-BAMBEY 21	White, no eye
16	09FCV-E-IT95M-190	White, brown eye
17	09FCV-E-IT95K-1491	White, black eye, greenish

Table 4. Cowpea Line Identification (for Figures 1 and 2)

When the samples were grouped based on seed coat color, the white varieties once again had the lowest antioxidant activity. The light brown, red, and black varieties had the highest antioxidant activity; the dark brown and streaked varieties had intermediate antioxidant activity. As was observed for phenol content, the antioxidant activity was concentrated in the seed coat. The cotyledons had on average less than three percent of the antioxidant activity observed in the cowpea seed. This further underscores the importance of processing method on potential health benefits of cowpeas.

Relationships between antioxidant activity and phenol content in the samples were strong. This implies that the phenolics in the cowpeas are a major contributor of the antioxidant activity observed. Thus it is possible that determination of phenolic content of cowpea would be a useful predictor of antioxidant properties of the cowpeas.

Significance of findings

The screening of the diverse lines of cowpea varying in seed coat color and other properties has revealed that the composition of phenolics as well as antioxidant properties of cowpeas vary widely, with orders of magnitudes over 50 for some attributes. This implies that studying in vivo health properties of cowpea requires a significant level of caution and clear characterization of the raw material to ensure that results can be interpreted in the proper context and to avoid arriving at misleading inferences.

The ranking of the samples based on seed coat color was consistent for samples from different locations, which implies that phenolic and antioxidant accumulation is significantly influenced by genetics. Based on the screening results, we believe the black, red, and light brown varieties have the best potential to produce health benefits. Two representative lines within each of these seed coat colors have been selected for detailed biochemical characterizations using human cell models. White cowpea varieties will be used as checks in these biochemical studies. The black, red, and light brown varieties were also selected for use in genetic trials.

Objective 3: Elucidate the mode of inheritance (heritability) of selected bioactive traits in cowpea and genetic association between physical and bioactive traits.

Research and Outreach Approaches, Results, and Achievements

Based on the results from Objectives one and two, the following 10 varieties representing different seed colors were selected for inheritance studies:

1. IT98K-1092-1 – solid black seed coat
2. IT97K-1042-3 – solid red seed coat
3. IT82D-889 – solid red seed coat
4. IT97K-556-4 – solid brown seed coat
5. TX2028-1-3-1 – green seed coat with large black eye
6. CB-46 – white seed coat with large black eye
7. IT98K-205-8 – white seed coat with small black eye
8. GEC – white seed coat with small brown eye
9. Coronet – white seed coat with small pink eye
10. Early acre – white seed coat without eye color (eyeless)

These varieties have been planted in greenhouse and crosses are being made using different combinations. These are also being reanalyzed for phenols, antioxidants, and pigment composition. Efforts are being made to make sufficient types and number of crosses to study the effect of seed coat color and eye patterns on the composition and inheritance of different pigments and antioxidant activity.

The first planting of these parents for crossing was done on July 26 and the second planting on August 25. Based on the date of flowering, some crosses have already been made and the process is continuing for other crosses. The resulting F1s would be soon planted along with their parents to make backcrosses and raise F2s for genetic studies.

Objective 4: Establish strong linkages with HC policymakers and other stakeholders, and develop outreach strategies that will lead to long-term increase in cowpea consumption for health and food security.

Research and Outreach Approaches, Results, and Achievements

HC PIs met with collaborators and representatives from government ministries (e.g., agriculture, education, public health); and local community-based NGOs within their respective countries. The meetings were aimed to 1. convey the project's long-term goal and current research plan, approaches, and the rationale behind them to stakeholders, and 2. based on expected research outputs, solicit stakeholder input on dissemination/outreach strategies that are most likely to influence policy makers and benefit target populations to achieve long-term development impact. Each HC PI, in conjunction with the project PI, compiled a report based on the meetings that summarizes stakeholder suggestions.

Zambia. Through a participatory approach, a one-day workshop was organized to which all the identified key stakeholders were invited. In attendance was the dean of the School of Agriculture, University of Zambia; the US PI, and the HC PI, who gave presentations and moderated the meeting. The collaborators were drawn from the School of Agriculture and ZARI; and key stakeholders were drawn from government ministries (agriculture, social and community development, health) and local community and key international NGOs (PAM, PELUM, Africare).

Specific key points

1. Link output with strong business minded partners who can see value and commercialize the output.
2. Production goes hand-in-hand with utilization; i.e., do not overpromise farmers market potential until clear demand is established.
3. Scientific evidence must be supported by facts when promoting utilization.
4. Involve medical doctors once data is available; people are more trusting of doctors.
5. Develop recipes, especially those that will be liked by children.

6. The Ministry of Agriculture has a program that promotes orphan crops; cowpea is one of the crops.

7. Change locals' attitudes, especially their relying on only one crop (maize) as a staple food.

8. Develop appropriate technologies for product use; e.g., using energy-saving jikos to require less fuel for cooking.

9. Properly document findings for policy makers.

10. Talk to implementers at province and district levels.

11. Investigate how people are using cowpeas.

12. Improve seed delivery systems.

13. Resources should be invested in developing product variety that will appeal to both poor and middle income families.

14. Develop a partnership with the stakeholders/industries to follow through once project is completed.

15. Incorporate cowpea as one of the items in world food program packages, school feeding programs, and World Vision relief foods

Objective 5 (Capacity Building): Strengthen cowpea nutrition research in Kenya and Zambia.

There are four Ph.D. students and one M.S. student affiliated with this project.

V. Networking and Linkages with Stakeholders

During the planning meeting and training workshop held in Pretoria, South Africa, from 26–29 July 2010, the U.S. PI and HC PIs met with Ms. Cecilia M Khupe, senior regional agriculture program manager, USAID Southern Africa, to introduce the new CRSP project and HC PIs to the mission.

USAID Zambia: The US PI and Zambia HC PI met with Mr. Mlotha Damaseke, Agriculture and Natural Resources and Mission Environmental Officer, at the USAID mission in Lusaka.

Impact Assessment of Bean/ Cowpea and Dry Grain Pulses CRSP Investments in Research, Institutional Capacity Building and Technology Dissemination in Africa, Latin America, and the U.S.

PIII-MSU-4

Principle Investigator

Mywish K. Maredia, Michigan State University, USA

Collaborating Scientists

Richard Bernsten, Michigan State University, USA

Eric Crawford, Michigan State University, USA

Jim Beaver, University of Puerto Rico, Puerto Rico

Juan Carlos Rosas, Escuela Agricola Panamericana–Zamorano (EAP), Honduas

Eduardo Peralta, Instituto Nacional Autonomo de Investigaciones Agropecuarias (INIAP), Ecuador

Emmanuel Prophete, Haiti,

Mathew Blair, Centro Internacional Agricultura Tropical (CIAT), Colombia

Ndiaga Cisse, Institut Senegalaia de Recherches Agricole (ISRA), Senegal

Issa Drabo, Institut de l'Environment et des Recherches Agricole (INERA), Burkina Faso

Phil Roberts, University of California, Riverside, USA

Jeff Ehlers, University of California, Riverside, USA

Abstract of Research Achievements and Impacts

A systematic search of past CRSP reports and literature was conducted to compile a database of 41 studies that report impacts related to the Bean/Cowpea or the Pulse CRSP program investments. The documented evidence ranges from anecdotal evidence to rigorous field-based substantiation. The database is developed in Access but is also available in Excel and Word.

The project team organized an educational session at the "All Researchers Meeting" held in April 2010 in Quito, Ecuador, to increase the awareness towards achieving developmental impacts and help researchers think through the impact pathways of their research. As a follow-up to this session and through a one-on-one consultation through e-mail and phone calls, all project PIs have completed impact pathway worksheets. A report summarizing the outputs of this analysis and a plan for next steps is being presented to the Management Office.

Field activities to collect data and information to assess ex post facto economic impacts of CRSP investments in bean improvement research in Central America and Ecuador were initiated in FY10. Researchers reported that CRSP's and CIAT's financial support have been fundamental for the maintenance of the bean network in Central America. CRSP's support became more important after 2002, when PROFRIJOL support ended. The resources were used to keep the supply of germplasm flowing, conduct research (small grants were provided by Zamorano to other institutions), and maintain the collaboration. Using seed production data, it was estimated that in 2009, Honduras, Nicaragua, and El Salvador distributed seed of improved varieties (IVs) to cover 24 to 39 thousand hectares in each country. Ecuador produced the smallest quantity of seed.

Using seed production data, in 2009 it was estimated that Deorho was planted on approximately 26 percent of the bean area in Honduras, followed by Amadeus 77. Amadeus 77 was also planted in three other countries: El Salvador, Nicaragua, and Costa Rica. In El Salvador, CENTA Pipil (another CRSP variety) was the variety most widely distributed by the government program.

Project Problem Statement and Justification

Impact assessment is essential for evaluating publicly funded research, capacity building and outreach 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 essential to document outputs, outcomes, and impacts of public investments in research for development (R4D) activities. Anecdotal data and qualitative information are important in communicating impact to policy makers and the public but must be augmented with empirical data, and sound and rigorous analysis. Methods have been developed to quantify the economic impacts of agricultural research investments, including impact assessment.

Impact assessments perform two functions—accountability and learning. Greater accountability (and strategic validation) is seen as a prerequisite for continued support. Better learning is crucial for improving the effectiveness of development projects and ensuring that the lessons from experience—both positive and negative—are heeded. Accountability and strategic validation have long been core concerns for ex-post facto impact assessments and learning has been primarily a concern of impact evaluation. (Although in the evaluation profession, the terms impact assessment and impact evaluation are used synonymously, in this project we make a nuanced distinction between ex post facto impact assessment and impact evaluation based on the timing of when they are conducted, the scale at which they occur, and the motivation for doing an assessment.) The primary focus of this project is on ex post facto impact assessment. However, attention is also devoted to including impact evaluation as part of CRSP projects in Phases II and III. In addition to measuring and evaluating impacts of past research investments, this project is also concerned with increasing impacts from current investments by examining the impact pathways of research projects and inculcating an impact culture within the Pulse CRSP research community.

Objectives

1. Build an inventory of past documented outputs, outcomes, and impacts of investments by the Bean/Cowpea CRSP and develop a trajectory of outputs and potential impacts of investments made by the Dry Grain Pulses CRSP.
2. Conduct ex post facto impact assessment of Bean/Cowpea and Dry Grain Pulses CRSP investments in research, institutional capacity building, and technology dissemination in Africa, Latin America, and the United States.
3. Review each CRSP project activities in Phases II and III and advise the management office (MO) and the project team on ways to integrate data collection and impact evaluation strategies as part of the CRSP project design.
4. Build institutional capacity and develop human resources in the area of impact assessment research.

Results, Achievements, and Outputs of Research

Objective 1: Build an inventory of past documented outputs, outcomes, and impacts of investments by the Bean/Cowpea CRSP and develop a trajectory of outputs and potential impacts of investments made by the Dry Grain Pulses CRSP.

1a. *Building an inventory of past outputs and documented impacts.* A systematic search of past CRSP reports and literature was conducted to compile a database of 41 studies that report impacts related to the Bean/Cowpea or the Pulse CRSP program investments. The database includes an inventory of major outputs (defined as technologies, practices, goods and services, intellectual properties, and policy recommendations, characteristics of those outputs, and any evidence of documented outcomes and impacts of those outputs. The documented evidence ranges from anecdotal to rigorous field-based substantiation.

1b. *Develop a trajectory of outputs and potential outcomes/impacts of ongoing investments by the Pulse CRSP (impact pathway analysis).* Pulse CRSP is responsible for quantifiably demonstrating outputs (the first node in the impact pathway) in the form of knowledge, improved materials, practices, intellectual properties, human capital improvement, and policy recommendations, which are intended to increase productivity, profitability, and sustainability of pulse value chains in developing countries and thus achieve the developmental goals set by USAID. One of the tasks of this project is to inculcate an impact-oriented research culture among researchers involved in the Pulse CRSP and help them lay out the vision of success (impact goal) and a) make them aware of the consecutive steps needed to achieve that vision of success and b) incorporate these steps into their workplan.

Towards this goal, the project team held a two-hour educational session at the Pulse-CRSP global meeting in Quito, Ecuador in April 2010. The session consisted of presentation on concepts related to impact pathway, breakout group discussions oriented towards completing an exercise, and brainstorming discussions in a plenary setting. As a follow-up to this session, each Phase II and Phase III project team was asked to complete a worksheet on impact pathways for their respective projects. Instructions on how to complete the worksheet were provided to all the lead PIs followed by a one-on-one consultation through e-mail and phone calls to help them think through the process of what their research plans to achieve in terms of development impacts and how to reach that vision.

To date, the project PI has received completed impact pathway worksheet from all Phase II and III project teams. This information should serve as a log frame for the MO (and project teams) to monitor progress on how the CRSP projects are moving towards achieving not only the outputs (in the form of new knowledge, technologies, and human capital) but how those outputs are translated into developmental outcomes and impacts.

Objective 2: Conduct ex post facto impact assessment of Bean/Cowpea and Dry Grain Pulses CRSP investments in research, institutional capacity building, and technology dissemination in Africa, Latin America, and the United States.

2a. *Synthesis and update study on the adoption and impact of CRSP's bean improvement efforts in the LAC region.* In February, Dr. Richard Bernsten and graduate student Byron Reyes met with Dr. Juan Carlos Rosas at Zamorano, Honduras, to collect names and contact information of potential key informants for each target country in Central America and to have Dr. Rosas provide a brief description of the key organizations in the bean subsector in these countries.

During the Dry Grain Pulses CRSP Global Meeting in April 2010, CRSP PIs, CIAT scientists, and Byron Reyes met to plan the study. Feedback was incorporated and five key informant instruments were developed, one for each key informant type. Table 1 shows the number of people interviewed between June and August 2010, by informant type.

Key informant type	Number of respondents
Bean researchers from government/ universities	10
Seed producers	25
Officials of the government's bean seed programs (whenever applicable)	9
Wholesalers	20
Officers of the research institutions	4
Total	**68**

Table 1. Key informants interviewed, June to August, 2010.

Quantitative historical data about the bean area planted/ harvested, production, and prices (when possible) were collected from the statistical offices in each country. As part of the impact evaluation methodology, the use of molecular markers was proposed as a complementary method to estimate adoption of IVs in Honduras. For this, 53 bean market samples from the main three markets in Tegucigalpa were collected and sent to CIAT for analysis (*bgm-1* gene). This information will be used to design the sampling methodology required to select a representative sample of seed in Honduras, if the analysis of the initial sample of seeds validates using molecular markers to evaluate farmer adoption of improved bean varieties.

Using preliminary results, two presentations were made at the *Conferencia Regional sobre el estado actual y Estrategia Futura de la Investigacion en Frijol en Centro America y El Caribe* conference held in August 2010 at Zamorano.

The following are preliminary results about adoption of IVs in the bean programs in each country not noted in the opening section "Abstract of Research Achievements and Impacts."

- Researchers estimated that in 2009, Deorho was planted in approximately 23 percent of the bean area of Honduras, followed by Amadeus 77 (16 percent of the bean area). Two other bean researchers estimated Amadeus 77 was planted in 40 to 70 percent of the bean area in their country (El Salvador and Nicaragua). For Ecuador, the most widely planted variety was INIAP 430 Portilla.
- It was found that many of the bean researchers are close to retirement (average of 8 years to retire). The (informal) bean network of the region could be used to train researchers' replacements, if no overlapping is possible in their institutions.
- Researchers reported that CRSP's and CIAT's respective financial support has been fundamental for the maintenance of the bean network in Central America.
- Detailed varietal information was collected. Except for Guatemala and Nicaragua, more than half of the bean varieties have been released in the past ten years.

• Table 3 shows the prices of certified/high quality seed in target countries for 2009. Seed is most expensive in Costa Rica and least expensive in Nicaragua.

Country	Sale Price ($/qq)*	Seed Type
Honduras	95	Certified
Guatemala	119	Certified
El Salvador	110	Artisanal
Nicaragua	80	Certified
Costa Rica	133	Certified
Ecuador	95	Non-conventional

Table 3. Price ($/quintal) of certified or high quality seed in target countries in 2009.

Note: Non-conventional seed type refers to high quality seed produced by trained farmers (as an alternative to a formal certification process, which is nonexistent in Ecuador).

2b. *Global contribution of CRSP to genetic improvement of common bean (including the UNITED STATES, LAC and SSA).* The Bean/Cowpea CRSP-supported bean breeding programs in the United States and in host countries have contributed to the genetic improvement of common beans in the form of direct varietal releases and indirect contributions to the gene pool present in the pedigree of released varieties. This second type of contribution of CRSP-supported research in molecular breeding and other advanced techniques can be seen today throughout the bean producing regions of the world, including the United States.

To take stock of all the genetic contributions of the research supported by the bean/cowpea and the Dry Grain Pulses CRSP, the following activities were conducted in FY10. Some of these are partly complementary to activity 1a and 2a.

1. A database template has been developed to inventory varietal releases of all commercially important bean varieties (*phaseolus vulgaris*) in countries and regions where CRSP has been historically active in bean improvement research. A data solicitation excel-based form was developed to solicit variety-specific information from national bean research programs and the CRSP project PIs (past and present) in respective countries. The data is being collected by each country since varietal releases are made at the national level.

Although, cowpea was not included in the original scope of this subobjective, a similar database of commercially important cowpea varieties is also being developed parallel to the bean varietal database.

2. Data on varietal releases collected from key informants are sufficiently detailed so that CRSP content and the dynamics of new varietal production and dissemination can be assessed. Key descriptors include the following:

a. Official name of the release (a common name, if any)

b. Year of the release

c. Institutional source of the material

d. Genetic background (parentage, genetic ancestry, pedigree)

e. Major distinguishing traits

f. Release classification (type of material, use of participatory plant breeding or molecular techniques, NARS input, IARC input, private sector input) (mainly for beans)

g. Dissemination efforts (information on seed multiplication efforts) (for beans only)

h. Any information on the size, scale, time, and location of its peak adoption by farmers and assessment on whether a variety is on an increasing or declining adoption trend.

i. Perceived adoption of improved varieties in 2009 to 2010 (beans only).

Once this comprehensive database is developed, the next steps are to estimate an economic value of the CRSP program in terms of value addition to genetic materials grown by bean farmers around the world. Adoption information by varieties is key to estimating an economic value.

2c. *Benefits of genetic improvement of cowpea in Senegal and West Africa.* Over the past 20 years, due to collaborative efforts of CRSP researchers, several varieties of cowpea with resistance to biotic and abiotic stresses have been released in Senegal and other countries in West Africa. Although a few studies in the past have documented the impact stories in Senegal, the evidence is still spotty when it comes to West Africa as a region. Thus, a study was initiated in FY10 to update and document the adoption of improved cowpea varieties in Senegal and to expand the analysis to include Burkina Faso where the Bean/Cowpea and the Pulse CRSP have been active for the past seven to 10 years. The goal is to document the adoption and benefits attributed to CRSP–NARS investments in cowpea improvement research.

During the Global PI meeting, the project team members discussed the objectives of this study and a data collection strategy with the PI-UCR-1 project team members. Based on a review of past documented impacts of cowpea research and subsequent follow-up discussion with cowpea breeders at the World Cowpea Conference and statistical data collection agency in Senegal, a proposal has been developed that lays out the scope and protocols of data collection efforts in Senegal and Burkina Faso.

Proposed Study in Senegal

The focus in Senegal is to collect household-level data on the adoption of improved varieties of cowpeas to achieve following objectives:

1. To identify the current extent of adoption by farmers in Senegal of improved cowpea varieties developed under the Bean/Cowpea (now Dry Grain Pulses) CRSP.

2. To gather information on the production and dissemination of improved cowpea seed, and the costs of these activities.

3. To gather information on the advantages (in the form of enhanced yield, quality, reduced yield variability, etc.) of improved cowpea varieties relative to traditional varieties, in order to estimate potential economic benefits of adoption of CRSP varieties.

The principal regions and departments in which CRSP-produced cowpea varieties have been disseminated will be identified through consultation with Ndiaga Cissé (CRSP/ISRA cowpea breeder) and representatives of NGOs and seed producer groups, and analysis of data from the 2010 DAPS national survey of farm households, which includes information on type of seed planted on each field.

A brief field survey will be carried out in the departments identified in objective one. The sample for survey would be a subsample of 2010 DAPS survey farmers who indicated that they used improved seed for cowpea. Provisionally, we anticipate drawing a subsample of 500 to 700 households. Questions to be asked of farmers include:

1. What is the name of the improved cowpea variety planted?

2. What was the source of the seed?

3. Why was this variety used?

4. When was the first time you used that variety?

5. Was cowpea planted in pure stand or intercropped?

6. If intercropped, what percentage of the field is in cowpea?

7. What do you believe are the advantages (drought resistance, disease or pest resistance, yield increase) of the improved variety relative to unimproved or traditional varieties?

8. How much cowpea did the farmer harvest from the plot (where improved variety was grown) last season in:

    a. Green pods?

    b. As grain?

    c. Any other form (i.e., fodder for animals)?

9. What variety or varieties of cowpea do you intend to plant next season?

10. What are your reason(s) for choosing those varieties you plan to plant next season?

Interviews will be conducted with NGOs and seed producer groups concerning current and past seed production and dissemination activities in Burkina Faso.

To assess the yield advantage, experimental data from breeders or from on-farm trials will be used as well as 2010 DAP yield plot data, if there are sufficient observations to compare yields from plots that planted both improved and traditional varieties.

Objective 3: Review each CRSP project activities in Phases II and III and advise the MO and the project team on ways to integrate data collection and impact evaluation strategies as part of the CRSP project design.

The workplans of all Phase II and III CRSP projects were reviewed in FY10 and a database of outputs and projected targets by activities has been developed. This report will identify and place different projects and show how the outputs of R4D fall across a time and space dimension in terms of achieving developmental outcomes and impacts.

Objective 4: Build institutional capacity and develop human resources in the area of impact assessment research.

Although this project does not include a host-country partner as in other CRSP projects, it does address the objective of institutional capacity building and human resource development through the following methods:

a. Field activities under objective two were conducted in collaboration with HC PIs and partners.

b. Activities under objectives one and three are conducted in close collaboration with the U.S. and HC PIs from existing CRSP projects.

c. The activities planned under this project involved two graduate students in the planning and conduct of field research.

Networking and Linkages with Stakeholders

None to report in FY10.

Leveraged Funds

None to report in FY10.

Scholarly Activities and Accomplishments

None to report in FY10.

Dry Grain Pulses CRSP
Institutional Capacity Building and Human Resource Development
FY 2010 Summary Report

Dry Grain Pulses CRSP

The Dry Grain Pulses CRSP seeks to build host country institutions' capacity building through three mechanisms—support for long-term degree training, short-term non-degree training, and purchase of equipment. The status of activities planned and undertaken under these three categories of capacity building activities is included in the annual technical progress reports of each project. Here we provide a summary of these activities for the whole Pulse CRSP program.

Degree Training

All Pulse CRSP degree training is closely linked to research activities and aligned with CRSP project research and outreach objectives. By integrating graduate students into the research and outreach activities, their dissertation research problem has relevance and application to the Host Country context plus they contribute much to the quality of Pulse CRSP project technical objectives. The graduate students' research both contributes to the development of technologies as well as enhances understanding into the socio-economic, agronomic, environmental, political, cultural, etc. realities in the Host Country.

Nearly all graduate degree students are under the guidance and supervision of Pulse CRSP Principal Investigators (PIs). If a CRSP PI is not the major professor, the PI is certainly a member of the guidance and thesis research committees of the student. When a trainee is pursuing an advanced degree at a university in the host country, the host country PI will typically serve as the major professor. As a consequence, the research and teaching activities of CRSP trainees form an integral part of the annual workplans of each project.

The Dry Grain Pulses CRSP is continuing to make human resource development and institutional capacity building a priority objective for all projects awarded. There is an expectation that all Pulse CRSP projects will include an institutional capacity building objective for the partner host countries and support an average of two to three degree training activities.

	No. of trainees
Training Status	
▪ Active:	31
▪ Delayed/Pending:	4
▪ Discontinued/cancelled:	5
▪ Training Completed:	4
Profile of "Active" trainees (31)	
Gender	
▪ Male	17
▪ Female	14
Region of Origin	
▪ East Africa	17
▪ Southern Africa	11
▪ West Africa	1
▪ Latin America/Caribbean	0
▪ United States	2
Degree program	
▪ M.S.	22
▪ Ph.D.	9
Training Location	
▪ U.S.	10
▪ Host countries	17
▪ Third countries	4

Table 1: Summary of Degree Training as of September 30, 2010.

Annex 1 provides data on all the degree trainees financially supported by the Dry Grain Pulses CRSP as of September 30, 2010. A total of 31 students were either fully or partially supported in graduate degree programs in FY 2010. Unfortunately nine degree training activities were either delayed or discontinued. A challenge being increasingly faced by U.S. universities is the lack of admissibility of candidates from non-English speaking countries. As a result, the Dry Grain Pulses CRSP has decided to approve English language training at U.S. universities if it is viewed as remediation and a prerequisite for official admission into a graduate program. A descriptive summary of the degree training activities supported by the Pulse CRSP is provided in Table 1.

An estimated six graduate students at U.S. universities in 2010 were indirectly supported by the Dry Grain Pulses CRSP. These are students who are on research assistantships. CRSP funds therefore are only used to compensate them in the form of salary to conduct the research activities as outlined in the workplans. CRSP funds were not used to cover traditional academic expenses such as tuition or the purchase of text books and computers. As a consequence, those universities supporting graduate students on assistantships are providing 25 percent match on these expenses as they are viewed as a cost to complete the CRSP research activities.

Non-Degree Training

Non-degree training and short-term training are also considered to be vitally important for attaining CRSP institutional capacity building goals. This includes training through organized workshops, group training, short-term individualized training at CRSP participating institutions, and participation in networking activities with peers working on pulses in their region or internationally. Training activities typically last only a few days (e.g., workshops) or involve a highly structured learning experience extending from a few weeks to several months or a year with individualized instruction in a lab/field setting. Like degree training, all non-degree training is integrated with research activities and is incorporated into the annual research workplans of each research project.

In FY 2010, an estimated 1,135 individuals benefitted from short term training through the Dry Grain Pulses CRSP. Of these short-term trainees, more than 53 percent were female. Experience has shown that short-term training is an effective strategy to build the capacity of technical staff at a research institution. These individuals do not require an advanced degree to conduct their analytical work nor are they able to be released from their positions for any extended period of time. Moreover, short-term training is highly cost effective and provides opportunities for the U.S. and host country PIs to join forces in the design and implementation of training activities.

Examples of Short-term Training Activities Supported by the Pulse CRSP, FY 2010.

Type of Training: Basic GIS tools with survey data

Description of Training: The training introduced participants to basic mapping skills in using the national household surveys.

Location of Short Term Training: Maputo, Mozambique

Beneficiaries: Analysts of the National Agricultural Research Institute (IIAM) and the Directorate of Economics of the Ministry of Agriculture, Mozambique

Number of Participants: 7 (4 males; 3 females)

Type of Training: Statistical analysis

Description of Training: The training refreshed skills in analyzing recent household surveys.

Location of Short Term Training: Huambo, Angola

Beneficiaries: Students and faculty members of the Agricultural Sciences Faculty at the University of Agostinho Neto, Angola

Number of Participants: 8 (5 males; 3 females)

Type of Training: Short practical training.

Description of Training: Construction of solar facilities for seed drying using local materials.

Location: Rural Development Program, Zacapa, Santa Bárbara, Honduras

Beneficiaries: Farmers and technicians collaborating in the production of organic beans.

Number of Beneficiaries: 15 (8 males; 7 females)

Type of Training: Technical Internship

Description of Training: Biocontrol of cowpea pests

Locations: IITA Benin & Burkina Faso and Niger

Beneficiaries: Students

Number of Participants: 6 (2 males; 4 females)

Type of Training: Informal training of Ascochyta blight research and participatory plant breeding techniques

Description of Training: Trainees learned laboratory and field research techniques related to breeding beans for resistance to Ascochyta blight.

Location: INIAP, Ecuador

Beneficiaries: Staff of the Instituto de Investigação Agronómica, Angola.

Number of Participants: 2

Type of Training: Informal training of IIA technical personnel to identify bean diseases

Description of Training: Technical personnel were trained in the field identification and disease severity evaluations of: Ascochyta leaf spot (*Phoma exigua*), Angular leaf spot (*Phaeoisariopsise griseola*), Anthracnose (*Colletotrichum lindemuthianum*), Common bacterial leaf blight (*Xanthomonas axonopodis* pv. *Phaseoli*) and Bean Common Mosaic. Serological test for *Xanthomonas axonopodis* pv. *phaseoli* was carried out at the plant pathology laboratory in Chianga. Inmunostrips tests for bacterial and fungal diseases were also tested. These tests were complemented with isolations of fungal and bacterial diseases on artificial media with further morphological identification.

Location: Chianga, Angola

Beneficiaries: IIA technical personnel

Number of Participants: 8 (5 males; 3 females)

Type of Training: Technical

Description of Training: Hands-on training on use of modern equipment and laboratory techniques essential for the proposed project activities.

Location: University of Pretoria, South Africa; Egerton University, Kenya

Beneficiaries: Host country PIs, staff

Number of Participants: 17 (10 males; 7 females)

Equipment for Host Country Capacity Building

The Dry Grain Pulses CRSP recognizes that for National Agriculture Research Systems (NARS) and agriculture universities to effectively address the challenges facing the pulse (bean, cowpea and related edible legume crops) sectors and to contribute to economic growth and food and nutritional security in their respective countries, these institutions need to build and maintain capacities in strategic areas of research, training and outreach. This requires investments in human resource development, scientific equipment, laboratory and field facilities, computer technology, and infrastructure.

The Management Office of the Dry Grain Pulses CRSP budgets, and competitively awards funds to host country institutions for capacity building. The intent is that these funds be utilized to address critical needs of host country (HC) collaborators which exceed the budgetary limits of the current projects, or to respond to the pulse program needs of agricultural research institutions in USAID priority countries which are projected as potential future collaborators.

In FY 2010, the management office (MO) in consultation with the Technical Management Advisory Committee (TMAC) approved the award of three supplemental activities totaling $76,180 that were considered to contribute to build capacity of host country institutions (see Annex 2). In addition, the Dry Grain Pulses CRSP MO supported the participation of 23 CRSP scientists and trainees in the World Cowpea Conference held in Saly, Senegal (27 September – 1 October, 2010). A total of $77,097 was committed for this purpose (See Annex 2).

Annex 1: Status of degree training planned and executed in FY 2010

Project	Given name	Last name	Country of citizenship	Gender	Training institute	Degree	Discipline	**Training status as of 09/30/10**	Start date	Anticipated completion date	Type of CRSP support
PI-CU-1	Crispus Mugambi	Njeru	Kenya	M	Moi University	M.S.	Soil Science	Completed	Feb-08	Feb-10	Full
PI-CU-1	Belinda Akinyi	Weya	Kenya	F	Egerton University	M.S.	Soil Science	Active	Aug-08	Feb-11	Full
PI-CU-1	Jane Francisca	Lusweti	Kenya	F	University of Nairobi	M.S.	Plant Protection	Completed	Oct-07	Oct-09	Partial
PI-CU-1	Silvester	Odundo	Kenya	M	Moi University	M.S.	Soil Science	Active	2009	Feb-11	Full
PI-CU-1	Eunice	Onyango	Kenya	F	Moi University	M.S.	Applied Environmental & Social Science	Completed ??	2009	Sep-10	Full
PI-CU-1	Roselyne	Juma	Kenya	F	Moi University	M.S.	Plant Breeding/Evaluation	Active	2010	Mar-11	Full
PI-CU-1	Stanley	Onyango	Kenya	M	University of Nairobi	M.S.	Food Technology & Nutrition	Active	2010	Apr-11	Full
PI-CU-1	Caren	Oloo	Kenya	F	University of Nairobi	M.S.	Plant Protection	Withdrew	2009		Full
PI-ISU-1	Cyrille	Syanobe	Rwanda	M	Makerere University	M.S.	Food Science & Technology	Withdrew	Aug-08		
PI-ISU-1	Gerald	Sebuwufu	Uganda	M	Iowa State University	Ph.D.	Agronomy	Active	Aug-08	Aug-12	Partial
PI-ISU-1	Geoffrey Arijole	Nyakuni	Uganda	M	Iowa State University	Ph.D.	Food Science & Human Nutrition	Canceled			
PI-ISU-1	Martin	Matambuka	Uganda	M	Iowa State University	Ph.D.	Food Science & Human Nutrition	Active	Jan-09	May-12	Partial
PI-ISU-1	Aisha Nakitto	Musaazi	Uganda	F	Makerere University	M.S.	Food Science & Technology	Active	Aug-08	Dec-10	Partial
PI-ISU-1	Simon	Okiror	Uganda	M	Makerere University	M.S.	Agricultural Economics/Agribusiness	Active	Aug-08	Dec-10	Partial
P1-ISU-1	Catherine	Ndagire	Uganda	F	Makerere University	M.S.	Food Science and Technolgy	Active	Aug-09	Aug-11	Partial
PI-ISU-1	George	Jjagwe	Uganda	M	Makerere University	M.S.	Ag. Extension & Education	Active	Aug-10	Aug-12	Partial
PI-ISU-1	Rose	Kambabazi	Uganda	F	Makerere University	M.S.	Food Science and Technolgy	Delayed/Not Enrolled yet			Partial
PI-MSU-1	Gerardine	Mukeshimana	Rwanda	F	Michigan State University	Ph.D.	Plant Breeding and Genetics	Active	Aug-08	Aug-11	Full
PI-MSU-1	Krista	Isaacs	USA	F	Michigan State University	Ph.D.	Ecology and Nutrition	Active	Aug-08	Aug-11	Partial

Annex 1: Status of degree training planned and executed in FY 2010

Project	Given name	Last name	Country of citizenship	Gender	Training institute	Degree	Discipline	**Training status as of 09/30/10**	Start date	Anticipated completion date	Type of CRSP support
PI-MSU-2	Maria da Luz	Quinhentos	Mozambique	F	Michigan State University	M.S.	Agricultural Economics	Canceled			
PI-MSU-2	Ana Lidia	Gungulo	Mozambique	F	University of Pretoria, South Africa	M.S.	Agricultural Economics	Active	Feb-09	Dec-11	Full
PI-MSU-2	Estaveo	Chaves	Angola	M	University Federal Vicosa, Brazil	M.S.	Agricultural Economics	Active	Apr-09	Jun-11	Full
PI-PSU-1	Samuel	Camilo	Mozambique		Penn State	M.S.	Agronomy	Delayed			
PI-PSU-1	IIAM Scientist 2	TBD	Mozambique		Penn State	M.S.	Plant Nutrition	Delayed			
PI-UPR-1	Ronald	Dorcinvil	Haiti	M	University of Puerto Rico	M.S.	Soil Sciences	Completed	Aug-06	May-09	Partial
PI-UPR-1	Monica	Mbui Martins	Angola	F	University of Puerto Rico	M.S.	Plant breeding	Active	Aug-09	Aug-11	Full
PI-UCR-1	Manuel	Costa	Angola	M	University of Puerto Rico	M.S.	Plant Breeding/Pathology	Canceled			
PI-UCR-1	TBD	TBD	W Africa	F	U. California-Riverside	Ph.D.	Plant Breeding/Pathology	Delayed			
PI-UCR-1	Marti	Portorff	USA	M	U. California-Riverside	Ph.D.	Plant Breeding/Pathology	Active	Oct-08	Mar-11	Full
PI-UCR-1	Antonio	David	Angola	M	University of Puerto Rico	M.S.	Plant Breeding	Active	Aug-09	Aug-11	Full
PI-UIUC-1	Traore	Fousseni	Burkina Faso	M	University of Ouagadougou	M.S.	Entomology	Active	Sep-08	Aug-12	Full
PIII-ISU-1	Mercy	Kabahuma	Uganda	F	Iowa State University	M.S.	Crop Production/Physiology	Active	Aug-10	Aug-12	Full
PIII-ISU-1	Martha	Abwate	Uganda	F	Makerere University	M.S.	Soil Science	Active	Sep-10	Aug-12	Full
PIII-ISU-1	Peter	Ssenyonga	Uganda	M	Makerere University	M.S.	Soil Microbiology	Active	Sep-10	Aug-12	Full
PIII-ISU-1	Charles	Komba	Tanzania	M	Sokoine U. of Agriculture	M.S.	Agronomy	Active	Sep-10	Sep-12	Full
PIII-ISU-1	Beata	Khafa	Tanzania	F	Sokoine U. of Agriculture	M.S.	Plant Breeding	Active	Sep-10	Sep-12	Full
PIII-MSU-3	Amos	Nyangi	Tanzania	M	Sokoine U. of Agriculture	M.S.	Food Science	Active	Sep-09	Sep-11	Full
PIII-MSU-3	Sarah	Johnson	Tanzania	M	Sokoine U. of Agriculture	M.S.	Food Science	Active	Aug-09	Aug-11	Full
PIII-MSU-3	Rosemary	Marealle	Tanzania	M	Sokoine U. of Agriculture	M.S.	Nutrition	Active	Aug-09	Aug-11	Full

Project	Given name	Last name	Country of citizenship	Gender	Training institute	Degree	Discipline	**Training status as of 09/30/10**	Start date	Anticipated completion date	Type of CRSP support
PIII-TAMU-1	Twambo	Hachibamba	Zambia	F	University of Pretoria	Ph.D.	Food Science	Active	Aug-10	Jun-13	Full
PIII-TAMU-1	Alice	Nderitu	Kenya	F	University of Pretoria	Ph.D.	Food Science	Active	Aug-10	Jun-13	Full
PIII-TAMU-1	Leonard	Ojwang	Kenya	M	Texas A&M University	Ph.D.	Nutrition/Food Science	Active	Jan-10	Sep-12	Partial
PIII-TAMU-1	Archana	Gawde	???	F	Texas A&M University	Ph.D.	Molecular/Env. Plant Sci	Active	Jan-09	Sep-12	Partial
PIII-TAMU-1	Billy	Kiprop	Kenya	M	Egerton University	M.S.	Biochemistry	Active	Jan-10	Sep-11	Partial

Annex 2: Supplemental Funding awarded by the Dry Grain Pulses CRSP for Institutional Capacity Building in FY 2011

Awards to Enhance HC Institutional Capacity Building (Approved in 2010 for expenditure in FY2011)

Dry Grain Pulses CRSP

Proposal Overview			
Project	Beneficiary Host Country Institution	Proposed Activity	**Recommended funding**
PII-UPR-1	Host Country Institution # 1: Instituto de Investigação Agronómica (IIA) Host Country Institution # 2: National Seed Program, Ministry of Agriculture, Haiti Host Country Institution # 3: Escuela Agrícola Panamericana (Zamorano0	This task will be accomplished through hands-on evaluation of inoculation trials previously planted at Zamorano. Trials will include greenhouse experiments with common beans inoculated with *Rhizobium leguminosarum, Rhizobium etli* and *Rhizobium tropici* strains and control treatments with and without nitrogen fertilizer. A field trial will be planted to demonstrate the response of common bean to inoculation with the more efficient Rhizobia strains UMR 1899 and UMR 632 compared with an un-inoculated control and nitrogen fertilization. Participants will return to their countries better prepared to train others of the benefits of biological nitrogen fixation. Participants will become familiar with applied scientific literature about nitrogen fixation and current inoculant production. Participants will also gain knowledge and awareness concerning the benefits of BNF and local production of inoculants, which can reduce the use and importation of N fertilizer. The workshop is designed to improve expertise concerning the use, production and storage of inoculants for beans. Because the use of inoculants is uncommon in developing countries, this workshop will provide participants with information and literature that will describe how inoculants can be successfully used. Because the workshop will include several host countries that currently share an interest in increasing BNF for bean production there is potential to create a network for future collaboration. The internet will be used to share research results and exchange information. Participants will be requested to prepare a presentation and a written document to provide a baseline of information concerning the potential of BNF in their country. This information will be used to discuss and prioritize research needs for the different countries as well as to identify gaps in human or fiscal resources that currently serve as barriers for BNF studies and inoculant production and utilization. As a precursor to participant presentations, some general information concerning biological control/integrated peat inoculants will be presented.	**$28,880.00**
PII-MSU-2	IIAM, Mozambique	Purchase of simple video equipment, including web camera and camcorder, as well as one laptop and needed sofware. Local specialists will be used to train the participants on using this simple technology to link video/audio to powerpoint and other presentation methods, creating low cost communication tools.	**$25,300.00**
PII-UIUC-1	INERA, Burkina Faso	An assessment of the availability of cell-phones among extension agents and farmers.	**$22,000.00**
PII- PSU-1	Workshop: "Enhancing Pulse Productivity on Problem soils by smallholders farmers- Challenges and Oppertunities". August 14-18, 2011 Pennsylvania State University.		**$100,000.00**
DGP CRSP MO	Sponsoring a total of 23 Lead US PIs, US PIs, and Host country PIs to attend the 5th annual "WORLD COWPEA CONFERENCE" held in Saly, Senegal		**$77,097.00**
		Total	**$253,277.00**