Dry Grain Pulses
Collaborative Research Support Program (CRSP)

2009
Technical Highlights

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Preface

Dry Grain Pulses Collaborative Research Support Program (CRSP)

FY 2009 Technical Highlights Report
(October 1, 2008 - September 30, 2009)

The global pulse industry is entering a new era characterized by globalization of markets and fundamental changes in food value-chains, presenting many challenges as well as opportunities for small-holder farmers in developing countries and the United States regarding access to these markets. At the same time, many developing countries around the globe continue to face food and nutritional security challenges as established in USAID's Global Strategy on Food Security.

Pulse crops, including such edible 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, generate income, enhance soil quality and thus the sustainability of agricultural systems, and perhaps most importantly provide essential 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 program "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 valued chains utilizing socially and environmentally compatible approaches,
- Empowerment and strengthened capacity of agriculture research institutions in USAID priority countries,
- USAID's developmental objectives as defined in the *Policy Framework for Bilateral Foreign Aid* and the *Presidential Initiative to End Hunger in Africa* (IEHA), 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 integrated, multi-disciplinary research, training and outreach 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 which 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 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 U.S. The MO subsequently issued subcontracts to seven "Lead" U.S. universities for the implementation of these Phase I collaborative projects.

The eight Phase I projects presented in the FY 2009 Technical Highlights Report involve collaborative research, long and short term training, and technology dissemination activities in ten African countries (Burkina Faso, Mali, Niger, Nigeria, Senegal, Kenya, Rwanda, Uganda, Mozambique and Angola) and three Latin American countries (Haiti, Honduras and Ecuador). Within this group, five countries (Mali, Nigeria, Kenya, Uganda and Mozambique) have the distinction of being designated as USAID priority countries under the "Presidential Initiative to End Hunger in Africa" (IEHA). A total of 22 Host Country institutions are collaborating with the Lead U.S. Universities in the Phase I projects of the Dry Grain Pulses CRSP.

The Objective of this report is to "Highlight" the technical progress and achievements made by each of the eight subcontracted Phase I projects in the Dry Grain Pulses CRSP. We hope that readers will be able to gain a macro-level understanding of the broad scope of research, outreach and institutional capacity initiatives that are being supported through this CRSP. Readers should be aware that the FY 09 Highlight reports of the Phase I projects are only one-year snapshots of the collaborative activities between the U.S. university and Host Country institutional scientists. 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 project performance and reporting by USAID on Title XII and IEHA (Presidential Initiative to End Hunger in Africa) programs to the United States Congress.

For those who will take the time to read the "2009 Technical Highlights" report, I want to encourage you to focus on identifying the vitally important outputs generated by each of the Phase I projects; the new knowledge and technologies resulting from the research activities. It is these outputs that will benefit stakeholders of pulse value chains, extending from producers to consumers not only in specific Host Countries but in regions plus in the U.S., and thus contribute to the CRSP's success in achieving its global vision. Noteworthy outputs which you will encounter in this 2009 Technical Highlights report include the following.

Theme- To reduce pulse production costs and reduce risk

- Improved varieties of bean and cowpea with high yield potential and resistance economically important diseases and insect pests
- Improved varieties of bean and cowpea with high adaptation to low fertility soils and drought stress
- Integrated crop management strategies for increased pulse productivity on degraded soils
- Integrated pest management approaches for cowpea insects including the use of bio-controls

Theme- To increase utilization of pulses

- Nutritional value-added pulse grain and products through appropriate crop management, grain handling and processing

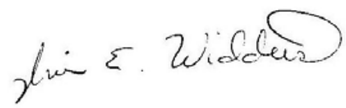
Theme- To improve pulse value chain performance

- Assessment of market structure, relationships throughout the domestic value chain and identification of key leverage points
- Policy brief on constraints to increasing small holder pulse productivity and market participation
- Identification of bean and cowpea market-sheds
- Research paper on constraints of and impacts on households to adoption of new pulse technologies
- Strategies for producing and marketing organic fair trade beans

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

As the Director of the Dry Grain Pulses CRSP, I want to thank the Office of Agriculture, Bureau of Economic Growth, Agriculture and Trade (EGAT), 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 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, to going the extra mile so that resource poor farmers and other stakeholders benefit, 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

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

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Abstract of Research and Outreach Achievements

The project has completed a one year cropping cycle comprised of a Short Rains and a Long Rains season focused on improving production of common bean and introducing a new pulse crop, *Lablab purpureus* in Western Kenya. Main project activities in FY09 included: participatory evaluation of vigor enhancing strategies by 95 collaborating farmers across a soil degradation gradient in South Nandi; training and on-farm testing of the strategies by 144 farmers associated with NGO/CBO groups in Busia and Vihiga districts; implementation of 3 researcher managed replicated experiments at 4 sites across the gradient; and financial/technical support for 6 students (4 women, 2 men) pursuing Masters degrees at Kenyan universities.

On-farm results indicate great promise for enhancing pulse productivity, increasing food security and income generation during both cropping seasons. During the Short Rains, KK8, a root rot tolerant bean variety gave farmers an average yield gain of 19% compared to their unfertilized, local varieties. Fertilizing KK8 with TSP produced on 63% gain across all sites. Farmers who planted lablab achieved grain yields that were comparable to the yields of unfertilized KK8 bean and were higher than the mean yields of farmers' local bean varieties.

During the Long Rains, farmers experimented with 5 alternative fertilization strategies for their main maize-bean intercrop which included concentrated applications of inorganic and/or organic fertilizers (compost or residues from the lablab crop grown during the Short Rains). Across the sites, all but one of the alternative fertilization strategies increased bean yields 33-200% compared to farmer practice. Also the alternative fertilization strategies produced 11 to 67% higher maize yields compared to those obtained with farmer practices.

Farmer to farmer exchange visits during each season ensured that the performance of the strategies at the different sites was observed by participants. Farmers were particularly enthusiastic about lablab because it offers multiple benefits in addition to grain (leaf for vegetable, fodder for livestock and soil improvement). Many farmers are already beginning to scale up the area planted after just one season and have shared seed with neighbors who have shown interest.

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 which 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 consumer's health and to assist policy makers in meeting desired national health outcomes. Recent national or regional level food composition data are often unavailable forcing researchers and policy makers to rely on international databases that do not adequately represent local environmental conditions, varieties, etc. 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. Providing opportunities for current and future scientific leaders to gain experience and expertise with participatory research and development approaches needs to be an essential part of the education process. These experiences will help students understand that adoptable and sustainable technologies are those that reduce risk and effectively address farmer constraints and resource levels.

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 - Verification trials were initiated with 64 farmers across the soil fertility gradient during the Short Rains 08-09 season. These trials allowed participants to experiment with lablab; KK8, a root rot tolerant bean variety; seed priming and phosphorus fertilizers: triple super phosphate (TSP); Minjingu Rock Phosphate (MRP).

Participants ranked the yield of KK8 bean much higher than their own bean varieties, but also recognized the impact of TSP and MRP on increasing production even more than KK8 alone.

Farmer feedback from the Short Rains (SR) experience was largely positive. Substantially better plant growth by KK8 relative to local bean varieties was visible on Kapkarer (low soil fertility site), Kiptaruwso (medium fertility site) and Bonjoge (medium high fertility site) farms, but fewer differences were evident at Koibem (high soil fertility site). Participants ranked the yield of KK8 bean much higher than their own bean varieties, but also recognized the impact of TSP and MRP on increasing production even more than KK8 alone.

Farmers were enthusiastic about lablab despite a slow start due to low quality seed and hailstone damage. A majority of the households liked the lablab grain as a new food item and found the taste similar to common bean. In addition, farmers commented lablab leaves to be more delicious than cowpea leaves, a commonly consumed vegetable in the region. Because it can also provide forage for their livestock, a key component of these mixed cropping systems, and produce very tangible soil fertility benefits (as discussed below), lablab has generated a lot of interest and excitement among our collaborating farmers. Many of them are already beginning to scale up the area planted after just one season.

Participants were encouraged to save KK8 bean and lablab seed for the next SR season planting. However bruchids quickly became a problem. Exploratory trials comparing low cost and locally available options to reduce bruchid damage (ash, leaves from a locally grown shrub (*Tephrosia vogelii*) and a commercially available chemical (Actellic)) were initiated with a subset of farmers across the gradient. Ash and *Tephrosia* demonstrated promise for reducing bruchid damage.

KARI conducted farmer training on boma compost making during the Short Rains, in order to have sufficient quantities to test as a vigor enhancing strategy during the Long Rains season.

Farmers were initially slow to make the compost, but after on farm demonstrations and frequent follow up visits by KARI staff, 80% of the participants developed compost piles.

Farmers in Western Kenya plant their main maize crop intercropped with beans during the Long Rains (LR) season. The standard practices consist either of planting maize and beans together in the same line at very close within row spacing (2 - 3 maize plants and up to 6-7 bean plants per 30 cm) or planting closely spaced hills (~ 30 cm apart) with multiple maize and bean plants. Farmers usually spread the little fertilizer they can afford over as large an area as possible, for example, by drizzling DAP lightly within the furrow at planting. Other farmers may use no fertilizer at all due to the high cost.

Prior to the LR09 season, Pulse CRSP farmers received training on alternative fertilization and spacing strategies with the potential to enhance crop vigor and productivity of both beans and maize. The fertilization strategies included concentrated applications of inorganic fertilizer with or without organic fertilizers (compost or green manure with lablab residues from the previous SR). All of the alternative treatments used a within row spacing of 25 cm for the maize and 12 cm for the beans. Forty seven farmers chose to compare some or all of the alternative fertilization and spacing approaches to their own practices during LR09. KK8 beans were sown in 68% of the trials along with either hybrid or local maize varieties.

Despite the vigor enhancing strategies and use of a root rot tolerant bean variety, beans performed poorly on farms across the gradient during LR09. Participants observed that late planting and climatic conditions exacerbated pests and diseases which decimated the beans. Nevertheless bean yields with the vigor enhancing strategies were consistently higher than farmer practice.

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.

Create awareness and identify additional NGO and female farmer groups for collaboration and dissemination of vigor enhancing strategies - Two NGO's (REFSO, ARDAP) and a CBO (Avene Group) were identified as likely partners for collaboration on this project. REFSO and ARDAP work in Busia, Teso, Samia and Bunyala districts and currently serve ~ 1,800 and 5,000 households, respectively. Avene is a smaller organization, with < 100 clients in Vihiga district, but it is part of a larger network established by Resource Kenya, a NGO focusing on soil fertility management strategies in Western Kenya.

Before the LR09 season, 64 farmers working with REFSO, ARDAP and Avene were introduced to vigor enhancing concepts through a series of training and sensitization workshops. Farmers selected seed priming, phosphorus fertilizers and KK8 bean for testing, and KARI supplied small amounts of seed and fertilizer to the groups to distribute.

Observations from the NGO/CBO groups have been quite positive. Farmers were impressed with seed priming because there was better emergence with primed seeds and seedlings emerged 3 days earlier than unprimed seeds. In addition participants noted a substantial benefit to bean growth with KK8 with or without TSP and MRP. Based on these successful results, REFSO, ARDAP and Avene trained an additional 80 farmers, who have begun verification trials with bean and lablab during the current SR0910 season. In total 144 farmers (72 females, 72 males) from the NGO/CBO groups are experimenting with vigor enhancing strategies for pulses.

Crop performance evaluation-

Bean performance SR 2008-09 - Farmers' bean verification trials in the short rains demonstrated that growing root rot tolerant KK8 beans gave a clear yield advantage (Figure 1). Across sites, KK8 alone without any fertilization increased farmers' yields by 19% compared to their own unfertilized, local varieties, while fertilizing KK8 with MRP or TSP gave an average 25% and 63% gain, respectively. In addition to resulting in the greatest mean yield response, TSP also gave consistent yield responses on individual farms (Figure 2).

Figure 1. Mean bean grain yields from on-farm trials across sites, SR0809 season

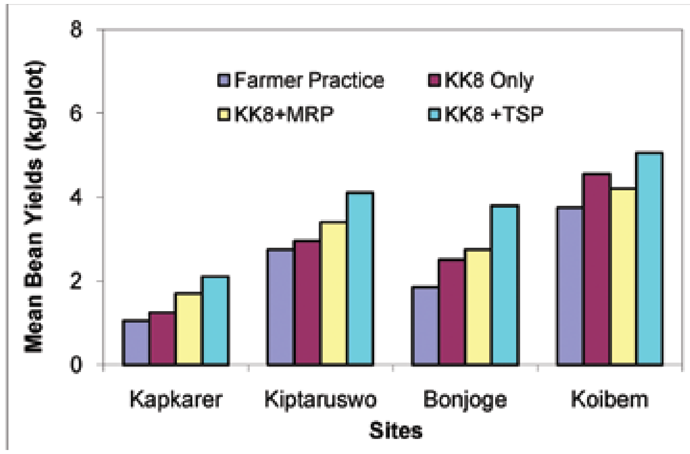
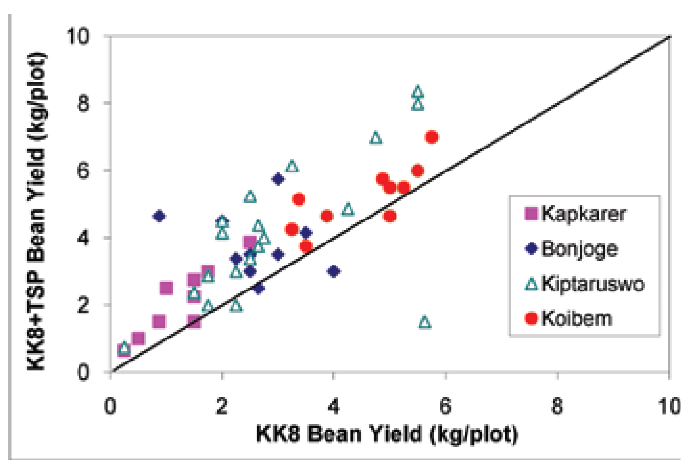


Figure 2. Bean yield results from individual farms comparing KK8 and KK8 with TSP, SR0809 season



Overall, yields followed the fertility gradient with the lowest yields obtained at the low fertility site Kapkarer and the highest at Koibem the high fertility site (Figure 1). The percent increment gained by fertilization also more or less followed the gradient, with the exception of lower than expected gains at Kiptaruswo, where aphid infestations seriously impacted crop performance. At Kapkarer, fertilizing the root rot tolerant beans with MRP or TSP gave an average yield gain of 62% and 100%, respectively compared to the current practice. These results are especially important, as these are farmers who experience chronic food security problems due to poor soil and crop productivity.

Lablab performance SR 2008-09 - As with beans, lablab grain yields followed the fertility gradient (Figure 3). Mean grain yields (kg/ha) were 359 at Kapkarer, 688 at Kaptaruswo, 872 at Bonjoge and 1204 at Koibem, although lablab performance across the gradient was somewhat more variable. None of the treatments evaluated (P fertilization, priming or a combination of the two) had a very large or consistent impact on lablab grain yields. Lablab exhibited vigorous vegetative growth across the gradient and produced grain that farmers found to be as palatable as common beans. Moreover, its mean grain yields were directly comparable to the mean KK8 grain yields (781 kg/ha for both) and higher than those obtained in the farmer practice beans (653 kg/ha).

Bean performance LR 2009- Bean emergence, evaluated 14 days after planting, was generally poor across sites due to inadequate rainfall at planting. Target plant populations were 450 plants per plot but mean establishment was 194, 260, 267 and 253 plants/plot in Kapkarer, Kiptaruswo, Bonjoge and Koibem, respectively. By 21 days after planting at both Kapkarer and Koibem, the greatest numbers of plants were established in the farmer practice and compost treatments and the fewest were established in the 3 treatments with DAP. We suspect that farmers' lack of experience with more concentrated applications of fertilizer.

Bean stand counts recorded for each plot at 21 and 28 days after planting were used to obtain plant mortality estimates (Table 2). These data show that: (1) across sites, post-emergence mortality followed a general pattern, with the highest mortality occurring at the two lowest fertility sites (Kapkarer and Kiptaruswo) and the lowest mortality at the two high fertility sites; and (2) at the lower fertility sites, the highest bean seedling mortality occurred in the lablab, farmer practice, and compost treatments. The greater survival in the treatments containing DAP is similar to the results observed in two other studies in Kenya, which showed that inorganic fertilizer application, either alone or in combination with compost, led to the greatest decrease in post-emergence damping-off of beans on smallholder farms (Medvecky & Ketterings (in press). Taken together, both trends (fertility gradient and type of fertilizer applied) suggest that bean seedling mortality is closely related to levels of available nutrients.

Higher bean mortality in the lablab treatment requires further investigation. It could be due to several factors, including higher populations of root-feeding chafer grubs (*Schizonycha* spp), increased inoculum density of the predominant root rot pathogens and/or nutrient dynamics related to the incorporation of lablab residues. At Kiptaruswo, KARI staff commented that they observed high populations of root-feeding chafer grubs on farms (Figure 3). Greater bean mortality in the sole lablab treatment may thus have been caused by the presence of higher

Figure 3. Chafer grubs (Schizonycha spp) collected from a South Nandi experimental site, LR09 season

populations of grubs in the lablab treatments. This would be consistent with results found in 18 replicated on-farm trials in Trans Nzoia district, Kenya (Medvecky and Ketterings (in press)) where significantly higher chafer grub populations were found in treatments where lablab residues were incorporated and associated with increased bean seedling mortality. If chafer grubs are a major driving force behind the higher mortality observed in the sole lablab treatments, the lower plant mortality observed in the half lablab DAP plots might be because the added phosphorus resulted in more extensive bean root development, such that fewer plants ultimately died. Both *Pythium* and *Fusarium* have saprophytic abilities and can use fresh residues as a food source.

Most farmers gave lablab and bean grain to their neighbors while 7% and 25% sold lablab and KK8 bean, respectively. Approximately 50% of the participants reported saving seed for the next season.

LR09 bean and maize yields - Beans produced minimal amounts of grain at all sites across the gradient. . The two organic-inorganic mixtures (half compost DAP; half lablab DAP) were always among the top two yielders and the farmer practice and sole lablab treatments were always among the bottom two.

The trends observed in the LR trials suggest that increased farmer awareness about important management practices is needed. These include: (i) application method to avoid seek scorching; (iii) improvement of compost quality; (iii) use of lablab residues to minimize negative effects.

Farmer-to-farmer exchange visit- Farmer-to-farmer exchange visits were conducted during both the SR0809 and LR09 seasons. Both visits were organized so that farmers from the high soil fertility part of the gradient got a chance to see the soil fertility status and crop productivity in the lower fertility part of the gradient and vice versa. In 2008, A total of 47 farmers participated in the Bonjoge – Kapkarer visits (31 male and 16 female), while 49 farmers (37 males and 12 females) participated in the Koibem-Kiptaruswo visits.

LR09 exchange visits - The LR exchange visits took place in July and gave the farmers the opportunity to assess the impact of alternative fertilization strategies on maize and bean performance at different soil fertility levels. A total of 28 farmers (23 male and 5 female participated. Farmers agreed that the soil improvement strategies had a major impact on soil and crop productivity, but recognized that a single round of compost and lablab incorporation would not be sufficient to rehabilitate their soils. The low bean yields were attributed by the farmers to late planting, poor climatic conditions, root rot and aphids in both areas. The majority of the farmers said they were attracted to the multiple uses of lablab and were interested to scale up to other farms. The Koibem-Kiptaruswo farmers said that the main lessons that they learned were that compost and lablab were inexpensive ways of improving soil fertility and crop productivity, that early planting has a very positive effect on bean and maize productivity, and that primed and no primed seed performed similarly due to planting in a wet year.

Scioeconomic surveys of farmers - Two surveys were developed jointly by KARI and Cornell collaborators to document farmers' understanding of the introduced concepts and reaction to the tested vigor enhancing strategies. Some of the findings were:

- FGD participants retained a good understanding of the vigor enhancing strategies, although seed priming was remembered the least.
- None of the farmers wanted to continue with their previous farm practices. At all the sites FGD participants indicated they would likely use boma compost, lablab, KK8 bean or organic (compost, lablab) plus inorganic fertilizers in the next season; whereas, farmers at only 2 sites were interested in using seed priming again.
- There was mixed reaction to the duration of lablab growth. Some farmers liked that the crop could provide leaves for vegetable over a period of time, while other farmers did not like the land occupied for such a long time.
- Farmers recognized the benefits of TSP and MRP fertilizers, but perceived that they were costly and largely unavailable, so were less interested in these strategies.
- Most farmers gave lablab and bean grain to their neighbors, while 7% and 25% sold lablab and KK8 bean, respectively. Approximately 50% of the participants reported saving seed for the next season.
- Lablab leaves were used for vegetable by a majority of the participants and 39% fed lablab to their livestock. Milk production was found to increase by up to 25% by some farmers.

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

SR 2008-09 Main Experiment (Lablab) - Lablab grain yields benefited from seed priming at the two low fertility sites (Kapkarer, Kiptaruswo) but not at the high fertility sites (Figure 4). Seed priming alone significantly increased lablab yield at Kapkarer by 87% over the other treatments.

Across the gradient, lablab grain yields increased with increasing soil fertility, which is consistent with the on-farm verification trial results. However lablab biomass yields from the replicated experiments tended to decrease with increasing soil fertility. Temperature and precipitation differences between the sites may have contributed to the observed effects - Kapkarer and Kiptaruswo are generally warmer and drier than Bonjoge and Koibem.

Diseases and pests of lablab were assessed in the Main Experiment starting 2 weeks after planting. Across the gradient, bean fly and bean root rot were of low to intermediate severity. Seed priming and phosphorus treatments had no impact on bean fly and root rot severity at any of the sites.

SR 2008-09 Lablab Satellite Experiment – Lablab grain yield and biomass data were highly variable and statistically inconclusive.

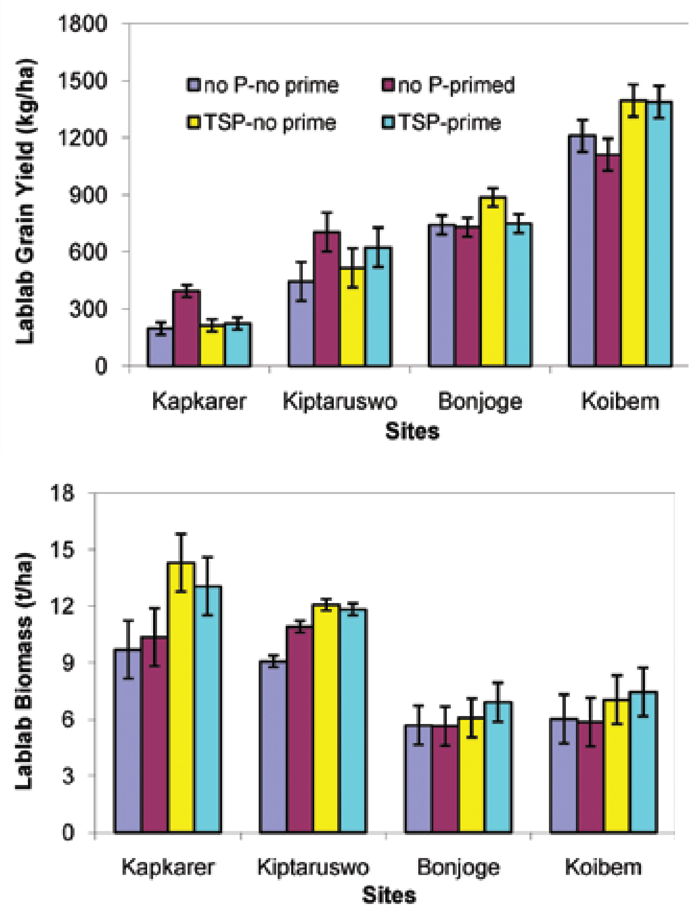


Figure 4. Lablab grain and biomass yields from SR0809 replicated Main Experiment

Minjingu Rock Phosphate significantly enhaced lablab grain yield in Kiptaruswa, however there no lablab yield response was observed to TSP across the gradient. Seedling emergence was good ranging from 81-90%, but TSP depressed lablab emergence at 3 of the 4 sites suggesting a high sensitivity to TSP fertilizer during emergence.

SR 2008-09 Bean Satellite Experiment - Bean grain yield ranged from 400 to nearly 2000 kg/ha depending upon the location and the treatment combination. TSP application resulted in a 12-50% with TSP compared to the no P control, but this effect was only statistically significant at Koibem. Little or no benefit of MRP on bean yields across the gradient.

Grain yield of KK8 (the root rot tolerant line) was similar to GLP2 in two of the three sites. Only in the high fertility site (Koibem) did KK8 out-perform GLP2 (by approximately 400%).

Post-emergent bean mortality was relatively low ranging from 25 to 31% across the gradient. Nevertheless disease and pest severity scores were higher in bean than in the lablab. Bean root rot and bean fly were the most prevalent biotic constraints. It was interesting to note that TSP effectively reduced bean root rot at all sites and bean fly severity at Kapkarer, Kiptaruswo and Koibem, but only Koibem was significant. As expected, the KK8 bean variety was more tolerant of root rot across all sites along the gradient. KK8 was also more tolerant of bean fly than GLP2 at all sites except Kiptaruswo.

LR 2009 Main Experiment (Maize-Bean Intercrop) - Plant mortality of the bean intercrop was very high at Kiptaruswo (82%), Bonjoge (56%) and Koibem (77%) due to late planting which accentuated bean root rot and bean fly damage. Consequently bean yields from these sites were highly variable and very low (< 300 kg/ha) making treatment inferences questionable.

Root rot severity and bean fly counts correlated well with the levels of plant mortality observed across the gradient. Chafer grubs varied across the gradient with higher counts at the high fertility sites and intermediate to nil counts at the low fertility sites. Aphid damage was low across all sites.

KK8 was more effective in reducing bean root rot severity than GLP2 across the gradient. Also KK8 showed more tolerance to bean fly than GLP2 at Kiptaruswo and Koibem.

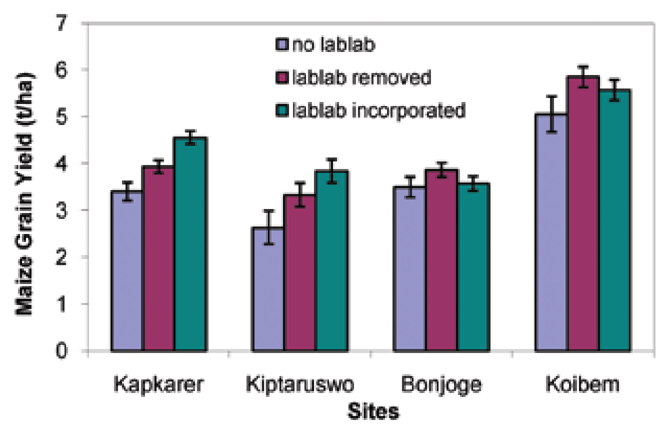
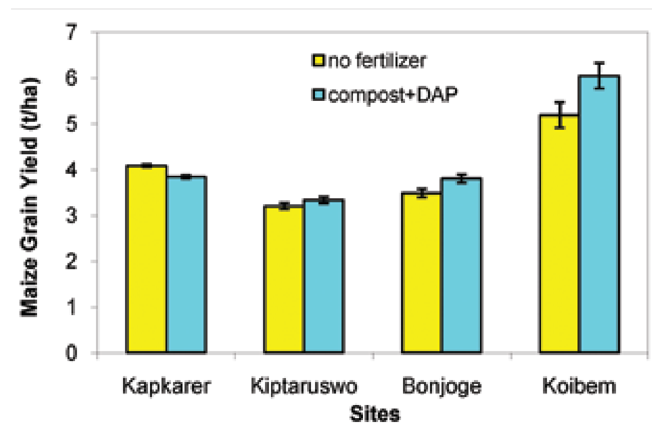


Figure 5. Maize grain yields from LR09 replicated Main Experiment



Lablab residue treatments increased maize yields at Kapkarer, Kiptaruswo and Koibem, but only the lower fertility locations were statistically significant (Figure 5). Maize yields increased 16-34% at Kapkarer, and 26-46% at Kiptaruswo.

Networking and Linkages With Stakeholders

KARI collaborated with two NGOs (REFSO, ARDAP) and one CBO (Avene). Activities were initiated in February 2009.

The Pulse CRSP project team established a collaborative relationship with Leldet, Inc., a private seed company based in Nakuru, Kenya. This company has a contract with AGRA but was finding it difficult to obtain improved bean materials for multiplication. Our project linked Leldet with a seed source in Kitale district, which provided seed of lablab and 2 root rot tolerant bean lines (KK8, KK15). Leldet is assisting the project to supplement seed needs, while increasing their capacity to supply quality pulse crop seeds to East African farmers.

Leveraged Funds

Cornell University scientists affiliated with this Dry Grain Pulses CRSP project have successfully leveraged in 2009 over $3,900,000 in external funding for research, outreach and educational programs.

Publications

Lusweti, Jane Francesca Nafula. 2009. Effects of phosphate fertilizers and seed priming on root rot and bean fly damage on beans and lablab in Nandi South District. M.Sc. thesis, Dept. Plant Science and Crop Protection, Univ. Nairobi, Kenya, 116 p.

Manuscript In Preparation

Medvecky, B.A. and Q.M. Ketterings (in press). Incorporation of legume residues does not increase productivity of intercropped beans on smallholder farms in Trans Nzoia district, Kenya. Biological Agriculture and Horticulture 26(4).

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

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Abstract of Research and Outreach Achievements

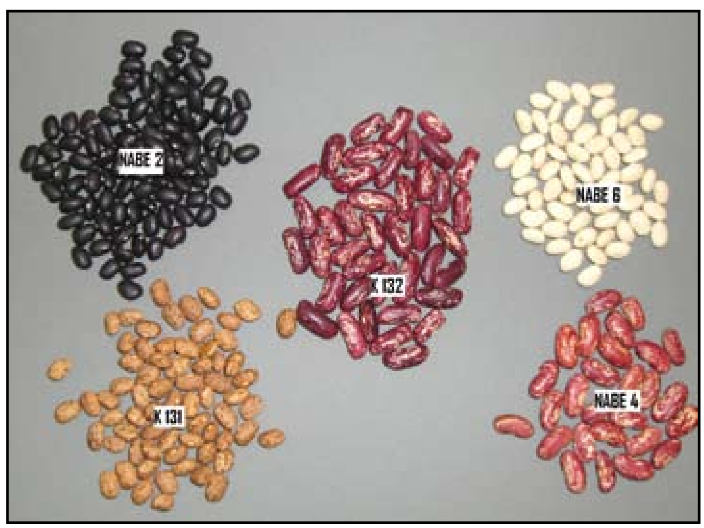
The Iowa State University-lead Pulse CRSP research team (PI-ISU-1) is operating effectively to address all project objectives. Activities to improve harvested bean quality and yields (first strategic objective) that have been successfully completed include documenting farmers' knowledge, attitudes, and practices regarding bean production, consumption, and marketing, and identifying key constraints. Farmer cooperators are actively participating in training and research, and appreciate the new knowledge gained, applied, and benefits derived to date. Yield and quality of beans from the first crop season were quantified and analyzed in relation to seed variety and methods and techniques of soil management, harvesting and storage. Preliminary laboratory analysis of harvested samples of five seed types has been completed. Existing extension training materials have been modified to reflect the results of preliminary analysis. Regarding the second strategic objective, enhancing the nutritional value and appeal of beans through appropriate handling and processing, research accomplishments include: documentation and analysis of post-harvest losses, and identification and promotion of the most effective post-harvest management techniques. Preliminary nutritional and physico-chemical analysis regarding key macronutrients and micronutrients has been completed. Determination of the effects of processing techniques on protein and carbohydrate digestibility is in progress. Development of protocols for making bean flour and identification of its key properties are progressing. Collaborative work to increase marketing and consumption of beans and bean products (our third strategic objective) has involved engaging local stakeholders in identification of rural consumer demand, preferences for beans, nutrition awareness,

Project Justification and Objectives

Agriculture in East Africa is characterized by women and men working in small scale, rain-fed production, averaging 2 hectares per household (FAO 2006). Erratic bimodal rainfall patterns in recent years further challenge cropping results. Farmers have very limited access to extension, training, inputs (quality seeds, fertilizers, etc.), improved agronomic practices, new technologies, and credit (KDA 2004; Nkonya et al. 2004). Producers 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. As a result of low production levels, hunger is widespread (WFP 2006) and the vast majority of the rural population lives in absolute poverty.

Ongoing collaboration since 2004 of Iowa State University (ISU), Makerere University (MAK), and Volunteer Efforts for Development Concerns (VEDCO) in Uganda's Kamuli District (Mazur et al. 2006; VEDCO 2006) using a "sustainable livelihoods" (SL) approach has increased food security and market readiness from 9% to 77% among 800+ farm households within 2½ years. The main crops grown in Kamuli district are maize, beans, sweet potatoes, cassava, bananas, rice and coffee. Most (90%) of participating households produce beans, but only 20% sold some in 2007. 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. Diversification of livelihood opportunities and activities is crucial to sustainability. 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 are able to apply for improving their individual and collective well-being.

Beans are a major food and cash crop in Uganda, accounting for 7% of the national agricultural Gross Domestic Product (GDP), ranking fifth in importance behind bananas, cassava, sweet potatoes, and maize (CIAT 2008). Bean production is entirely done by smallholder farmers and is concentrated mainly in the central, eastern, and western regions of Uganda. The common varieties grown are small black beans (NABE 2), red mottled (NABE 4), small white bean (NABE 6), light brown mottled (K131), large red mottled (K132). Bean production is increasing, mainly attributable to human population growth and the resumption of peace and stability in northern Uganda. Approximately 80% of bean production is consumed domestically, with 20% exported. The major bean export markets are the East African Region and southern Sudan. The bean industry in Uganda still faces many challenges such as poor linkage of producers to profitable markets (emerging domestic and regional markets), price fluctuations and limited access to market information.



Central Problems Limiting High Yields of Quality Beans include: (1) Declining soil fertility and inefficient cropping systems unable to utilize available resources effectively and efficiently; (2) Limited accessibility and affordability of quality seeds, non-seed inputs and other yield improving technologies; (3) Effects of drought and other weather related factors compromise productivity and quality; and (4) Diseases (root rot, anthracnose, angular leaf spot, common bacterial blight, viruses, rust, ascochyta blight) and insect pests (bean stem maggots, aphids, storage weevils).

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 post-harvest practices and poor on-farm storage facilities. Poor pre- and post-harvest handling also results in the majority of beans on the market 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 which have shorter preparation times makes bean preparation laborious with high fuel requirements; consumers also tire of monotonous flavor. As a result, an increasing number of people are abandoning or reducing their bean consumption despite its documented high nutrient content and health benefits.

Central Problems Inhibiting Increased Marketing of Beans and Derived Food Products - Enhancing prospects of marketing more beans and new agro-processed bean products within the Ugandan and regional markets requires 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 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 & Consumption

Research and Outreach Approaches, Results and Achievements

Objective 1: To improve harvested bean quality and yields.

Local Agronomic Knowledge, Attitudes, and Practices Documented- Key informant interviews were conducted with 87 farmers in Kamuli in 2008 and three focus group discussions were conducted (averaging ten people in each group). The majority of farmers involved in the production, harvesting and marketing of beans are women (77%); farmers have low education levels (53% less than primary-level). Most farmers use less than 10% of their land (averaging less than 5 acres) for cultivation of beans. At present, beans tend to be grown more for household consumption (because of their nutritional benefits) than for marketing. Households indicated a high level of interest in information about other ways to consume beans (e.g., recipes). Nonetheless, bean production and sales have increased during the past five years. It is estimated that in Kamuli women are responsible for 77% of the planting, weeding, land preparation for bean cultivation, and 98% of all food processing (threshing, winnowing and cooking). In contrast, decisions to market beans are usually made by men (56%), women (26%), or both (18%).

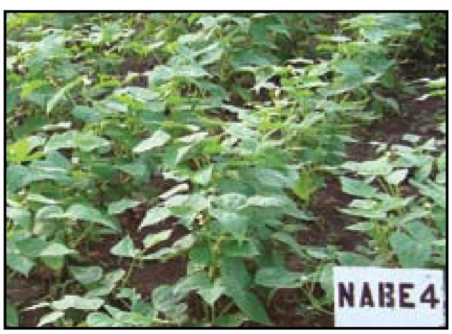
During the same period, interviews were conducted in three villages (15 farmers in each) in Umutara in Rwanda's Eastern province. There, most (78%) farmers are men; many use hired land to cultivate beans on their land. Half of those interviewed belonged to cooperatives. Beans are an integral component of their food security and income earning strategies, followed by maize, groundnuts, sorghum and cassava. Bean yield per unit area decreased approximately 18% during the last 10 years. Major factors responsible are reduced farm size (median size 2 acres), limited access to fertilizer or manure, pests, diseases, and lack of extension services. The farmers were challenged by the sudden outbursts of rain while harvesting beans (28%), cleaning beans (19%), and storage (19%). Price fluctuation (31%) and transportation (25%) were the greatest challenges for improved marketing. Among the crops cultivated by the farmers, beans ranked the highest followed by maize, groundnuts, sorghum and cassava.

The principal characteristics considered when choosing among of the varieties available to produce are marketability, resistance to weather conditions, and yield. Factors limiting bean production and productivity, in order of importance, are: unreliable weather (especially rainfall), small landholding size, limited access to quality seeds, pests and diseases, lack of capital (credit is either not available or tends not to be used when available), soil exhaustion, storage facilities, and drying facilities. Producers currently practice organic, conservation agriculture and generally do not use chemical herbicides and pesticides. Post-harvest issues appear as the biggest impediment in bean production, with most farmers (84%) reporting the 'shelf life' of stored beans as less than three months, even with periodic re-drying in the sun.

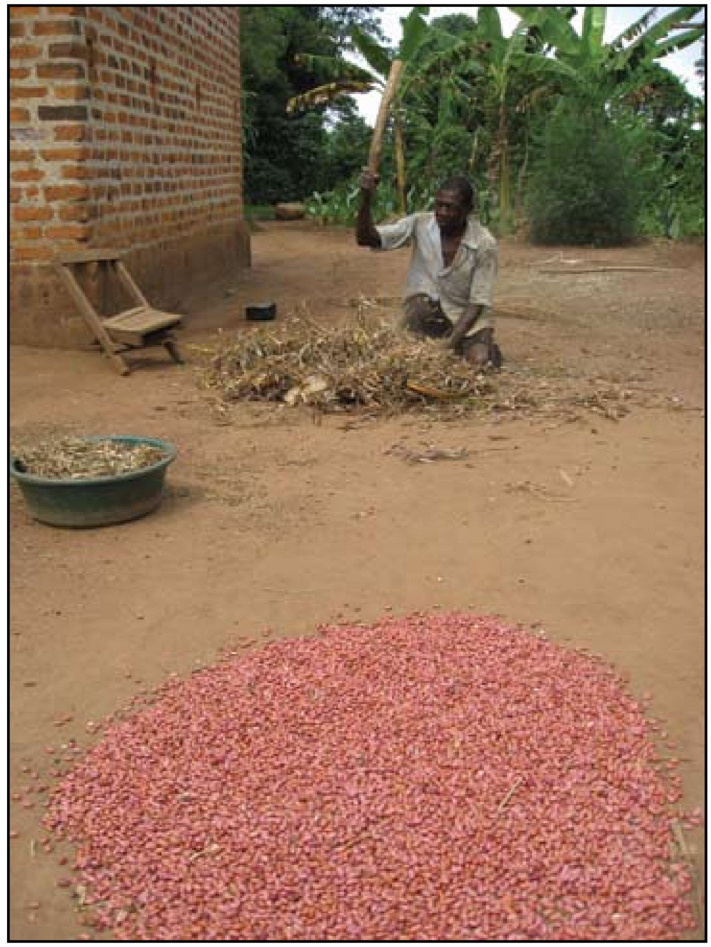
Field Sampling Technologies and Laboratory Procedures Established- Through the efforts of VEDCO and NaCRRI, field sites for March 2009 planting in Uganda were identified. Six groups of 10-12 farmers have been involved in the field trials. Each farmer group is responsible for planting, maintaining, and harvesting common beans in 5 gardens (field plots) (total of 30 gardens). Three of these field plots compare the yield of four selected bean varieties developed by NaCRRI plus the local variety chosen by the farmer group. The four selected varieties are NABE 2, NABE 6, K132, and K131. The local variety could vary with location and farmer preference, but in our project was always Kanyebwa. The two remaining field plots assessed the benefits of improved soil fertility by comparing the yield of plots with and without manure fertilizer treatment. Two varieties are compared in these gardens, K132 (the most popular variety) and a locally-selected variety. The amount of manure applied was estimated by volume, procured from local sources (normally apply 5-10 tons of manure per hectare depending on initial soil fertility and availability of the manure).

A training manual was prepared for this project. Participating farmers were trained in production practices and the importance of careful record keeping for this type of research and demonstration activity (general experimental procedures including site selection, replication and treatment application).

In Rwanda, based on results from the initial study of farmers' knowledge, attitudes and practices (KAP), the following varieties were selected for analysis: *Gakwekane* (dull and dark), *Kenyera, Kavaruganda*, *Umushingiriro*, and mixed variety (a combination of different beans – small and large seeded). From the KAP study, we learned that farmers typically plant a mixture of a diverse range of bean seeds. Hence, they often harvest and sell mixed varieties. However, established East African Community standards make it impossible to market mixed variety beans in other countries. Since *Umushingiriro* was identified as the most widely consumed, it was selected for research on its soaking treatment, cooking time, and physical characteristics (specific gravity, length, breadth and thickness). Due to seed size differences, farmers experience problems of uniform drying. Rwanda has initiated the Good Agricultural Practices (GAP) protocol in the horticultural sector. Hence, bean farmers must meet the standards to be competitive in marketing their produce for diverse markets.



Trials Planted, Managed and Harvested- Planting during the 'second season' was not possible in 2009 because there was no rainfall until mid-April. Thus, analytic activities could only be initiated following harvest of the first project-initiated season crop in July 2009.



The first set of field trials was successfully implemented in Kamuli District. The specific areas of operation were Bugulumbya sub-county (Kasambira and Nawanende Parishes) and Butansi sub-county (Naluwoli and Butansi Parishes). The trials involved three farmer groups from Butansi sub-county and three farmer groups from Bugulumbya sub-county. Each group managed five field sites: two for fertility trials and three for variety trials. Fertility trials compared the responses of three varieties (one farmer selected and two NaCRRI improved varieties) to 10 T/ha organic fertilizer application. Variety trials compared the performance of five varieties (one farmer selected and four NaCRRI improved varieties). The farmer-selected variety was Kanyebwa at all locations. Each variety/treatment plot was 5m x 5m established randomly within two replicate blocks. In total, there were 30 trial sites (324 plots) with each group managing 54 plots.

Plots were harvested sequentially as soon as the seeds reached physiological maturity (maximum seed dry weight), June to July 2009. The farmer-selected variety, Kanyebwa, was first to reach harvest maturity followed by K132, NABE 4, K131 and, lastly, NABE 6. In most cases, NABE 4 was harvested with K131, although it flowered earlier. To avoid border effects, the first and last rows and the end 50 cm of each row were also not included in the yield for each plot.

Experimental plots that were laid in poor draining areas were most affected by excess rain due to water logging. Such plots

were more affected by diseases and in some case were completely destroyed. Approximately 14% (45 out of 324) plots were not harvested because they were either destroyed by a combination of diseases, water logging and a hail storm. Some of the late planted NABE 6 was just vegetative, with very few pods, if any.

Bean Yields- Results show that there were significant location, variety, and location by variety interaction effects on the total yield, recoverable yield, 100 seed weight, pods per plant and seeds per pod. The range in average yields across locations was high, 110.9 to 1065.5 kg/ha for total yields and 62.1 to 899.8 kg/ha for recoverable yield. The locations with high yields were generally planted earlier (3 weeks) than the low yielding sites, and thus were able to escape drought during flowering and early seed filling.

Generally, K131 had the highest yields, while NABE 6 had the lowest yields. While NABE 4 had high total yields, its recoverable yield was lower than the other varieties because it had poorly filled, discolored and/or damaged seeds than the other varieties. K132 and NABE 4 had large seeds and therefore had a higher seed weight, followed by Kanyebwa.

Soil Analysis- Most of the soils were sandy clay loam (37 of 60 samples), 22 soil samples were sandy clay, while only one sample was sandy loam. The soil pH was between 6.0 and 7.3. The organic matter content in the soil was generally fair; only 18 out of 60 soil samples were below the critical value of 3.0%. Extractable (available) phosphorous content in almost all the soils was below detectable range (trace) of 5.0 ppm.

Effect of farm yard manure on the yield of the five varieties- Farm yard manure increased the yield for 2 varieties, with the recoverable yield for K131, Kanyebwa and NABE 4 increasing by 118.3 (27%) and 97 (28%) Kg/Ha respectively. NABE 4 yields, however, were reduced by 117 (35%) Kg/Ha. No significant differences were observed for the other yield parameters. Recoverable yield was significantly affected by location, variety, location by fertility and variety by fertility interactions. For 100 seed weight, significant effects were only due to location and variety.

Total and recoverable yield for K131 and Kanyebwa responded positively to farm yard manure but NABE 4 did not. Field observation showed that under fertile conditions, NABE 4 produced luxury (vegetative) growth. In general, realized yields were low compared to potential yields. Our yields were at best 50% of potential yields. Greater emphasis on increasing soil nutrient status is needed.

Harvest and Storage Techniques Impacts Documented- Harvested beans were stored at the host farmer's home for further drying and initial sorting. The host farmer was provided with gunny sacks and cloth bags for each harvested plot.

If periodically re-sunned (once in two weeks), bean quality in terms of incidence of insect damage - is maintained irrespective of the storage facility but better in well aerated facilities such as sisal sacks and polypropylene bags. When beans are not re-sunned, bean quality progressively declined irrespective of the storage facility but more so in less aerated facilities like pots and plastic Jerri cans.

Strengthen Farmers' Collective Capabilities to Learn and Share Innovative Practices- The "Training Manual for Bean Growing Farmers in Kamuli District" has been drafted and edited. It includes sections on bean seeds, production, pre- and post-harvest techniques (drying and threshing of pods, drying bean seeds, winnowing and sorting, testing for germination, determination of moisture content, storage, and re-sunning) of bean grains, disease and pest management, and record keeping. It has be used for training farmers during the first growing season of 2009 and then revised for use in the second growing season, and subsequently for wider application.


Clay pots


Sisal sacks


Polypropylene sacks

Plastic Jerri cans


Beans on Tarpaulin Sheet

Farmers Trained- Farmers were oriented to the specific objectives and methods used in field trials in Kamuli during Sept. 23–28, 2008. Trainers for the 67 farmers (58 women, 9 men) were Ms. Jane Mukabaranga (NaCRRI), Mr. Richard Ssekabembe (NaCRRI), and Mrs. Agnes Nakimuli (VEDCO). The following topics were covered: (1) research, (2) experimentation, (3) requirements for experiment (site selection, plot size, layout, treatments, replication/blocking, randomization), (4) benefits of researchers and farmers working together, and (5) reasons for testing varieties/technologies in several places (environment and genotype).

Research Results Incorporated in Training- The following practices are being recommended.

- Field pests controlled to reduce losses due to insect damages
- Timely harvesting to reduce risk of loss of grains due to sprouting and field pests; early morning harvesting reduces risks of shattering of pods and spillage of grains
- Beans wrapped in polypropylene sheets during transportation from the field to reduce spillage of grains

- Drying immediately after harvesting to reduce discoloring and sprouting of grains; drying of bean pods and grains on covered ground (tarpaulin sheets) to reduce spillage and contamination of grains with foreign matter
- Before storage, quality of grain verified as high to be able to obtain good market prices (parameters: insect damage, discoloration, pure variety, moisture content, germination rate, broken/split grains, diseased, live insect infestation, and foreign matter)
- Before storage, containers and structures sanitized to kill pests from previous storage
- Storage of bean grains in facilities that permit aeration, similar in temperature and relative humidity with the surrounding environment; sisal bags are preferred, though polypropylene bags are adequate; filled containers stored upright and off the ground

- Structures where bean grains are stored should be properly constructed ensuring no crevices to permit rodent entry; no cracks in the walls to otherwise hide storage pests and should be leak proof to protect grains from bad weather of rain water.

- Beans re-sunned during storage at least once in two weeks to terminate pests' life cycle and to maintain appropriate grain moisture content
- Farm records, particularly on post-harvest losses, should be well documented and assessed periodically to facilitate improving on post-harvest practices

Objective 2: To enhance nutritional value and appeal of beans through appropriate handling and processing.

To identify key causes of post-harvest losses, farmers' knowledge, attitudes and practices related to proper post-harvest handling of beans, as well as the major hindrances to proper post-harvest handling, focus group discussions and semi-structured interviews were held with farmers. Further, observations of farmers' post-harvest practices were made to understand some of their post-harvest handling practices. The effect of various storage techniques on bean seed quality and germination percentage/viability was then studied under different storage conditions, both in the lab and at farmer level. The effect of re-sunning, as a means of maintaining the quality of stored beans was also assessed.

Results show that insect damage was the major cause of qualitative loss during storage, while breakage and spillage of beans during transportation, threshing and drying caused most quantitative loss. Many (54%) farmers reported field pests as the major cause of grain loss, with the majority (61%) conceding that nothing had been done to control pests at harvesting. Most (77%) of the farmers reported spillage as a key cause of losses during transportation; beans were transported from gardens by head load with no wrapping provided to arrest spillage. Since all farmers threshed beans by beating them with sticks on bare ground, breakage of grains was reported as a major cause of losses during threshing.

Farmers in Kamuli were found to generally have sufficient knowledge on good harvesting and post-harvest practices. All the farmers sun dried their grain on bare ground. A majority of the farmers (69%) stored their beans in their houses where most of them (54%) packaged them in polypropylene bags. Most farmers (54%) re-sunned their beans once in two weeks but in spite of this precaution, 69% cited insect damage as a key cause of losses during storage.

Without re-sunning, insect damage was highest in samples kept in pots and lowest in samples kept in sisal sacks. In re-sunned beans, insect infestation was minimal in all samples after four months of storage.

From these results, the following recommendations were suggested to farmers in Kamuli district for consideration and as possible interventions: periodic re-sunning, field pest control, timely harvesting and drying, sanitizing bean stores before fresh storage, drying on covered ground (e.g., on tarpaulin sheets), wrapping beans for transportation, palleting of filled containers and use of properly aerated facilities for storage (e.g., sisal sacks).

Post-Harvest Management Innovations Promoted- To address loss-inducing practices observed in the field and during key informant interviews and focus group discussions, training in post-harvest handling was conducted in June prior to harvesting of the trial plots. This was organized by VEDCO (Agnes Nakimuli) and the training was conducted by the technicians from NaCRRI (Richard Sekabembe and Salongo Sulume). Farmers were trained in best practices of post-harvesting handling. Areas covered included the following: drying in pods (focus on timely harvesting to avoid insect infestation), threshing (when properly dry, at least two days, and avoiding breakage, damage or mixing with dirt), drying (on mats, tarpaulins, or raised platforms, and turning for uniformity and avoiding overheating), winnowing and sorting (remove shriveled, diseased, broken seed), measuring moisture content (using the salt test to verify 13-15% moisture content), testing for at least 90% germination (with two moist cloths for five days before storage, sale, or planting), treatment (banana juice, neem seed or leave oil, ash, hot pepper, Eucalyptus leaves, termite soil, bean debris and Actellic dust), storing (avoiding excess temperature and humidity, disinfected container, palleted), and re-sunning (every other week during the dry season and weekly during the rainy season).

Nutritional/Physico-Chemical Analysis Initiated- Preliminary chemical composition studies show significant differences (p=0.05) across bean varieties in total polyphenol, phytic acid, zinc and protein but not iron content. The moisture content fell within a very narrow range and varied from 9.2 to 10%. Protein content ranged from 25.7-31.6% and was highest in NABE 6 and lowest in K132 varieties. The total polyphenol content (catechin equivalents) ranged from 0.07-0.37 mg/g and seemed to correlate with seed coat color; black colored NABE 2 had the highest concentration while the white colored NABE 6 had the lowest, with the intermediate multicolored samples falling in between but also showing correlation to color density. Similarly, the phytate content ranged from 0.91-2.17g/100g and was higher in dark colored beans compared to lighter ones. Bean ferritin content ranged from 5.14-14.35 μg/g, and was highest in K131 and lowest in K132.

In summary, soaking reduced total available carbohydrates while both malting and de-hulling the soaked beans improved carbohydrate levels. On the other hand, total protein content increased with soaking but reduced with both de-hulling and malting. Both tannin and phytate content was reduced on soaking and further malting and de-hulling completely eliminated the anti-nutritional factors. However, zinc content reduced with malting and de-hulling while iron content increased with de-hulling and soaking but reduced with malting.

In Rwanda, the *Umushingiro* bean variety was subject to various treatments at *KIST's Department of Food Science and Technology*: soaking, germination, fermentation, puffing and a combination of these treatments. Soaking was for a period of 72 hours, and germination for 32 hours. The changes in their physical parameters such as the soaked weight and germinated grain weight were recorded.

Germinating and steaming beans reduced carbohydrates when compared to those untreated (control). This is attributed to partial degradation of starch into water soluble simple sugars while others are converted into energy for germ formation. Ash was also reduced by germination and steaming. This may be due to leaching of some minerals during the soaking process. Little or no change was observed in protein content, Vitamin C, reducing sugar, and total sugars.

The addition of fermentation to the germination and steaming treatment brought about drastic changes in the nutrient content of the beans when compared to the control sample and to the germination and steaming treatment. Ash content showed no additional change with fermentation. In contrast, carbohydrates, protein, fat, Vitamin C, and reducing sugar decreased significantly.

Bean Flour Development- The Ugandan M.S. student mentored at Makerere University (Aisha Musaazi) has been successful in accomplishing the objectives of her thesis in the Department of Food Science & Technology: "Development of a Nutritious Quick-Cooking Bean Flour." She has developed a processing protocol for the quick-cooking bean flour. Soaking and malting conditions, as well as roasting or steaming conditions, were determined.

Bean Flour Protocol- A protocol for the processing of dry beans into quick-cooking flour is being developed. Different processing pre-treatments were tested for their ability to enhance nutritional value. The processing treatments include: soaking followed by sprouting and roasting or steaming. The developed bean flour from the best processing method will be analyzed for nutritional and other quality characteristics.

The optimum soaking time required to achieve maximum water absorption was determined to be 12 hours. Following the 12 hours of soaking, the optimum sprouting time resulting in the maximum number of K131 sprouted beans (with adequate root size but no root hairs and no leaves) was determined to be 48 hours. The beans were then de-hulled (the testa/seed coat was removed), followed by either roasting or steaming. The optimum steaming time (under pressure), which resulted in tender beans without making them too soggy was determined to be 15 minutes while the optimum roasting time/temperature combination, which drove off maximum moisture, without burning the beans was 170o C for 15 minutes.

Objective 3: To identify solutions for constraints to increased marketing & consumption

The master's degree thesis research by Simon Okiror, Agriculture Economics at Makerere University, is entitled "Analysis of Factors Affecting Market Participation of Smallholder Bean Farmers in Kamuli District." The objectives are to: (1) identify socioeconomic characteristics of smallholder farmers involved in bean production; (2) examine the nature and organization of bean markets; and (3) determine factors contributing to participation and the level of participation of smallholder farmers in bean markets.

Data were collected using a survey of farm households and semi-structured interviews with bean processors and traders. The sample was clustered into CRSP-VEDCO project households; VEDCO assisted households that are not part of the CRSP project, and households not assisted by CRSP or VEDCO. Each cluster had 67 households, yielding a total of 201 households. The Heckman (1979) selectivity model that used a two-step estimation procedure was used to identify factors contributing to participation and the level of participation of smallholder farmers in the bean market.

Most traders deal with beans that have been sorted by variety. Varieties mostly demanded and traded by merchants were Kanyebwa (77%), Nambale – K132 and NABE 4 (72%) and white variety – NABE 6 (65%). The main factors that influenced demand of beans were grain color, cooking time and taste.

The bean value chain is comprised of bean producers and traders who ensure movement of produce from rural markets to urban wholesale markets and, finally, to consumer markets. Bean producing households in Kamuli use two main market outlets - farm gate (80%) and local village markets (20%). At the farm gate, 58% of bean produce is sold to intermediaries, 30% to traveling traders, 7% to households, 3% to institutions and 2% to wholesalers. Local retailers are the main buyers of produce brought to the local village markets (54%).

The results of multivariate analysis of the marketing decision show that the price of beans (per kilo) increased the probability of selling beans, and household size decreased the probability of selling beans. The condition of the road to the nearest market location and additional household resources (measured as the number of goats owned) also increase the probability of participating in the market by selling beans. After accounting for the participation decision, household resources (number of goats owned), the price of beans and the size of harvest all have a positive effect on the quantity of beans sold.

The new master's degree student, George Jjagwe, Agricultural Extension and Agricultural Economics at Makerere University, is initiating research on "Evaluating the Market Potential of Value-Added Bean Products and the Economic Impact on Rural Bean Producers in Kamuli District."

Farmers Trained and Facilitated for Marketing- Six farmer groups have been trained in marketing. Farmers are encouraged to view bean production as a key income source in their livelihood activities to improve their standard of living. Farmers were encouraged to increase the proportion of their land used for growing beans, as survey results indicate that beans yield higher income compared with other crops. To reinforce the concept of conducting bean farming as a business, farmers in the project were trained to consider carefully how much they plant, how much they sell, and the quality of their produce. They were also trained in keeping good records of all inputs and outputs and calculating the profitability of their agricultural enterprises.

Other areas of training included: (1) sorting of grain before harvest to add value; (2 packaging and labeling beans in smaller packages rather than selling in bulk in order to take advantage of market opportunities.

Consumer Preferences and Demand Characterized- Beans are regarded as a very important food for their nutrient and dietary benefits. They are consumed by every individual in the household starting as early as 6 month of age, on average 4 days per week. Processing of bean products was minimal and only done by a small proportion (5.2%) of households in Kamuli. Beans are mixed with millet, amaranth, maize and soya. The mixture was then milled to flour used for preparing porridge.

Networking and Linkages With Shareholders

To realize project objectives and actively promote institutionalization of positive impacts of research project findings and impacts, we effectively engage diverse key stakeholders throughout the project:

- Facilitate broad involvement in research design, data collection instruments and processes, and data analysis
- Hold periodic planning and review meetings to involve all partners so that challenges and constraints are discussed and strategies to deal with them developed together
- Share results from various stages of the project to encourage constructive criticism and strengthen usefulness, impact and sustainability of intervention results

- Work with farmers, groups and associations to understand local livelihoods, agronomic practices, their previous and current linkages with various types of institutions and service providers (governmental and non-governmental), private sector traders, transporters, distributors, and processors.

- In the future, we will involve other developmental partners with similar interests for complementarily and dissemination of results to other areas and countries

- Project results will be shared with the research and developments communities in Uganda, Rwanda and the region through workshops and various types of publications

Leveraged Funds

The PIs involved in this project have leveraged approximately $90,000 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

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

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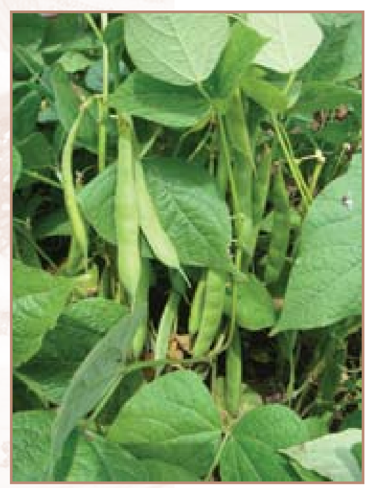

Abstract of Research and Outreach Achievements

In Ecuador, three varieties (INIAP 429- "Paragachi Andino", INIAP 430- "Portilla", and INIAP 480- "Rocha") were released to the public at field days during May 2009. Farmers from six CIALs in the Choto and Mira Valleys grew six varieties and four advanced lines, and produced 5 T of high quality seed. A small seed storage and cleaning plant was established to handle this seed production. In Rwanda climbing beans: MAC 9, MAC 49, MAC 44 (adapted to low altitude zone); RWV 2070, Gasirida, RWV 2373, RWV 2269, RWV 1368, RWV 1892 (for mid to high altitude zones); and bush lines: RWR 2245, RWR 1668, and RWR 1180, UBR (96) 26, RWR 2091, RWR 3042, RWR 2240, RWR 2340 were planted, characterized and descriptors developed in readiness for their official release in the 2010A season. Research activities conducted by a doctoral student in Rwanda included the identification of collaborative partners for implementation of on-farm participatory field trials, a survey of past and current agro-ecology research efforts, development and completion of farmer focus groups in three regions, and identification of challenges and areas for improvement in the ISAR participatory bean breeding program.

Certified seed was produced of three new bean varieties, "Zorro Black", "Santa Fe Pinto" and "Fuji Otebo", released in Michigan in 2008. A new vine cranberry bean is under consideration for release. High-yielding black, navy, red, pinto and kidney lines with resistance to common bacterial blight and anthracnose were identified for production conditions in Michigan; and bean lines were screened for tolerance to drought as part of a doctoral study at MSU. 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.

Project Justification and Objectives

Common bean (*Phaseolus vulgaris* L.) is the most important grain legume (pulse) 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, and staple food for thousands of Ecuadorian families, and the vast majority of small scale farmers in Rwanda. Improvement of bean genotypes for Ecuador environments has a potentially significant spinoff in terms of the high potential 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, but particularly on the Ecuador experience and germplasm, a tremendous opportunity is present 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 will provide unique materials for small-holder farmers, while providing insights into plant tolerance mechanisms for enhanced plant breeding methods. Results of this project would contribute to improved yield, farm profitability and human resources in the host countries and indirect benefit to participating U.S. Institutions and bean producers.

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 U.S.

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 U.S.

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 U.S.

The MSU breeding program is considering the release of new upright vine cranberry bean variety. The plant type is less decumbent than the current vine varieties, and produces a large (55g) round seed with excellent canning quality. This would be the first vine cranberry bean to be released by the breeding program at MSU. The seed type would have commercial appeal in both Ecuador and Rwanda.

> *...the first cranberry bean to be released by the breeding program at Michigan State University.*

Certified seed of three new varieties Zorro Black, Santa Fe Pinto and Fuji Tebo bean was produced in 2009 and will be available in sufficient quantity to meet needs of commercial growers in the U.S. in 2010. Over 3500 yield trial plots were harvested and 3800 single plant selections were made as part of the MSU breeding program activities in 2009.

Research continues to develop a stable transformation system for common bean. The effect of different factors including media formulation, genotypes, and explants that influence both regeneration and transformation of common bean were studied. Six basal media formulations were evaluated for their capacity to induce direct regeneration and different hormone combinations were also assayed. Four bean genotypes, (Redhawk, Matterhorn, Merlot and Zorro) were tested to evaluate their capacity for regeneration and transformation. Merlot seems to be the best cultivar for regeneration in media formulations tested. Different types of explants, leaves, stem, cotyledonary node, and mature embryos were assayed. To date mature embryos were the only explants that have been able to regenerate. This work and the next two studies were conducted by doctoral candidate, Ms. Mukeshimana.

In Rwanda more than 500 double cross and single cross F1 seed derived from new or previous single crosses for multiple resistances to major diseases were harvested in July 2009. The selected F1 seed of the different populations were planted in the field alongside the parental materials for seed increase and individual plant selection during the current season. The populations were created using some of the differential materials for angular leaf spot (MEX 54), anthracnose (G2333) and BCMV (USCR-7, USCR-9) that were acquired through this project crossed with adapted Andean lines from Rwanda. The full set of differential materials for angular leaf spot, anthracnose, bean rust and BCMV that were received from Ecuador, USA and Puerto Rica were maintained and are being used to create new F1 Andean recombinant populations for advance in 2010.

The variety selection process continued as different promising lines were selected from previous trials in 2008 after evaluation in the stepwise preliminary, intermediate, advanced and multi-location trials in Rwanda. These include bush and climbing beans in the low, mid and high altitude stations and on-farm test sites. Farmer participatory approaches were used to select for high yield, tolerance to diseases, general adaptability as well as for farmer and market preferences criteria among the advanced lines. New varieties SER 12, SER 14, SER 16, SER 30 were among the new bush types with good adaptation to the semi-arid conditions of Umutara and Bugesera zones of eastern Rwanda that were selected through the participatory approaches. Their potential yields range from 2.5 to 3 T per ha. They have small red seed types associated with good taste and red broth color, important in mixed diets with tubers and cereals.

During the previous season in Rwanda, a field day was planned as an occasion to release new bush and climbing varieties to farmers. The following new varieties were planted, characterized and descriptors developed in readiness for official release in the 2010A season. The climbing beans are: MAC 9, MAC 49, MAC 44 (for low altitude zone); RWV 2070, Gasirida, RWV 2373, RWV 2269, RWV 1368, RWV 1892 (for mid or high altitude zones); while the bush lines are: RWR 2245, RWR 1668, and RWR 1180, UBR (96) 26, RWR 2091, RWR 3042, RWR 2240, RWR 2340 (for low, mid or high altitude zones). Nearly all the new varieties represent a diversity of seed color and are of Andean gene pool. The varieties will be released for yield, tolerance to diseases or drought and potential market attributes. The bush beans yield up to 2.5 T per ha, while the climbers have a potential yield of between 3 T to 5 T per ha.

Three promising red mottled lines TP6, ARME2BC2 S143 and, ARME II and two black lines G21212 y L88-63 were increased by the CIALs in the Choto Valley in Ecuador. The L88-63 is a drought tolerant line developed by the former CRSP Project in Central America and Mexico (Frahm et al., 2004). Lines were also identified for use in the local canning industry. Seed increases of the promising lines for testing in canning trials were made and seed of I-402 and the two black lines G21212 and L88-63 were sent to SNOB-CIPIA Company in Quito for canning trials.

During the Oct-Dec 2008 growing season, a group of 740 bush bean accessions from the germplasm bank in Ecuador were grown out to renew the seed and collect data on agronomic and phenological traits, disease reaction and seed traits. 94 accessions were identified with resistance to rust. Disease reactions in the selections were verified in 2009 season and resistant accessions will be used as parents in crossing program to improve resistance and broaden genetic diversity of materials in the breeding program. A collection of 152 local materials recently collected in six localities from north and south of Quito were evaluated in field at Tumbaco and agronomic and phenological characteristics noted prior to submission to the seed bank in INIAP. Materials included 36 climbers, 3 were P. coccineus. Among the remaining bush types 78 were evaluated for drought tolerance under a rain shelter in an attempt to identify new sources of drought tolerance in local germplasm.

The breeding program in Ecuador identified five large seeded advanced lines in 2008 with favorable agronomic comportment, resistance to anthracnose, rust, yield and seed quality were reconfirmed in 2009 season. A second group of elite lines selected from among 63 selections derived from crosses with BelDakMI RMR-16 were selected for rust resistance and represent new source of rust resistance in adapted red mottled bush lines. A third group 109 F4 lines derived from triple crosses were screened and 26 F5 lines were selected for combination of anthracnose and rust resistance. An elite group of 6 lines with superior seed quality were selected from among these lines. A group of 258 F5 lines with multiple disease resistances to rust, anthracnose, and angular leaf spot were identified and will be further screened for yield, local adaptation and seed quality.

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

The mapping population to identify QTL for drought resistance in photoperiod sensitive Andean population (CONCEPCIÓN * 2/RAB651) is being advanced in tropical environment by Drs. Beaver and Porch in Puerto Rico. The population will be evaluated under moisture stress in Rwanda in 2010. Meanwhile, genotyping of the parental lines with SSR markers has been initiated. To date, 200 SSR primers were run on the parents RAB561 and Concepcion and over one-quarter (56) showed polymorphisms between the two parents.

Two preliminary greenhouse experiments at MSU were conducted to identify bean lines with high levels of drought tolerance. Seven cultivars, Blackhawk, Jaguar, Phantom, Zorro, TARS-SR05, L88-63, and B98311, were tested in the study. The first experiment was conducted in 9-cm square plastic pots where moisture is withheld. The root is constrained in this system to investigate shoot mechanisms underlying drought resistance in bean seedlings. The second experiment was conducted in 10-liter black plastic pots were moisture was withheld. Various variables including maintenance of stem greenness, unifoliate abscission, wilting, trifoliate senescence, recovery after rewatering, and dry matter were recorded. Data are still being analyzed, but it appears that the capacity of the bean plant to maintain a green stem might be associated with recovery after prolonged moisture stress.

At Geneva, NY, a total of 19 bean lines mostly from the bean program of collaborators in Ecuador (also 3 pintos from Mexico and several checks including Pink Panther, CLRK and Red Kanner) were evaluated under greenhouse conditions in soil artificially infested with a highly pathogenic isolate of *Rhizoctonia solani*. Three trials were conducted during April-May, 2009, the first 2 to determine the appropriate inoculum density (disease pressure) for the evaluation and the third test/trial for evaluating the materials on hand. I-424 Concepcion, I-425 Fanesquero/Blanco, and Negro San Luis appeared the most promising as they had the highest number of surviving plants in the third test.

During the June-September, 2009 growing season, a replicated root rot evaluation trial was conducted at the experimental root rot field at the Vegetable Research Farm, NYSAES in Geneva, NY. A total of 43 advanced bean lines and varieties were evaluated for their reaction to root rot pathogens. Symptoms of Fusarium, Pythium and Thielaviopsis infections were observed on infected plants, but unfortunately no symptoms of Rhizoctonia infections were observed. In addition, severe and uniform infections (epidemics) of Common Bacterial Blight (CBB) and Viruses (symptoms observed suggested the presence

of Clover Yellow Vein Virus, Bean Yellow Mosaic Virus, and/or Cucumber Mosaic Virus) occurred at this site in 2009. Thirty three of the entries included in this trial were provided by Dr. Tim Porch (USDA/PR), six from MSU and 2 from the NY bean program. All the susceptible checks included in the evaluation (DRK, Pink Panther, Hystyle and Goldmine) were highly susceptible to all the pathogens observed. However, the advanced breeding bean lines differed greatly in their reaction to root rot, CBB and/or viruses. Twelve advanced lines were selected for advancement in the breeding programs as well as to conduct a follow-up test in the greenhouse on their reaction to individual pathogens over the next few months as well as for possible re-evaluation in the field next season. Also, leaves have been collected from one of the susceptible checks (exhibiting 100% virus infections) and also from the 4 highly virus-tolerant lines to identify the virus(s) present in each line by Dr. Marc Fuchs in Plant Pathology department at Geneva.

Ms. Mana Ohkura completed her thesis showing that a number of strains of R. solani have become capable of infecting and surviving on corn, thus questioning the standard crop rotation recommendation for controlling this pathogen (Plant Disease 93:615-624; 2009). In June 2009, we established a replicated trial in field microplots to further investigate the impact of corn and other small grain on the survival of R. solani and its damage to the following bean crop. Soil of the microplots were infected with one of three strains of R. solani (AG 2-2, AG 4 and a Binucleate) and planted to the various grain crops. In late August, the crops were cut and incorporated into the soil. Two weeks after incorporation of the grain crops, the soils of the microplots were bioassayed for the infectivity of *R. solani* (on-going now). Next spring (May 2010), all the plots will be planted to beans (CELRK) and the incidence of *R. solani* infection severity will be recorded as well as marketable yield. Information collected will contribute to our ability to formulate a sound crop rotation recommendation against this important pathogen of beans in NY and elsewhere.

The project continues investigations on assessing the impact of soil health management practices individually and in combination on root health and yield of beans and other crops as well. Several growing cycles are generally needed before significant differences are usually observed. However, to-date we have found that snap and dry bean yield are increased in zone-tiled plots as compared to no-till or conventionally-tilled plots. Yield increases were observed in-spite of only minor differences in root rot severity/root health scores were observed on the plants. However, a good contact of seeds and soil (firming of the planting zone/row) is critical for attaining good yield. Also, we have observed that yield of beans is reduced after a cover crop of grain rye than vetch or no-cover crop, probably due to nitrogen tie-up early in the season.

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

Isolates of anthracnose collected in Ecuador and Rwanda were characterized on the differential series at MSU. In both countries Andean anthracnose races were identified. Race 1 and race 4 were identified in Santana and Caldera, Ecuador, respectively and in Rwanda race 27 was identified in Rwerere and race 55 in Ruhengeri. The later race is a very virulent Andean race capable of defeating all known Andean resistance genes. This underscores the strategy of using broadly resistant Mesoamerica genes such as the Co-42 as the best resistance sources against these virulent Andean races present in both countries.

Anthracnose was a problem in Michigan in 2009. 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 farmer continue to plant 'bin-run' seed of susceptible varieties with having it verified to be disease free. The problem is most obvious on white beans as 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 in 2009. The strain appears to be similar to that collected over the last two seasons. The new strain characterized as race 22-2 defeats many of the current resistance genes deployed in MI. A similar race 20-3 was recently detected in North Dakota. Race 22-2 has been found previously in the U.S. (Stavely, 1984; Plant Dis. 68:95-99) and coded as race 48, collected from N. Platte NE in 1982. Likewise 22-2 is the same as race 62 from PR, DR and FL (Stavely, Steadman, McMillan, 1989; Plant Dis 73:428-432). A race collected in Arenac county MI by Fred Saettler in 1975 (based on isolate code), characterized as race 40 has a very similar profile to race 48 or 22-2 (source Stavely, 1984) as it has the ability to defeat the Ur-3 gene. The fact that similar races have been detected in the past and not persisted may suggest that this race has a low fitness and this is borne out by the fact that infection occurs late in the season and is not very widespread. Resistance has been identified in elite MSU black and navy bean germplasm.

Isolates of bean rust, anthracnose, and angular leaf spot have been extensively collected in Nyagatare, Gatsibo and Kabarore districts by ISAR staff in collaboration with students of Umutara University. The isolates are being preserved for race typing both in the screenhouse on the differential cultivars (sent to Rwanda in 2008) and by molecular analysis in collaboration with Cornell University.

The experimental farm at Tumbaco has become a useful site to screen for resistance to Fusarium wilt caused by *Fusarium oxysporum*. The continual cropping of beans had lead to a build up of the pathogen in the soil. A group of 18 lines previously selected for resistance to wilt were re evaluated in this site and they exhibited high levels of resistance and will be used as parents in future breeding for resistance to Fusarium wilt. The program recently acquired access to a greenhouse at Tumbaco (2400m) for use in screening for resistance to angular leaf spot (ALS). Attempts to work with the pathogen at the main farm (Santa Catalina 3000m) proved ineffective due to colder temperatures at the higher elevation. Mist chambers were constructed in the greenhouse in preparation for screening with ALS. Monosporic isolates of six isolates of ALS collected from Northern valleys and from Tumbaco will be characterized on the differential cultivars prior to screening to ensure that adequate pathogenic variability is present in these races to screen the local bean germplasm.

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

The scarcity of staking materials remains a big challenge for the adoption and expansion of climbing beans to newer farmers, especially those that live in regions where agroforestry has not been established in Rwanda. Following the learning exchange visit by Louis Butare and the experience from Ecuador bean breeding project, validation and demonstration trials of six different options for staking climbing beans were conducted in seven different sites last season. Through participatory evaluation, the farmers from all the seven locations opted for the option that reduces staking wood from the recommended 50,000 to 16,700 stakes per ha that were reinforced with strings and cords. A lack of staking wood, less labor and costs as well as environmental issues were sited as reasons for the ranking of the staking innovations.

Approximately 10 tons of breeder and pre-basic seed of the pre-released and released bush and climbing beans mentioned above were produced on research stations in Rwanda. Seed was sold and distributed to farmers and farmers cooperatives; NGOs such as ADRA and to RWASCO, IMBARAGA, DERN, COAMV and RADA partners for secondary seed multiplication and distribution to more farmers. During the National Agriculture Show in Kigali on July 4, 2009, posters displaying new bean technologies: New Marketable Varieties; Integrated Soil Fertility and Root Rot Diseases Management; Staking Options; Variety Selection Scheme; as well as brochures of descriptors of 10 new varieties were displayed to thousands of show goers. Partner seed multiplication agents displayed and sold tons of seed of new varieties at the same show.

Three varieties, INIAP 429 Paragachi Andino, INIAP 430 Portilla and INIAP 480 Rocha, were released to the public at field days during May 2009 to help promote the distribution of new bean varieties in different CIALs in the Choto and Mira Valleys.

Three varieties INIAP 429 Paragachi Andino, INIAP 430 Portilla and INIAP 480 Rocha were released to the public at field days during May 2009 to help promote the distribution of new bean varieties in different CIALs in the Choto and Mira Valleys. In addition to the growers who attended the field days technicians from eight public institutions and different NGOs were in attendance. Release of Portilla was attended by 46 farmers in San Clemente; Paragachi Andino attended by 36 farmers in El Juncal and a larger field day was attended by 150 growers from 11 CIALs in San Vicente de Pusir in the Chota Valley to promote all three new varieties. Production of these varieties is directed to consumption of fresh green shell and dry seed for both the national market and exportation to Colombia. Seed increases of promising lines selected by members of individual CIALs in Choto and Mira Valleys were increased during the second season 2008. Eleven farmers from 6 CIALs grew 6 varieties and 4 advanced lines, planted 275kg basic seed and produced 4,724 kg of high quality seed. With assistance from Foundation PRODECI a small seed cleaning plant was established in the Choto valley with storage containers and electronic balances and silos with 4 T capacity.

A new CIAL was established in Pallatanga in 2008, with 49 people (35 men and 14 women) from different local communities and grower organizations in attendance. Preference was shown for new red mottled bush variety Portilla followed by Concepción, while red mottled varieties with short runners are still being evaluated. In canario seed types, preference for Guarandeño over Rocha was noted while in whites Blanco Belén was preferred over Fanesquero. Seed was evaluated in second season 2008 and based on seed quality the following varieties Yunguilla, Portilla, I-Libertador, Guarandeño, Rocha and Canario del Chota were chosen for planting at two locations in 2009.

Networking and Linkages With Stakeholders

ISAR and the bean program hosted the first AGRA Legume Breeders Network that was held in Kigali in October, 2008. ISAR collaborates with Government Extension, Farmers cooperatives and seed production agencies, and NGOs in Rwanda including World Vision, CARE, ADRA, and Catholic Relief Services. In Ecuador, INIAP collaborates with NGOs (PRODECI, PRODER, and the CRUZ ROJ) , and Agricultural Organizations (COPCAVIC, 10 CIALs, Grupo de Evaluadores

de Frijol de Bolivar, Assoc. de Productores de Frejol de INTAG). Government Organizations with which CRSP project partners in Ecuador includes MAGAP, Univ. Tecnia del Norte, and Univ. Catolica de Ibarra. mmon bean LR09 exchange visits - The LR exchange visits took place in July and gave the farmers the opportunity to assess the impact of alternative fertilization strategies on maize and bean performance at different soil fertility levels. We also wanted to facilitate discussion of their perception of lablab (benefits, constraints, utilization, marketing) since it is a new crop that farmers had never grown before. The exchange groups were the same as for the short rains (Kapkere-Bonjoge and Koibem-Kiptaruswo). A total of 28 farmers (23 male and 5 female participated. In retrospect, we found that fewer people, particularly women, participated in the long rains visits because they were inadvertently conducted on market days.

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

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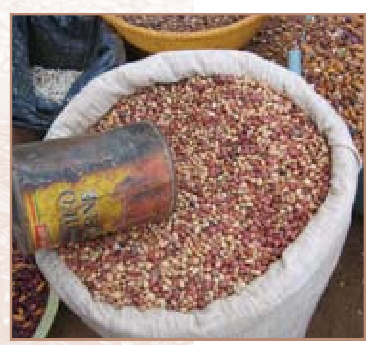

Abstract of Research and Outreach Achievements

Angola. Markets were visited and a market enumerator was trained. In 2009, Esteveo Chaves visited bean value chain actors (Huambo area) & developed a preliminary value chain diagnosis. Chaves will develop his thesis proposal in late-2009 with Dr. Donovan and his advisor at the University of Vicosa in Brazil, using price information & value chain data. Donovan worked with World Vision on a smallholder survey and identified survey areas with bean marketing. The report from the smallholder survey (WV ProRenda project) is drafted and being edited. UAN students conducted household surveys in 2 zones of Huambo Province to understand smallholder production/marketing systems, are analyzing the data, and are writing their Licenciatura under the supervision of Dr.Kiala with input from Dr. Donovan. Mozambique. Due to staff changes at SIMA, the draft report of the 2009 study is only partially completed. The spatial analysis will be completed when the cleaned time series data are available. SIMA price data analysis will be included in the rapid appraisal report. Research was conducted using rapid appraisal and key informant interviews. Information from last year's rapid appraisal and price data collected through SIMA will provide the basis for the MS CRSP trainee's thesis research at the University of Pretoria. With Dr. Donovan now in Mozambique, the collaborative research with IIAM will more effectively move forward.

Honduras. Organic/sustainable practice certifiers were initially contacted as fair trade bean certification was not available. FLO recently established standards for beans. As follow up, TransFair USA was contacted and the requirements for fair trade beans were obtained. A workshop in the Lago Yojoa region identified farmers' organic practices. Results of trials (organic vs conventional) in several regions depended on farmers' fertilizer/pesticide application rates--organic practices are good alternatives, given similar yields & rising fertilizer/pesticide costs. Meetings with the ARSAGRO/CIALs in Danli, Honduras, outlined project goals. Constraints include: CIALs farmers have small plots or rent land; ARSAGRO farmers had better land, but are less interested unless facilitated by a large investment of funds. A meeting with the company Rojitos obtained information on cleaning/exporting costs and the bean export embargo by Honduras. At a meeting with SAG/DICTA, the PIs learned that farmer organizations can export by applying to SAG. A meeting with APHIS/Honduran identified US export inspection requirements for dry beans.

Project Justification and Objectives

Markets are critical to farmer adoption of new technologies and management practices, as they offer farmers an opportunity to specialize and take advantage of 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/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/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/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 semi-subsistence 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/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/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 crop. This project focuses on developing a new market opportunity for smallholders--producing and exporting organic fair trade beans to the US 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 small-holder bean farmers in Honduras to export organic fair trade beans to U.S. markets

Research and Outreach Approaches, Results and Achievements

Objective 1: Angola. This project component has 4 sub-objectives: sub-objective 1.1: summarize secondary data on bean/cowpea production and marketing, including the identification of gaps to guide future research; sub-objective 1.2: identify production areas, marketing channels, and marketing margins; and sub-objective 1.3: identify constraints, opportunities, and potential pilot interventions to improve competitiveness.

Visit Key Informants to Identify Information and Data Sources- Several markets were visited by Cynthia Donovan and Esteveo Chavez (a Pulse CRSP MS degree trainee) in Angola to collect data on trends in bean and cowpea production and marketing. Chavez also trained a market enumerator who will continue to collect price information for Chavez's dissertation research in Brazil.

Interview Key Subsector Participants to Develop a Value Chain Diagnosis- Key actors in the bean value chain were interviewed by Esteveo Chavez in the Huambo area. A preliminary value chain diagnosis was developed, however, and additional visit to the area is necessary for further diagnostics. The goal is to collect information need to improve performance and identify constraints to subsector growth.

Conduct a Smallholder Survey- In early 2009, Donovan again traveled to Angola and worked with World Vision staff on smallholder surveying, and identification of survey areas, including areas known to have bean markets and trade. Given the lack of an agricultural census and the lack of agricultural surveys in Angola, identifying survey areas was based on rapid assessments and key informant interviews. This new survey is one of the first in Angola in the post-war period to collect information on agricultural production and marketing.

The baseline document from the small holder survey with World Vision ProRenda project is drafted but undergoing edits. Delays unfortunately occurred in data entry and data verification. These delays are understandable given that the enumerators and data entry staff were all new to the work and extensive training for them to be effective. Careful checking of data is also required as follow up.

Data indicate that about 60 percent of the households in the zones under study produce beans and it is the major income source for farmers in the ProRenda target zones. Women farmers tend to get higher prices for the beans that they sell. The result is higher total revenues to women farmers, even though they

produce an average of only 112 kilograms, selling 75% of production compared to 314 kilograms produced among males, and 86% is sold.

Only limited household surveys were conducted in the two zones of Huambo Province were conducted by two students at UAN. The objective of the survey was to understand smallholder production and marketing systems in depth, while gaining greater experience in field survey data collection. David Kiala supervised the development of the research for their "Licenciatura" degrees, Cynthia Donovan provided input, and the students are currently analyzing data and writing up the research.

Objective 2: Mozambique. This project component has 3 sub-objectives: Sub-objective 2.1: analyze spatial and temporal patterns of bean/cowpea production and marketing, using national survey data (TIA), disaggregated by gender; Sub-objective 2.2: map market-sheds for bean/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/cowpea varieties; and

Multidisciplinary Action Research, Spacial and Temporal Analysis, and Institutional Capacity Building - During the first 18 months, the project sought to implement a multidisciplinary action research approach that engages stakeholders from public and private sectors and NGOs. This research approach includes the development of a working group across sectors. Researchers would assess with partners the development of a formal Bean/Cowpea Task Force. The task force would have input into the design of the activities and receive regular feedback on findings.

Due to staffing changes at the market information service (SIMA), the analysis and draft report are delayed and only partially completed. A total of 38 traders of vulgar (common) beans (known locally as "feijao manteiga") were interviewed, buying a median of 343 kilograms per day. Another 8 traders were interviewed who deal with pigeon peas, buying a median of 122 kilograms per day. Pigeon peas are not as commonly marketed for retail sales as are vulgar beans. For the majority of traders, vulgar beans and pigeon peas were minor crops, as opposed to the major crop for marketing. With Cynthia Donovan now based in Mozambique, this work will be completed by the end of 2009. The spatial analysis (by province) using simple tables will be completed as soon as the cleaned time series data through 2008 on production and other aspects are available from the Directorate of Economics of MINAG. The SIMA price data analysis will be included in the Rapid Appraisal Report, as the data are already compiled for the various markets.

Multidisciplinary Action Research- In Mozambique, field research was conducted using rapid appraisal and key informant interviews. The draft report still requires more complete information. Only then can the outreach occur and the stakeholders group be developed with concrete evidence. The desire is to use the documents as a basis for the meetings indicated under this objective, as previous efforts with task forces for other commodities have identified the need to begin work with an information base in hand. Having Cynthia Donovan in country to work with Mozambique PI will be valuable to move forward in the coming year.

...in recent months, the international Fair Trade Labeling Organization has established standards for dry beans...

Objective 3: Honduras. This project component has 4 sub-objectives for this period. The sub-objectives in the current workplan are the following: sub-objective: 3.1) identify markets in the US for organic fair trade common beans, including the grades and standards required by these markets; 3.2) validate via field trails existing agronomic recommendations for growing organic beans; 3.3) identify interested smallholders and train the farmers to produce organic beans that meet the grades and standards required by US retailers; 3.4) establish local market linkages required for small-scale bean farmers to export organic fair trade beans to US markets.

Identification of Organic Fair Trade Bean Markets in the US- Initial contacts have been made with potential buyers/retailers of organic bens produced in Honduras, including Whole Foods, Sam's Club, United Natural Foods, and Alter-Eco—all retailers/distributors of organic and/or fair trade food products. Due to delays in initiating the organic field trials, the Pulse CRSP

project is still in the process of assessing the feasibility of producing organic dry beans. In addition, while two farmers groups initially expressed interest in growing organic beans, one of the groups is now hesitant about participating in the initiative and the other group may not have the capacity to produce organic beans (see 3.3 below). Thus, these constraints need to be addressed, before recontacting potential U.S. retailers to negotiate supply contracts.

During the first 6 months of the project, contact were made with potential third-party certifiers, including ECOHONDURAS (a firm associated with Guatemalan-based MAYACERT which could provide USDA-approved organic certification) and the Rainforest Alliance's local third-party certifier (ICADE), which could provide certification that the farmers are using sustainable practices—a type of certification that is recognized by some US retailers as a substitute for fair trade certification.

Regarding fair trade certification, TransFair USA is the only US certifier of fair trade food products. During the first 6 months of the project, it was not possible to obtain TransFair USA certification for dry beans because standards had not been established for dry beans. However, in recent months, the international Fair Trade Labeling organization (FLO) has established standards for dry beans, which makes it now possible for TransFair USA to certify dry beans. TransFair USA has been contacted and information has been obtained, regarding protocols that are required to certify dry beans, via FLO's representative in Honduras. As fair trade certification does not require the use of organic production methods, this may be a more promising option for the project to pursue.

Identification of Organic Methods for Producing Beans- During 2008 and 2009, integrated crop management practices commonly used by small farmers on their crops and those recommended in the literature were identified for beans. A workshop was held with farmers from the Lago Yojoa region of Honduras in 2008 to identify and document the organic practices most commonly used by farmers; nine farmers from CIALs and two technicians from the Rural Reconstruction Program (PRR), our NGO collaborator in this region, participated in this event. A document with recommended organic practices was developed. The common practices include the preparation and use of organic fertilizers such as compost and bokashi, the judicious use of natural pesticides from neem, madreado (*Glyricidia sepium*) and other plants, and the application of manure ash, lime and other materials to improve soil health and fertility. Biological control of pests with already available products was identified as promising by farmers and some were already testing these products (*Trichoderma, Beauveria*). Also, the use of rhizobium and mycorrhizae inoculation was suggested for more efficient mineral uptake from the soil.

Field trials to compare organic vs. conventional bean production using farmer practices, identified as ECOFRIJOL trials, were conducted during 2008-09 at different sites from the east central region with farmers from ARSAGRO and at the Lago Yojoa and Yorito regions of Honduras in collaboration with CIALs. Results were variable depending of the level of fertilizers and pesticides used as conventional practices by farmers. In those sites were farmers use very low inputs, the organic practices gave good results increasing bean productivity. In those sites were farmers use inputs (chemical fertilizers and pesticides) yield was rather similar or less than conventional practices; however, organic practices are considered to be a good alternative because of the rising costs of fertilizers and pesticides and the similar productivity observed in organic plots, at least in the short term.

Identification of Farmer Groups to Produce Organic Beans- During FY 2008 and 09, meetings were held with the leaders and farmer members of ARSAGRO--one of the largest bean farmer associations in Honduras, based in Danli. 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 dry beans and expressed interest in participating in the project. In addition to the area being a good bean-growing environment, the association recently built a new processing/bagging facility. The association is a major player in domestic bean marketing (previously making large sales to Horti Fruti/Walmart-Honduras) and has previous made export sales to traders. We have also met with CIALs (farmer groups involved in participatory plant breeding activities) which have expressed a good level of interest in getting involved in organic bean production.

There are two contrasting issues depending on the type of farmer group and its members. Small and poor farmers from the hillsides of the Lago Yojoa and Yorito regions, 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 with some practices already being implemented by some farmers. In contrast, farmers from the large organization ARSAGRO with better land and access to fertilizer and pesticides are less interested in getting involved in organic farming of beans unless the process is facilitated by the project which would required a larger investment of funds. Both groups have participated in the training activities offered by the project and in conducting the organic bean ECOFRIJOL trial.

Identification of Private Sector Agents- In February 2009, the PIs again conducted key informant interviews regarding the recent volatility of Honduran bean prices and collected data on the costs for transporting, cleaning, and shipping/exporting beans to Houston. It was learned that a US-based distributor might be interested in importing specialty beans (i.e., certified as organic, sustainably produced, fair trade). It was also noted that because each year, the Government of Honduras places an export embargo on beans, it would not be possible to export beans to the U.S. unless a waiver is obtained. In a meeting with one of Honduras' largest bean wholesalers/ exporters (typically exporting 16 containers of 20 MT/month), it was learned that during the past year, exports of beans were dramatically lower due to the closure of the border. Subsequently, the PI's met with Director of SAG/DICTA, who reported that Honduras did not have an embargo on bean exports—rather, it was only issuing phyto-sanitary certifications (required for exporting) to farmer cooperatives but not to private brokers/traders. The PIs were assured that the Ministry of Agriculture (SAG) would allow the project to export beans, if a farmer association initiated a request to SAG to export. Moreover, DICTA would be willing to provide technical assistance to the project. In addition, meetings were held with USAID and APHIS officials in Honduras who provided information on inspection requirements for exporting beans to the U.S. In a meeting with the Director of the farmer association ARSAGRO and several farmer members, the participants expressed possible interest in participating in the project - depending on the price they would received for their beans and the availability of funding to support the initiative.

Networking and Linkages With Shareholders

Angola: During the first 18 months of the project, MSU and UAN will collaborate with various agencies. It is anticipated that the MSU PI will participate in monitoring and evaluation activities with World Vision on their new Gates Foundation Project on Horticultural Value Chains. This work will enable a strong collaboration between MSU, UAN and World Vision in the implementation of a smallholder baseline survey and the data from that survey may be available for research and analysis focused on beans and cowpeas. Other NGOs in Angola are also involved in activities for agricultural production and marketing, including CLUSA, SNV, and ADRA, and the HC PI will reinforce to linkages with those partners, to share research results on the value chain as well as learn from their experiences.

The Ministry of Agriculture in Angola has several units that will be involved for they are currently active in either market information system development (e.g., DSA- Food Security Department; INCER- Cereals Institute) or in extension activities with smallholders (e.g., IDA-Extension Service). The working relationship between IIA (Angolan Agricultural 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 University of Puerto Rico will be particularly important as work on the value chain proceeds.

Private sector agents will be interviewed and later involved in outreach concerning the value chain analysis. These include Nosso Super (supermarket chain), Shoprite (supermarket chain), Jumbo, Angolan Chamber of Commerce, and UNAC (farmers association).

Honduras: The P1-MSU-1 project PIs in the Dry Grain Pulses CRSP have interacted with several stakeholders/HC institutions to provide an overview of the research project and solicit their suggestions for implementation, including the USAID Mission in Honduras, APHIS, Rojitos (a bean processor/exporter), SAG/DICTA, and the farmer association, ARSAGRO. The Program for Rural Rehabilitation (PRR) , supported by World Accord from Canada, and the Foundation for Farmer Research in Honduras (FIPAH) assisted by the University of Guelph and supported by Unitarian Services Church from Canada, collaborated with the project by facilitating organic bean production activities in the Yorito and Lago Yojoa regions though CIAL groups.

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 2009

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

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Abstract of Research and Outreach Achievements

At Zamorano in Honduras, 3 inbred backcross (IB) populations were developed. 275 BC2S3 lines from three populations were selfed and seed increased for further studies to identify lines which recombine desirable root traits for drought and low fertility stresses. A greenhouse study with one of these populations was conducted. A field study under low fertility was conducted with small red IB lines to generate near isogenic lines for on-farm testing. Superior lines selected from previous studies are being characterized under drought and low fertility in the greenhouse and field. In Mozambique germplasm was collected and profiled for root traits in the field. Large genetic variation was observed for several root traits affecting adaptation to drought and low soil fertility. Contrasting lines are being evaluated under stress conditions. Crosses were made with parents contrasting in root traits. Individual plant selections were made. About 450 F4 families and 600 individual plants selected from the F2 generation are being advanced. At PSU, QTLs for Basal Root Whorl Number were identified, and aerenchyma was identified as a novel trait for low P adaptation.

Erosion studies were established, rock phosphate (RP) was acquired, ground, and used in a greenhouse study of genotypic variation in utilization of this local P source. An intercropping study at PSU showed that bean/maize and bean/maize/squash polycultures may have better tolerance to low soil fertility than bean monocultures.

The baseline Mozambique Vulnerable Soil Vulnerable Household (VSVH) Survey was completed across 8 villages in Angonia, Gurue, Lichinga and Sussundenga. Males and females in households randomly sampled across villages identified adoption barriers, and constraints to achieving potential income and nutrition impacts. Access to seed including improved seed, through local markets, traders, extension, NGOS, and local sharing networks, was identified as a major obstacle. Current work is focusing on seed systems, and design of quasi-experimental approaches (to reduce observed barriers) that will be tested in Phase II.

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, 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, and 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.

Genetic variation for these traits is associated with from 30-250% variation in growth and P uptake among related genotypes in field studies.

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% better than existent checks such as Carioca. Studies with these genotypes identified a number of distinct root traits that contribute to P acquisition through topsoil foraging, including root hair length and density, adventitious rooting, basal root shallowness, and traits that reduce the metabolic costs of soil exploration such as root etiolation and root cortical aerenchyma. Genetic variation for these traits is associated with from 30 – 250% variation in growth and P uptake among related genotypes in field studies.

Drought is a primary yield constraint to bean production throughout Latin America and Eastern and Southern Africa. Beans vary substantially in drought tolerance, due primarily to variation in root depth and thereby access to soil water, earliness (drought escape), and secondarily to seed filling capacity. 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 (eg 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. Factors such as family structure may play a role in determining whether the introduction of more productive germplasm is likely to have positive or even negative effects 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. The overall goal of this project is to realize the promise of this opportunity to substantially improve bean productivity in Africa and Latin America.

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 intra-household 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: Three inbred backcross (IB) populations were developed using Amadeus 77, the most grown small red bean cultivar in Central America, as a recurrent parent and three lines from the L88 population developed in MSU (L88-13, L88-33 and L88-62) using the inbred backcross method. The L88 population derived from the cross of B98311, a drought tolerant line, and TLP 19, a low fertility tolerant line, have been evaluated intensively at PSU facilities and in the field in Honduras. These L88 lines were used as donor parents and they have higher expressions of root traits associated with tolerance to drought and/or low fertility stresses. The IB recombinant lines are expected to be used for on-farm testing of the multiline approach, which had been studied previously in Honduras and Puerto Rico (Henry et al. 2009).

In 2008-09, 275 BC2S3 lines from three populations were selfed and seed increased for further greenhouse studies to identify lines which recombine desirable root traits considered to be important for better performance of bean genotypes under drought and low fertility stresses. A greenhouse study with one of this IB population (Amadeus 77/L88-13) was conducted using the soil cylinder technique and the Winrhizo program for evaluating root traits. A field study under low fertility stress conditions was conducted during the first (primera) raining season of 2009 in a low fertility plot at Zamorano to identify lines with similar agronomic and seed traits but differing on root characteristics, to assemble a group of near isogenic lines for testing under farmer conditions.

Two promising lines derived from a earlier Bean/Cowpea CRSP project were included in on-farm validation trials of drought and low fertility tolerant common bean lines conducted in Honduras and Nicaragua, in collaboration with researchers from CIAT and national bean programs of Nicaragua, Honduras, El Salvador and Costa Rica. A group of six promising lines was evaluated during 2008 with partial funding of the Red SICTA Project. The six lines included in this validation trial have been root phenotyped using soil cylinders for greenhouse evaluation and on field trials. The two promising lines developed by the project recombine tolerance to these two abiotic stresses with good architecture, resistance to major diseases including to BGYMV and commercial small red seed type. It is expected that one of these lines will be released in 2010, after the last field trials being established in several countries during the current postrera season (Oct- Dec 2009).

Preliminary results from Angola indicated that several drought and low fertility tolerant lines were among the best lines. In the other hand, drought /low fertility tolerant lines developed by this project, in collaboration with the UPR/USDA-TARS/ Zamorano DGPC Project, are evaluated by farmer groups in Honduras and El Salvador using participatory plant breeding (PPB) approaches. Two lines were released as local cultivars by CIALs (Local Agricultural Research Committees) in the Yojoa Lake region during 2009.

IIAM/Mozambique: Collection of common bean germplasm- The objective of this activity was to collect common bean materials to be evaluated in different trials in Mozambique and to select parents with important traits for drought tolerance or for low P conditions. In 2008 and 2009 common bean germplasm was collected in Mozambique and surrounding bean production regions. The germplasm included several lines from CIAT, local germplasm and the Southern Africa Bean Network.

Identification of common bean genotypes with root traits adapted to low P soils- The objective of this study was to phenotype several bean genotypes and identify genotypes adapted to low P soils. Several bean lines were planted and root trait characterization was done in the field in Chokwe and Sussundenga in 2008 and repeated in

2009. The root traits were evaluated at 45 days after germination (podding stage). Four plants were selected at random for root evaluation. A shovel was used to excavate within 20 cm of shoot, and the roots were gently removed from the soil by hand. The excavations were performed by one person for consistency.

Preliminary results show variation in traits of these root classes. The average number of basal whorls varied from 2 to 2.75 and most of the genotypes had 2 whorls. Using our root rating scale, 73% of the genotypes had long basal roots, that is, rate 7 to 9 corresponding to more than 12 cm long. The number of basal roots varied from 4.25 to 8.5. High variation in primary and adventitious root traits was also found (data not shown). Variation in root traits was also found in 25 lines from Lichinga evaluated in Chokwe, and other genotypes from CIAT evaluated in Sussundenga in 2008 (Data not shown).

Evaluation of the root traits of common bean genotypes- The main objective of this study was to identify common bean genotypes with root traits adapted to soils with low levels of phosphorus and tolerance to drought. The evaluation of root traits was done in 2008 in Chokwe and Umbeluzi; and in 2009 the trials ware repeated in Chokwe and Sussundenga.

Only results of the Chokwe 2008 trail grown under water stress (the irrigation interval was 28 days, while normal irrigation was 15 days), can be presented at this time. Preliminary results show genetic variation among genotypes in number of adventitious and basal roots. The differences were significant for adventitious root number ($P < 0.001$) and for basal root number ($P = 0.002$). The average number of adventitious roots varied from 21.9 (G 19833) to 7.4 (DOR 500). The average number of basal roots varied from 10.68 (LIC-04-1-3) to 5.3 (SXB 418). In addition, the average number of basal root whorls varied from 3.31 to 1.75 and differences were significant ($P < 0.001$). The number of whorls in individual plants varied from 1 to 4. The highest mean number of whorls (3.31) was found in genotypes collected in Northern Mozambique DOUTOR and LIC-04-1-3, followed by CAL 96, AFRO 298, G 19833 and CAL 143 from CIAT. The results show a positive relationship between number of root whorls and number of basal roots.

Significant differences in basal root architecture among genotypes were found ($P = 0.0025$). VAX 1 had the highest rating (7) corresponding to deep rooted genotypes on our rating scale (12-13 cm), followed by DOR 364, Tio Canela and BAT 477. Most of the genotypes were rated intermediate and others had shallow roots (rate less than 4). Significant differences were found in adventitious root branching ($P = 0.005$), adventitious root length ($P < 0.001$) and basal root length ($P = 0.04$). The length of primary root and branching of basal root were significant at 10%. The results from this trial did not show significant differences in number of nodules and root rot infections.

Development of common bean genotypes adapted to low P soils - The objective of the study is to develop bean populations and bean varieties with root traits adapted to low P conditions and drought tolerance in Mozambique. In 2008 and 2009 the generations of selfing from 5 single crosses were advanced to F2, F3 and F4. These crosses were made using parents contrasting in root traits: parents with long and dense root hair and genotypes tolerant to drought. Individual plant selection was made in 2008 and 2009. Currently, in Chokwe we have about 450 F4 families from crosses SEA 5 x SXB 418; VAX 1 x SXB 418 and AFR 298 x PVA 773 and 600 individual plants selected from F2 generation of the crosses G 14665 x SUG 47, Entry 63 (G 19833xBRB 183) x SUG 47 and F3 generation of AFR 298 x PVA 773 to be advanced for next generations and evaluated for performance in the next seasons.

Identification of bean genotypes with root traits conferring P efficiency and drought tolerance- To identify bean genotypes with root traits suitable for low P soils and for drought tolerance diverse bean genotypes from CIAT, Southern African Bean Network and Mozambique are being evaluated for adaptability to Low P, tolerance to drought and yield performance. Several genotypes developed by CIAT and germplasm from Mozambique totaling 130 lines were planted in 2008 and 2009 for root trait screening in the field. Each genotype was planted in one row of 5 meters and planting space was 0.7 x 0.2 m. Four plants were selected at random and excavated at 45 days after germination for root trait evaluations. Results from field screening from BILFA lines (2008) show variation in basal root number, basal root length, whorls number and root architecture. The following genotypes had in average 8.5 to 7.0 basal roots: MORE 92018, VTTT 925/7-6, VTTT 918/15-1, VTTT 924/15-2, VTTT 924/18-6, VTTT 925/1-2-1, VTTT 925/3-2-2-1 and VTTT 928/9-1. Genotypes with an average of 2.75 to 2.5 whorls included VTTT 928/9-1, MORE 92018, BF 13572-10, VTTT 925/3-2-2-1, BF 13573-7, VTTT 924/15-2 and VTTT 918/15-1.

VTTT 925/3-2-2-1, RA 13019-3-1-4, VTTT 920/24-3 and MN 13509-8-1 had ratings of 9 for basal root length, corresponding to long basal root (15-20 cm to >20 cm). Shallow rooted genotypes included VTTT 923/9-1-2, VTTT 928/9-1, VTT 925/2-7-1, VTTT 925/7-6, BF 13573-6 and VTTT 920/24-3. Several other genotypes from CIAT and Mozambique are still under evaluation. Promising genotypes will be selected for advanced trials and for use in breeding as parents.

At PSU: Seed increase of promising genotypes and germplasm maintenance- We identified perform quantitative trait loci (QTL) for BRWN using recombinant inbred lines (RILs) developed from two populations: DOR364xG19833 and G2333xG198339. Phenotypic data on the number of basal root whorls and number of basal roots were obtained from the RILs 3 days after imbibition. QTL analysis for root whorl and root number was performed using composite interval mapping. The results suggest that few QTLs are associated with these traits. We found that almost 25% of the variation for BRWN in DOR364xG19833 and over 58% of the variation for BRWN in G2333 x G19839 RIL populations were controlled by the locus Rwn7.1 on chromosome B7. The high proportion of variance explained by this single locus suggests that this trait is associated with relatively few genes, and that this trait can be used as a criterion for selection of genotypes with better performance in low phosphorus environments.

The model showed that at low soil P, RCA formation in bean roots could increase plant growth at flowering by up to 80%.

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. We have previously shown that bean genotypes differ in RCA formation. The model simulates the growth of bean roots in 3 dimensions through simulated soil, estimated P uptake via diffusion to root surfaces, and shoot and root budgets for both carbon and P. The model showed that at low soil P, RCA formation in bean roots could increase plant growth at flowering by up to 80%. This trait has never before been considered in bean breeding programs, but these results suggest that it is worth further evaluation.

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

IIAM/Mozambique- Establishment of lysimeters and erosion studies in Lichinga- In February 2009, a trial was installed at the Lichinga Agriculture Research Station to evaluate the effects of phosphorus-efficient common bean genotypes on erosion. The field trial included 7 treatments (1 = L88-57, 2 = L88-57 cut above ground biomass at flowering, 3 = L88-30, 4 = L88-14, 5 = L88-43, 6 = L88-43 cut above ground biomass at flowering, and 7 = Bare Soil) per replication. The trial has 5 replications, with a total of 35 lysimeters/plots installed in a field with slope of about 6%. The replications are laid in contour lines of uniform slope. From each lysimeter was collected the runoff water from each event of natural rainfall. After each rainfall event the amount of runoff water collected is measured in the containers of a maximum of 50 L. From the container was extracted a sample of 300 mL after measuring total amount and stirring the collected runoff water. The samples are filtered in the lab for sediment weight and dissolved P analysis. The lab analyses have been completed but not available at the time of preparation of this report.

Location, Extraction and Grinding of Rock Phosphate in Monapo-Nampula- In February 2009, Rock Phosphate (RP, phosphorite) was collected in Nampula Province in Monapo District which has the largest reserves known in Mozambique at shallow depth. The phosphate rock from Monapo contains about 18% P and is located at a depth of 3 to 4 m, which is considered very shallow. Generally, RP is located at a depth of more than 1000 m. In this case it will be relatively cheap to mine the RP. The RP was then ground for use in future experiments.

A pot experiment was conducted in Chókwe Research Station with the objective to evaluate the effect of RP on growth of P-efficient and P-inefficient common beans. The experiment had two factors: factor 1- three bean genotypes (L88-30, a P-inefficient genotype; L88-57, a P-efficient genotype; and Lichinga, a local P-efficient genotype); and factor 2 comprising 3 levels of RP at 18% P applied to supply 5, 15 and 30 ppm per pot with 22 kg of dry weight of soil and the same (3) levels of SSP (10.5% $P2O5$) were supplied per pot. Each pot contained 1 plant, and the treatments were replicated 4 times. The measurements included growth parameters such as number of leaves, stems and height of plants at 15, 30 and 45 days after emergence; plant and root biomass measurements were taken 45 days after emergence. Preliminary analyses indicate that on average at $p=0.05$ significance level, the Lichinga P-efficient genotype had bigger number of leaves and stems, but L88-57 (P-efficient) did not differ significantly from L88-30 (P-inefficient).

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

The pilot baseline survey was completed in the village of Munhinga in Sussundenga (Manica Province). Following the pilot work, the VSVH household and village leader surveys were conducted across all 8 villages in Angonia, Gurue, Lichinga and Sussundenga. All baseline (benchmark) surveys have now been completed. All surveys were scanned to create electronic files, and master maps were created for all villages participating in the socioeconomic study. The goal of coverage of at least 35 households at each site was met, yielding an N of over 280 for analysis. After data cleaning, a final (useable) household sample size of approximately N=250 is anticipated, with multiple respondents within each household.

Analysis for Angonia, the first region being analyzed, indicates that access to improved seed is extremely limited, with broad segments of the villages' populations unable to access improved seed. Cross-community seed sharing and marketing are found to be limited. Further, relatively small percentages of households purchase improved seed in local markets or receive it from traders. Seed sharing, thought to be the principal distribution mechanism for bean seed distribution, occurs but not as broadly across the communities as anticipated.

Results for Angonia also suggest lack of ability to smooth consumption levels over the year through saving or formal or informal borrowing is also a major issue, with comparatively few households saving or borrowing to deal with periods of hardship. The 1st planting season, beginning of hunger season and when malaria rates are high in the villages coincide, creating constraints in terms of having income for improved seed, other required inputs, and productive labor resources (i.e., well labor). Approximately half of all households in the Angonia villages reported migrating to find food during periods of hardship.

The research planned for 2010 and beyond includes coding of all surveys, further development of materials characterizing current social and economic network structures at the local level, and analysis of data. Master maps for all sites (total of 9 sites, including the pilot site) are now being entered into Google Pro.

Observations are being geo-coded (example shown above), to use in the network analyses.

The baseline effort provides critical background for future work. Phase II activities will focus on a post-assessment of a series of interventions (e.g., scaling up and distribution of small low-P bean seed packets carrying a variety of beans) to be conducted at the experimental sites. Post-assessment activities will evaluate: new low-P bean seed acceptance for home consumption and marketing for income, actual adoption behaviors and documented patterns of diffusion across economic and social networks (within communities and inter-community), and intra-household impacts (men, women, children). The activities under Phase II will focus on the 8 communities in the baseline research, with testing of approaches across sites.

Networking With Stakeholders

Jill Findeis and Rachel Smith visited the USAID Field Mission in Maputo in August 2009, meeting with John McMahon, Office Chief, Trade and Business, and Irene D'Souza.. The potential to link this project in the future to cell phone providers to better 'link' low-income women growing the new low-P beans to markets was of particular interest.

Leveraged Funds

Drs. Lynch and Findeis and their collaborators have successfully leveraged over $4,700,000 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.

Accomplishments

Dr. Jill Findeis was named University Distinguished Professor at the Pennsylvania State University in 2009.

Publications

Henry, A, NF Chaves, PJA Kleinman, JP Lynch. 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, in press.

Henry, A, P Kleinman, JP Lynch. 2009. Phosphorus runoff from a phosphorus deficient soil under common bean (*Phaseolus vulgaris* L.) and soybean (*Glycine* max L.) genotypes with contrasting root architecture. Plant and Soil 317:1-16.

Nord, EA, JP Lynch. 2009. Plant phenology: a critical controller of soil resource acquisition. Journal of Experimental Botany, 60:1927-1937 (doi:10.1093/jxb/erp018)

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

Principle Investigators

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Abstract of Research and Outreach Achievements

The primary objective of this project is "to develop improved, pest resistant and drought tolerant cowpea varieties for target regions in sub-Saharan Africa and the U.S." In Burkina Faso, two new cowpea varieties achieved improved yields (700-800 kg/ha) in field tests and generated strong farmer interest. In Senegal, on-farm tests were completed and Foundation Seed produced for the release of the improved line "ISRA-2065" with thrips and aphid resistance. Advanced yield trials were conducted during the 2008 and 2009 seasons in Burkina Faso, Senegal and California on a total of 180 lines for release selection based on grain quality, yield, and disease and insect resistances. Crosses for developing new breeding lines were made in Burkina Faso, Senegal and California to combine high yield, grain quality, and abiotic and biotic stress resistance traits. Most crosses were advanced to F3-F4 stage in 2009.

To strengthen cowpea seed production and delivery systems to ensure delivery of improved varieties, the following was achieved in 2009: In Burkina Faso, Breeder Seed of 10 improved varieties (>100 kg/entry) and Foundation Seed of 4 varieties was produced, and 2.5 MT of Foundation Seed of 4 varieties from off-season production was sold to Certified Seed producers. Forty lead farmers were trained as Certified Seed producers. In Senegal, 2 ha each of Melakh and Yacine Foundation Seed were produced to supply the EWA NGO seed producer network. Multiple women and men farmer groups were trained in seed production. From Foundation Seed provided to the Producers Professional Training Center, Sangalkam, Certified Seed was produced of Melakh and Yacine seed was produced by 10 farmer organizations. A student from Angola began a M.S. graduate program at the University of Puerto Rico in plant breeding and genetics with a focus on cowpea improvement.

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 primary constraints under the Topical Areas of Inquiry for Theme A "reducing cowpea production costs and risks for enhanced profitability and competitiveness", and Theme B "increasing the utilization of cowpea grain, food products and ingredients so as to expand market opportunities and improve human health." Until now cowpea, as an 'orphan crop', 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 ten 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.

Productivity is central to increasing rural incomes irrespective of changes in cowpea acreage, because less land, labor, and capital are needed to produce the same amount of cowpeas. The resources can then be invested in other activities that help boost total family income. Productivity increases also help reduce prices to urban consumers since some farmer cost-savings can be passed through to consumers. Sustainable increases in cowpea productivity in Africa and the U.S. can be achieved by developing varieties with resistance to insects, nematodes and pathogens, drought tolerance, and 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, and if over-produced, prices offered to farmers can be low because of limited demand. Large white grains with rough seed-coat are preferred throughout West Africa and can be marketed over a wide area, 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 both Africa and the U.S. There is also considerable demand for large rough-brown seed type, especially in urban centers in Nigeria, but the standard rough-brown 'Ife Brown' is susceptible to pests and diseases. Other opportunities exist for new cowpea products based on the 'sweet' trait; sweeter and milder taste could help broaden cowpea consumption in the U.S. and Africa and to Latin America and elsewhere.

Increasing Seed Supply of Improved Varieties: Cowpea breeding by the CRSP, African NARS, and IITA (Senegal, Burkina Faso, Nigeria, and other countries) has led to improved cowpea varieties that are near release. However, only about 5% of the cowpea area in Africa is planted to improved varieties and their potential goes largely unrealized. Common bean research showed that rural African farmers will buy seed when it is available, suggesting that there is likely to be a market for cowpea seed as well.

Effective models for production and dissemination of improved cowpea seed have evolved in Burkina Faso and Senegal, based on collectives (e.g. women farmer organizations) and for-profit seed cooperatives (NGO-established, but now largely self-sustaining). However, their limited scope 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. Strengthening seed production and delivery at the early breeder-involved stages will promote availability of high quality planting seed.

Objectives:

1. Develop improved, pest resistant and drought tolerant cowpea varieties for target regions in sub Saharan Africa and the US 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

Final Testing and Release of Varieties:

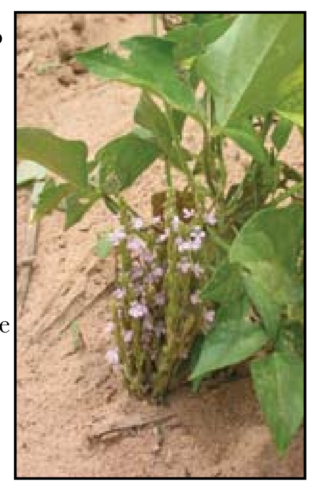
Completing varietal release protocols for 03Sh-50 and application for Plant Variety Protection (PVP): 03Sh-50 was released by the University of California, Riverside in May 2008 as "California Blackeye 50" (CB50). PVP has been applied for and is pending approval (PVP Application 200800395). A variety registration manuscript was published in the Journal of Plant Registrations (Ehlers et al., 2009) and a seed sample supplied to the National Center for Genetic Resources Preservation (NCGRP) in Fort Collins. CB50 has been designated as US Plant Introduction (PI) 655235 by the NCGRP. Data from 15 reliable trials conducted over four years showed that the yield potential of CB50 is equivalent to CB46, but that the grain of CB50 is more attractive than CB46 due to whiter color and larger size. CB50 also has resistance to Fusarium wilt race 4 which CB46 does not. About 8,000 kg of Certified Seed was produced in 2008 and sold out for the 2009 planting season. This variety has received excellent 'Press' in local farm journals and the 2009 crop is being sold by several warehouses as a premium export class of this crop. We anticipate an expanded California production acreage of CB50 in 2010.

Selecting superior blackeye breeding lines from early and advanced generation nurseries: Breeding nurseries with early and late generation blackeye breeding lines were evaluated at Shafter, Kearney, and Riverside. About 200 single plant selections were made in 2008 for further development and evaluated in 2009, including progenies developed from crosses between CB50 and CB46, and other lines that are part of a breeding effort to develop later maturing blackeyes with one large single flush, and blackeyes with superior grain quality.

Developing lygus and aphid resistant blackeyes: A large lygus resistance trial was conducted in 2008 under unprotected (no insecticide) conditions at Kearney, with 30 entries including CB27, CB46, and CB50. Three lines, 07KN-42, 07KN-46 and 07KN-74, had outstanding yields that were significantly greater than CB46. All three lines had similar percentage of grain damaged by lygus as CB46, ranging from 27.0 to 38.5% among the 4 lines, which were not statistically separable. Although the grain quality of 07KN-42 and 07KN-46 is not up to commercial blackeye standards, these lines both have very large seed which will simplify breeding large-seeded blackeyes when they are used as parents in crosses with California blackeyes. In 2009, the highest 14 performing lines were included in trials with both protected (insecticide treated) and unprotected plots in two trials with different planting dates and good insect pressure.

All-white and dry-green grain classes: Tests in 2008 and 2009 at two locations on the yield potential of the 'all-white' 07-11-572 advanced line determined that it has grain yields equivalent to CB46. A 'fast-track' release protocol is being followed to accommodate the needs of potential licensees for 07-11-572, so that this variety can be made available as quickly as possible. This is possible because the 'all-white' grain type of this is breeding line is new and unique, meaning it does not have existing standard varieties with which it can be compared and must compete with for release approval.

In Burkina Faso (INERA): Field evaluations for final yield testing to support release of new varieties IT98K-205-8 and Melakh were made during the 2008 and 2009 seasons. These are improved varieties obtained from the previous Bean/Cowpea CRSP collaborative activities. They are early (60 days to maturity), high yielding varieties that are adapted to the main cowpea growing area of Burkina Faso, and as such, represent an excellent opportunity to have immediate impact for cowpea farmers through INERA release. On-farm yield tests were conducted in 5 villages of 5 different provinces of the country. Average yields in 2008 obtained were 700kg/ha for IT98K-205-8 and 800kg/ha for Melakh. The two varieties were preferred because of Striga resistance and their earliness. Farmers start to harvest in some localities 55 days after planting. Hundreds of visitors from the farming community and cowpea sector visited the trials. The positive responses to these evaluations indicated that cowpea farmers are ready to adopt these new varieties.



In Senegal (ISRA): In Senegal, 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', with the objective of developing a cultivar with the yield and stability of Mouride but with resistance to aphids and thrips. ISRA-2065 is as early as Melakh (60 days from planting to maturity) and has the same desirable grain quality. This variety 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.

Advanced Yield Trials:

I*n Burkina Faso (INERA)*: In Burkina Faso, two advanced yield trials were conducted at Saria and Pobe Mengao and a set of 23 improved insect tolerant lines were compared to a popular released variety (KVx 396-4-5-2D).

In Senegal (ISRA): Two advanced yield trials were conducted at the Bambey and Thilmakha ISRA field stations. The first trial included 98 lines from the cross Nd. AW x Yacine and the two parents. The second trial included 54 lines from the following crosses: Mélakh x UCR 232; CB 27 x Mélakh; Mélakh x Monteiro derived lines, and ND. AW x Yacine. The control entries were Mouride, Mélakh, Yacine, and ISRA 2065. 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. Two trials each were conducted in the Mekhe and Louga areas. Similarly, the same number of lines was selected based on grain size (100 grain-weight > 25g) from the second 2008 trial and tested under the same conditions.

In California: Evaluation of three 'new' advanced blackeye breeding lines for grain yield and quality, and agronomic characteristics was conducted at two locations: Replicated trials comparing yields and grain quality of CB46, CB50 and three 'new' blackeye breeding lines (Table 1) were conducted under double-flush production systems in 2008 and 2009. The three lines (UCR P-191, UCR P-203 and UCR P-87) have resistance to both race 3 and race 4 of Fusarium wilt and resistance to Meloidogyne incognita root-knot nematode. Two of the lines, P-191 and P-203, also have greater resistance to M. javanica root-knot nematode, compared to CB46. New blackeye line P-87 showed both high yield potential and lower levels of 'skin checking' (seed-coat splitting) than CB46. This line has resistance to race 3 and race 4 of Fusarium wilt, with medium sized seeds, and we plan to include this line in large plot tests in 2010 in a move toward release.

Crosses for Developing New Breeding Lines:

In Burkina Faso (INERA): Crosses were made as summarized in Table 1. The F1 generation seed of each cross was advanced to F3 stage during the current reporting period. 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 characteristics of commercial preference in the sub-region. The national cowpea plan of action for Burkina Faso has stressed the importance of exporting the surplus cowpea production to the neighboring countries that have deficits of more than 500,000 metric tons.

Table 1. Crosses (High x High) made with Burkina Faso breeding lines.

Recurrent parent	Traits being introgressed	Donor parents
KVx 745-11P	Medium seed size white and rough	KVx 414-22-2 derived lines and KVx 775-33-2
KVx 396-4-5-2D	Striga resistance and seed size	Kvx 414-22-2 derived lines and KVx 775-33-2
KVx775-33-2	Increased seed size	Montiero
KVx 414-22-2	Increased seed size Striga and virus resistance	KVx 414-22-2 derived lines and Montiero
KVx 414-22-2	Increased seed size and virus resistance	KVx 775-33-2
KVx 771-10	Striga and insect resistance	IT86D-716 and Moussa Local
KVx 775-33-2	Virulent race of Striga resistance	IT93K-693-2

In Senegal (ISRA): Crosses were completed as summarized in Table 2. For introgressing Striga resistance, Yacine was crossed with a more recent line (IT90K-76) instead of Suvita 2. Advanced lines from Melakh and Montiero derived genotypes with large seeds were included in the 2009 yield trials. The Mouride x Monteiro lines introduce large grain quality into a drought and Striga resistant background. Additional crosses were also made and included ISRA-2065, Yacine and Melakh, each crossed with the Striga resistant lines IT82D-849 and IT90K-77, and with IT98K-1111-1 for Macrophomina resistance. The 58-57 x Suvita cross, which is part of the 'High x High' elite line long-term breeding strategy, was also made.

Table 2. Senegal varieties being improved by introgression of specific traits by backcrossing.

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)	ISRA	Striga
Mouride	Montiero derived line	ISRA	Large grain
Melakh	IT97K-499-39	ISRA	Striga resistance
Melakh	UCR 03-11-747	ISRA	Green grain

In California: Under the planned 'Longer Term Strategy' to pyramid resistance and grain quality factors in varieties desired by farmers using crosses between elite parents having complementary parental lines, several activities were conducted. To develop high performing, drought tolerant varieties, a 'two-stream' recurrent selection approach was utilized. For the first stream, five bi-parental crosses between highly drought tolerant lines SuVita 2, Mouride, IT97K-499-39, IT97K-556-6, IT84S-2246, and IT93K-503-1 were made during the spring of 2008 at UC Riverside. The resulting F1's were then advanced to the F2 generation during the summer in the greenhouse. 100 F2 individuals per cross were then advanced in the greenhouse to obtain 100 F3 families in 2009. Other sets of F2 populations between drought tolerant lines Mouride, IT93K-503-1, IT97K-499-39, IT98D-1399, and Ein El Ghazal (Sudan) and elite African breeding lines KVx61-1 and KVx544-6-151 (both from Burkina Faso), Apagbaala and Marfo-Tuya (both from Ghana), UCR 779 (Botswana), and IT82E-18, IT95K-1479, IT97K-819-45 and IT98K-558-1 were planted at the Coachella Valley Agricultural Research Station (CVARS) in mid-August 2008 under drip-irrigation and subjected to terminal drought conditions by withholding water just prior to flowering until the end of the crop cycle. Single plant selections from these F2 were made based on visual performance under drought in November 2008. These selections were advanced in the greenhouse during winter-spring 2009, and the progenies were planted for the next round of selection and testing at CVARS in September 2009.Thus we are on track for later generation selections being distributed to each program (UCR, ISRA, and INERA) for drought tolerance phenotyping and for use in crossing to the improved lines developed under the backcrossing program summarized in Tables 3-5.

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 (Muchero et al., 2009). We have begun to implement MABC during the latter half of 2009 by collecting leaf tissues of backcross progenies with the goal of identifying individuals carrying a majority of molecular markers associated with the genetic background of the recurrent parent, with the addition of the trait markers from the donor parent. The trait-marker associations have been identified through QTL mapping efforts that combined AFLP and SNP marker data with extensive phenotyping data for drought tolerance (Muchero et al., 2008, 2009a.b), insect resistance (Muchero et al, 2009c) and continuing efforts for root-knot nematode, Macrophomina, Fusarium, and other disease resistance traits.

Table 3. California blackeye lines being improved by introgression of specific traits using backcrossing at UCR, indicating status following advancement in 2008 and 2009.

Recurrent Parent Line	Trait donor (non-recurrent) parent	Trait being introgressed	Current Generation (October 2009)
CB5	CB27	Fusarium wilt	BC2F6
CB46	UCR 03-11-747	Green grain	BC4F8
CB46	IT84S-2049	Root-knot nematodes	BC6F7
CB46	Montiero (Brazil)	Large grain size	BC3F8
CB46	Bambey 21(Senegal)	All-white grain	BC4F8
CB46	IT97K-556-6 & UCR 779	Aphid resistance	BC1F5
CB46	IT93K-2046	Lygus resistance	BC3F7

Objective 2. Strengthen cowpea seed production and delivery systems

In Burkina Faso: In order 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. The varieties were KVx 396-4-4, KVx 396-4-5-2D, KVx 414-22-2, KVx 421-2J, KVx 771-10, KVx 775-33-2, Gorom Local, Melakh, KVx 745-11P, and IT98K-205-8. At least100 kg of seeds of each entry were obtained. One hectare of Foundation Seed for each of four varieties (KVx 61-1, KVx 396-4-4, KVx 396-4-5-2D, KVx 745-11P) was produced at Saria and Pobe- Mengao. The objective was to complement the national Foundation Seed demand, estimated to be 35 metric tonnes in the current year for Burkina Faso. Foundation Seed of varieties KVx 414-22-2 (2 ha), IT98K-205-8 (0.5 ha) and Melakh (0.5 ha) were produced during the off-season in October 2008 and February 2009 under irrigation at three identified sites. 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. 40 leader-farmers have been trained to produce and conserve Certified Seed in the 2010 rainy season.

In Senegal: With additional support of EWA, 2 ha each of Melakh and Yacine 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. This network has several women seed producers as members. In the Thilmakha area, Foundation Seeds were distributed to two farmers and a women's group for production of 1 ha of Melakh and 1 ha of Yacine Certified Seeds during the 2009 season. These lead-farmers were part of the mini-kit on-farm testing network established under the previous Bean/Cowpea CRSP and they were familiar with the improved production practices promoted by ISRA. Certified Seed production was also conducted in collaboration with a farmers' union (UGPM) in Mekhe with 40 kg of Melakh and Yacine and in the Merina area on 1 ha each. In UGPM, the group is comprised of both women and men members while in Merina only women seed producers were included. Training of farmers during the 2009 season 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. The Producers Professional Training Center (CPFP) of Sangalkam (West of Thiès) has produced a second generation of Foundation Seed from the 2008 production in their facilities, while Certified Seed production was made by 10 farmer organizations from 2 villages.

Networking and Linking With Shareholders

The UC Riverside Dry Grain Pulses CRSP team works 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 University of Virginia, and Larry Murdock at Purdue Univ. The project also has close ties with the California Dry Bean Advisory Board and its Blackeye Council for setting research priorities that respond to industry needs. Dr. Ehlers represented the project team and made three presentations in a bean and cowpea breeders' workshop in Honduras in August 2009, coordinated by Dr. Jim Beaver, PI of the Pulse CRSP bean breeding project. Under the CGIAR-GCP funded project Tropical Legumes I, the University of California team of Ehlers and Roberts are leading the cowpea improvement Objective and interact with a large international network of tropical legumes researchers.

In Burkina Faso, Pulse CRSP scientists collaborate with AFRICARE, a NGO financed by USAID to ensure food security. The project aims to develop new Striga resistant varieties adapted to intercropping. In collaboration with LVIA, a NGO financed by the EU and Italy, farmers are trained in cowpea certified seed production and conservation. With the Association FERT, a French NGO whose aim is to improve cowpea production in the northern part of the country, the CRSP supported INERA cowpea scientists have initiated on-farm tests of improved varieties and are helping them to 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.

In Senegal, collaborations have been established with the extension programs of ANCAR in the Kaolack region and with the PADER project of EWA in the southern region of Sedhiou, for on-farm testing of the advanced breeding line ISRA-2065. EWA, ANCAR-Thiès and CPFP of Sangalkam were involved in seed production in the Louga, Mekhe and Merina regions. The Kirkhouse Trust provides support to the cowpea breeding program for marker assisted backcrossing for Striga resistance.

Leveraged Funds

The University of California Riverside cowpea breeding program team has been able to leverage over $1,375,000 in external research funding in part due to the assistance provided by the Dry Grain Pulses CRSP.

Accomplishments

Dr. Issa Drabo, INERA, Burkina Faso, was awarded on October 5, 2008 "Chevalier de l'Ordre des Palmes Academiques" for his outstanding work on cowpea in Burkina Faso by the Minister of Higher Education and Research on behalf of the Chief of State.

Dr. Ndiaga Cisse was promoted to Director of the ISRA/CNRA Bambey Research Station in 2009.

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

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Abstract of Research and Outreach Achievements

This project is focused on immediate, tangible, and cost-effective solutions to the largest biotic constraint on cowpea production in West Africa – pest insects in the field. Cowpeas crops in West Africa can be attacked by upwards of six major field pest insects. The project seeks to (1) develop and disseminate the most practical solutions for control of these pest insects, (2) build institutional infrastructure to sustain these strategies, as well as (3) to explore and enable cost-effective educational programs to increase the impact of these approaches in the target countries of Nigeria, Niger, Burkina Faso, Mali, and Benin. The project team has taken a leadership role in the development of a new paradigm for pest control, an integration of genomics tools for making integrated pest management decisions. This approach we have termed "Integrated Pest Management Omics" (IPM-Omics)(Pittendrigh *et al*. 2008; Gassmann *et al*., 2009). The necessary molecular tools to understand population dynamics and movement patterns of the legume pod borer (*Maruca vitrata*) in West Africa have been developed and are being applied to insect populations that we have been studying over the past 18 months using light trapping, scouting, and alternative host plant studies. The critical information gained from these efforts will enable effective determine of where best to release biological control agents in order substantially reduce *M. vitrata* populations. Additionally, we now have the working knowledge and skill sets to apply IPM-omics strategies to the other pests of cowpea for the next phase of the project. In order to optimize the impact of the project, a diversity of extension approaches for deployment of the educational component of cowpea pest control strategies are being explored and developed. Farmer field schools, in collaboration with other groups, *e.g*. Peace Corps, are being used to deploy technologies and train farmers in basic pest biology, in order to set the stage for the release and monitoring of bio-control agents of the pests of cowpeas. We have and are continuing to develop audio and video programs (with the videos being adapted for use on laptops and cell phones) that can be used by extension groups and even by the farmers themselves (*e.g.*, on cell phones). The long-term potential of these pest control and educational strategies to impact cowpea farmers is being investigated.

Project Justification and Objectives

Unquestionably, the greatest biotic constraints to cowpea (*Vigna unguiculata* [L.] Walp.) productivity in West African countries are insect pests. The major pests of cowpea in the field in West Africa include: the legume pod borer, *Maruca vitrata* Fabricius; the coreid pod sucking-bugs, *Clavigralla tomentosicollis* Stal and *Anoplocnemis curvipes* (F.); the groundnut aphid, *Aphis craccivora* Koch; and, thrips, *Megalurothrips sjostedti* Trybom and *Sericothrips occipitalis* Hood. There is a dire need for pest control strategies that can have the greatest positive impact on improving the livelihoods of those that produce and consume cowpeas.

When deciding which pest control approach can have the greatest impact for any given insect system(s), one must first ascertain the limitations and advantages of each of these options. In the long-term, pesticides are likely to become a less viable option for control of pests on cowpea. Increasingly, pesticides sold in West Africa are coming from China, where manufacturers skip steps in the production process, resulting in pesticides with potentially health damaging impurities and low levels of active ingredients. Host plant resistance traits will certainly help for the control of a few of the pest species of cowpea, and should be actively pursued, however, they need to be complimented by other strategies that directly reduce the pest populations. Transgenic Bt cowpea for the control of *M. vitrata* has been in development for almost two decades, however, significant technical and legal issues still need to be overcome 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; no such practical physical approaches exist for the field pests of cowpea. Thus, immediate, tangible, and cost-effective solutions are needed that can be placed in the hands of resource-poor farmers for the control of insects that attack cowpeas in the field.

The most pragmatic solution for the control of pests of cowpea is the use of biological control agents (*e.g.*, parasitoids). Host Country scientists and their institutions have had major successes with the use of biological control agents for pests of other crops (*e.g.*, cassava and millet). We now have numerous biological control agents against pests of cowpeas, ready for release in association with a recently funded Pulse CRSP Technology Dissemination project.

One of the challenges of releasing bio-control agents has been where best to release these organisms in order to have the greatest impact. The best place to release these agents is (i) where the insects are endemic and hence they can support the bio-control agent populations; and, (ii) in endemic populations that cause the most damage in the cowpea fields. Thus, there is a need to monitor the insect populations, as well as to 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 of study, which we have termed "Integrated Pest Management-omics" (IPM-omics) (Pittendrigh *et al.*, 2008; Gassmann *et al.*, 2009).

Objectives

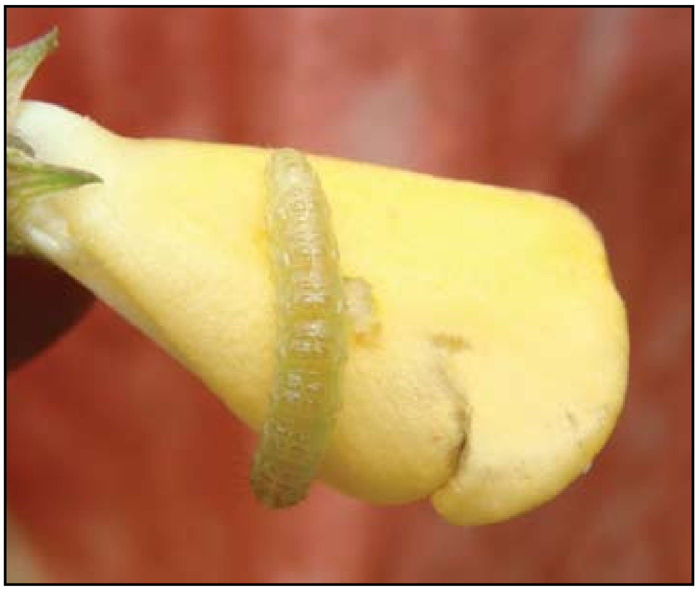
1. To combine surveys of pest populations with genomic analysis tools to determine where best to release bio-control agents for *M. vitrata* to maximize the control of this pest;

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

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 was conducted in 2008 and 2009 at the following locations: (i) Maradi in Niger; (ii) Zaria in Nigeria; and, (iii) Farako-ba, Kamboinsé, Fada N'Gourma and Dori in Burkina Faso. In Niger we also added a location at Kornaka and moved the light trap from Niamey to Gaya. In Nigeria, additional traps will be stationed at Kadawa and Minjbir. Adults were monitored and collected from the light traps on a daily basis. Adults were sent to UIUC through a courier service for microsatellite analysis. The microsatellite analysis was performed by Dr. Weilin Sun, in Dr. Pittendrigh's laboratory.



This activity has allowed us to (i) build institutional infrastructures to monitor *Maruca vitrata* using light traps, (ii) develop multiple standard and novel molecular approaches for studying *M. vitrata* population dynamics, (iii) use these genomics tools for insect management decisions for the next phase of our project, and (iv) 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 most cost-effectively deploy insect control strategies for this pest of cowpeas (*e.g.*, biological control agents). Data from initial experiments with light trapping and scouting have resulted in a recent publication (Ba *et al.* 2009) where we have tested our migratory hypothesis on the movement patterns of *M. vitrata*. Based on our light trapping and molecular data, we now have a better understanding of when and where biological control agents should be released in order optimize the impact of this approach.

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

(1) To date, development of microsatellites for studying Lepidopteran insects has proved challenging due to the nature of the genomes of the insects in this order (i.e., they have transposable elements that can interfere with some of the microsatellites in the insect population) [Van't Hof *et al.*, (2007) Heredity, 98:320-328]. The Pulse CRSP team is using 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 (*i.e.*, we can bioinformatically find microsatellites that do not have this transposable element interference problem). What it now means is that we have a series of microsatellites useful to understanding *M. vitrata* populations. We have and will continue to characterize *M. vitrata* populations from across West Africa using these microsatellites. This novel approach for microsatellite identification can now be used for other lepidopterous pests, including species that are important for U.S. crops such as corn. In fact, this work has come out of our collaborations with USDA scientists Drs. Brad Coates and Richard Hellmich. They will be using these 454 and bioinformatics approaches to study the population dynamics of European corn borer (*Ostrinia nubilalis*), a major pest of corn in the mid-West. This represents an important outcome of our project that will directly benefit U.S. agriculture.

(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 (b) to identify which genes vary locally and regionally (in West Africa) and across the planet. As a result we can now easily characterize *M. vitrata* populations from distinct locations in West Africa in order to determine their movement patterns. This represents, to our knowledge the first use of 454 sequencing technology to identify worldwide polymorphisms of a mitochondrial genome of an insect species. In practical terms, other researchers will now be able to use simple PCR tools to easily monitor *M. vitrata* populations in West Africa. Again, this will provide our collaborators at INERA, IAR, and ITTA with important information for molecular tools that can now be used at their institutions to further characterize *M. vitrata* populations.

(3) We have used 454 sequencing technology to determine single nucleotide polymorphisms (SNPs) across a great diversity

...we now have a better understanding of when and where biological control agents should be released...

(hundreds) of *M. vitrata* nuclear genes and 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. As a result, we now can easily characterize *M. vitrata* populations locally, regionally, or across continents. We have already 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. Again, this information will help us make informed decisions as where to best deploy bio-control agents for the control of *M. vitrata* populations that impact cultivated cowpeas.

(4) We have used the above molecular tools to (a) determine that *M. vitrata* is actually two separate species of insects (only one species is found in West Africa) and (b) we have been able to determine important information on the migratory patterns of this pest in West Africa (the molecular tools were coupled with our light trapping data). By understanding the migratory patterns, we now have a much clearer idea of where biological control agents need to be released in order to have the greatest impact on *M. vitrata* populations. Thus, by using genomics tools and pest monitoring we are well positioned in the next stage of this project to make well-informed decisions as where to release biological control agents in order to maximize the positive impacts for cowpea farmers in West Africa.

(5) Based on the above molecular strategies, we have also developed diagnostic PCR-based assays for other researchers to further test details of *M. vitrata* populations. These approaches will allow African host country institutions (which do not have the in-house capacity to sequence genotypes) with basic molecular biology equipment to easily characterize *M. vitrata* populations (*e.g.*, INERA, IAR, and IITA all have the equipment to take advantage of these new tools).

(6) Our increased insights into the movement patterns of *M. vitrata* have been important for the development of modeling strategies for minimizing resistance in the insect populations if or when the transgenic cowpea is released in West Africa. Although our current work for our CRSP project is not focused on the transgenic cowpea, the information gained from project will help other USAID funded projects focused on transgenic Bt cowpea. We (Drs. Onstad, Ba, Dabire, Tamò, and Pittendrigh) have developed a computational model, based on our datasets, which 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. Thus, we now have the capacity to extend these approaches to all of the pest insects of cowpea. Thus, we are now in a position to develop *IPM-Omics* strategies for all of the other pests of cowpeas.

Objective 2: This activity studied the presence and detailed life-history of the five major pests of cowpea (in the field and where necessary in the laboratory). This will be achieved through the use of randomized complete block design experiments using multiple lines of cowpea and alternative host plants. Planting for these experiments occurred in the summer of 2008 in Burkina Faso, Niger and Nigeria. Data collection was conducted into November/December of 2008. The data were tabulated, shared with the group, and analyzed. Another round of planting and data collection was conducted in the summer of 2009.

Insect Pests on Cultivated Cowpeas- Experiments have been were performed during the field growing seasons of 2008 and 2009. A minimum of three varieties of cowpeas (early, medium, and late flowering), along with wild alternative host plants for pests of cowpeas, were planted at each of the experimental locations (in Burkina Faso, Niger, and Nigeria). Data were recorded for all details relative to which pests attacked which plants and at what time interval. All aspects of the experiments were designed with the help of a statistician (Dr. William Muir, Purdue University). 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.

Even with two seasons of data, important trends have emerged that will be helpful for us in future insect control efforts. For example, in Niger, earlier flowering varieties did not sustain the same levels of insect attack than did the medium and late flowering varieties. In host plant resistance, this phenomenon is termed avoidance; the plants simply mature before the pest populations reach their peak numbers and thus the plants simply avoid the problematic time intervals of pest attack. Thus, at least in Niger (and similar eco-agricultural zones in Burkina Faso and Mali), earlier flowering varieties may be of great benefit to farmers as the varieties can literally "avoid" some of the pest problems. This approach has the potential to assist farmers to partially deal with their pest problems.

These experiments have also helped us determine in which regions certain pest insects are important for impacting cowpea crops, and thus, this information will be important for us to determine where to deploy certain biological control agents for given pest insects and which regions where there is little need for such control measures for specific insect pests.

Additionally, separate experiments were also performed to evaluate separate varieties of cowpeas that are tolerant to thrips and pod-sucking bugs. Our initial experiments (in the summer of 2009) showed positive results for these varieties (in terms of them being more tolerant to insect attack) and we expect to repeat these field experiments in the summer of 2010. Additionally, these varieties are being used in our farmer field schools, and other extension programs, for evaluations by farmers.

Large-scale collections of insects from these experiments have been made by the CRSP project team that can be used in our genomics experiments to better understand the movement of pest populations. Thus, the materials collected in this part of the project will be critical for development of genomics tools to understanding the nature of these pest populations and thereby make informed decisions on the best places and times to release biological control agents.

Objective 3: This activity focuses on scouting of pest insects of cowpeas as well as of alternative host plants of these pests both during the growing season and the off-season for cowpeas in West African. Although these efforts are not specifically focused on *Bt* cowpea, this work will lay the basis for the development of a refuge system for *Bt* cowpea, as well as potentially providing the basis for other IPM-based pest control strategies for both *Maruca* and other pest insects of cowpea.

Based on our findings biological control agents, useful in controlling M. vitrata, should be deployed in Southern Burkina Faso, and in the northern parts of the countries that are located at Burkina Faso's southern border...

Survey Wild Alternative host plants (in and off season) of M. vitrata- Scouting trips were completed in Niger, Nigeria, Benin, and Burkina Faso prior to and during 2008 and 2009. The results of these efforts have already provided an important basis for where biological control agents for *M. vitrata* need to be released in order to have the greatest potential impact on *M. vitrata* populations that impact cowpea crops in northern Nigeria, Niger, and Burkina Faso. For example, in Burkina Faso data show that *M. vitrata* is endemic in the southern most region of the country (which is further north of where it had previously been thought to have been endemic). Our scouting data (coupled with our molecular data) strongly suggests that *M. vitrata* moves almost directly north from these endemic areas during the growing season and impacts cowpea crops in the central areas of Burkina Faso. Based on our findings biological control agents, useful in controlling *M. vitrata*, should be deployed in Southern Burkina Faso, and in the northern parts of the countries that are located at Burkina Faso's southern boarder (*e.g.*, northern Benin, Ghana and Togo). Release of bio-control agents for *M. vitrata* in Niger will have to occur in northern Benin and in Nigeria. 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, the Pulse CRSP team is now in a position to determine where best to release these parasitoids in order to maximize their potential impact on *M. vitrata* populations.

Scouting will continue in 2010 in order to (1) obtain more *M. vitrata* samples for our molecular studies and (2) further pin-point where the endemic populations move from and to in the growing season.

The next logical step in this project would be to extend these combined scouting and molecular approaches to the other pests of cowpeas in order to best determine where the bio-control agents would be most effective in initially impacting the pest insect populations. Bio-control agents are currently in hand and ready for deployment for the control of flower thrips, pod sucking bugs, and aphids. Thus, these scouting and molecular studies would allow us to more effectively disseminate bio-control agents through the Pulse CRSP Technology Dissemination Project.

Farmer Field Schools- Farmer Field Schools (FFSs) have been held in Nigeria, Niger, Burkina Faso, and Mali in both 2008 and 2009. The FFS represent multi-month half-day a week training sessions with a minimum of 20 farmers per village (10 men and 10 women). These training sessions have been held in conjunction with local develop groups (*e.g.*, Peace Corps volunteers or extension agents). The overall learning objective of these FFS are to educate farmers about the pests of cowpeas, such that they can play an active role in assessing, disseminating, and releasing improved methods for pest control (and overall production) in cowpeas. Farmers are trained to identify the major pests of cowpea, and understand their basic biology and the impact on their crops. It is critical that farmers understand their pest problems in depth as part of the deployment of pest control strategies.

As part of the farmer field schools, the farmers directly set up test plots with different technologies for cowpea production, assess insect attack in detail along with the impact of other production technologies, and make decisions on the outcomes of these experiments. Thus, as part of the FFSs, farmer understanding of new technologies and how to assess those technologies is improved. Technologies deployed in the farm field schools involve: (1) insect/pest tolerant varieties of cowpeas (over five new varieties tested), (2) local biological/botanical sprays (3 technologies tested), (3) early, medium, and late flowering varieties, (4) a diversity of fertilizer strategies (manure and fertilizer combinations), (5) inter-cropping approaches, (6) appropriate practices for storage of cowpeas, (7) soil preparation and planting density testing, and (8) how to minimize the use of traditional pesticide sprays in areas where farmers typically spray their cowpea crops. In the summers of 2010-2012, the farmers will receive instruction on the release of biological control agents in the cowpea growing areas.

Data from these FFSs have also allowed us to identify (in an economically efficient manner) which pest problems are the greatest concern in various regions of each country. Cowpea farmers also gain the knowledge and skills to be able to identify early on in the field season which pest problems may be present, such that they can take logical measures to manage the pest populations. This latter point will ultimately help farmers who use pesticides to use IMP technologies in a more responsible and economically viable manner.

The long-term goal of this project is to release biological control agents (to control the pests of cowpeas) into those areas where we have held FFSs. The fact that the FFSs have monitored the pest populations in these areas will give us some base-line data as to the levels of the pest populations in these areas. When biological control agents are ultimately released into these areas, the FFSs will continue and play an important role in monitoring the pest populations and also the presence of the biological control agents. This way we will engage farmers to assist us in playing a role in determining if the biological control agents do have a practical (or at least perceived) impact on these crops. Thus, our farmer field schools (in 2008 and 2009) will allow us (1) to determine an estimate of the levels of pest populations before the release of the biological control agents and (2) when we release the bio-control agents in 2010. The following years we will work with these same farmer groups to determine the impact on these pest populations. In addition, tightly controlled experiments will be conducted by INERA and INRAN in order to measure these same variables (pest populations and the presence of biological control agents after their release) in order to obtain scientifically rigorous datasets on the impact of this biological control strategy on pest populations.

In order to increase impact of this project on a larger number of farmers, the following measures have been taken. First, as part of these FFSs, one-day sessions have been held where other farmers, production groups, and people from other villages are invited to attend and interact with the FFSs to see the impacts of the various pest control strategies (and other technological improvements) on cowpea production. Secondly, seed of improved cowpea varieties have been given out to other farmer

organizations to assess, multiple, and promote the use of these seeds in their regions. Third, we are currently producing printed and electronic media that can be used by future Peace Corps volunteers for deployment of technologies to assist in cowpea production. This then provides a framework for continued integration of new technologies relative to cowpea in their village-level programs.

As part of the FFSs we have also been focused on determining

It is critical that farmers understand their pest problems in depth as part of the deployment of pest control strategies.

the needs and roles of women in various aspects of cowpea production. Dr. Bello at UIUC has initiated a project with several host country collaborators to identify targeted issues that we need to address regarding gender roles and outcomes as it relates to women and FFSs. Dr. Bello received funding from UIUC to travel to Benin to interact with IITA staff to initiate this project and she is currently working with Sounkoura Adetonah at IITA, Dr. Anthony Youdeowei at FAO, and Tolulope Agunbiade (a female Nigerian graduate student) at UIUC on manuscript to summarize the critical "knowns" and "unknowns" of the gender differences. Dr. Bello is planning, based on availability of funding from internal UIUC sources, to initiate a survey of women in FFSs to begin to address some of the potential aspects of how to increase the impact of FFSs on women in some of the regions where the current CRSP project is active.

Dr. Pittendrigh is also collaborating with Dr. Madhu Viswanathan of UIUC on extension strategies (including assessment), especially as they relate to issues of low literate learners. Dr. Madhu Viswanathan is (1) an Associate Professor in the Department of Bus. Admin. (Marketing) at UIUC, (2) the director of the Coordinated Sciences Laboratory, and Women and Gender in Global Perspectives Program at the University of Illinois, and (3) an author on numerous books and publications on extension/education strategies for oral/low literate learners in developing nations. For his efforts of developing novel educational and assessment tools for low literate learners in developing nations, he was recently awarded the "Bharat Gaurav Award" by the India International Friendship Society (note other recipients of the award include the late Mother Teresa and a former Vice President of India). He is currently assisting in the development of assessment tools for extension materials to be tested in the field in 2010.

Training of Host Country Collaborators in the Rearing of Biological Control Agents of Pests of Cowpeas- With supplemental funding from the Pulses CRSP in FY09, cross-training of host country scientists was conducted with Dr. Tamò of IITA on the best practices for rearing and release of biological control agents for the insect pests of cowpea. This training has been instrumental to establish the initial information for the development of a biological control program for the pests of cowpeas. Dr. Tamò is continuing to develop in laboratory rearing processes, for both pests of cowpeas and bio-control agents, that can be easily adopted by the national programs and in case of viral control systems for Lepidopterous pests potentially even by farmers themselves. These training interactions between scientists have resulted in novel (and far more cost-effective) rearing strategies that will make the deployment of a bio-control agent program far more feasible on limited budgets.

Networking and Linkages With Shareholders

U***S Peace Corps***- This Pulse CRSP project through INRAN (Niger) has partnered with the Peace Corps, utilizing volunteers (i) to organize Farmer Field Schools (FFS), (ii) to provide an on the ground person to interact with the farmers on a regular basis in support of FFS activities, and (iii) to provide for literacy and scientific methodology training as part of the FFSs. The latter point has allowed us to impact villagers in regards to literacy issues and help them to develop life-long learning skills as it relates to assessing new technologies and ideas for improvement of their crops.

Government Organizations- National extension programs have partnered with INRAN and INERA in all aspects of organization, implementation, instruction and evaluation of Farmer Field Schools in Niger and Burkina Faso.

Moreover, Dr. Manuelle Tamo in cultivating strong collaborative relationships with national agricultural programs in Togo and Ghana in regards to release of biological control agents for insect pests of cowpeas.

Private Industry- A public-private sector partnership has been formed with Dow AgroSciences to conduct research to determine the impact of the "Green Chemistry" pesticide Spinosad on pests of cowpeas. The funding for this projected was provided directly to INERA (Dr. Dabire was the PI) and the work resulted in a publication. The findings of this work indicate that Spinosad may be effective in controlling storage pests of cowpeas.

Dr. Pittendrigh is has also established a partnership is with Monsanto Company to investigate issues regarding the deployment of transgenic Bt cowpea.

Leveraged Funds

Dr. Pittendrigh and his Co-Principal Investigators have successfully leveraged approximately $540,000 in external funding in FY 2009 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.

Accomplishments

Dr. Pittendrigh was appointed as the C.W. Kearns, C.L. Metcalf, and W.P. Flint Endowed Chair in Insect Toxicology at the University of Illinois at Urbana-Champaign.

Dr. Madhu Viswanathan, was awarded "Bharat Gaurav Award" by the India International Friendship Society for his development of extension programs for women and low literate learners in developing nations.

Publications

Ba, N.M., Margam V. M., Dabire-Binso, C. L., Sanon, A., McNeil, J., Murdock, L.L. and B.R. Pittendrigh. 2009. Seasonal and regional distribution of the cowpea pod borer, *Maruca vitrata* Fabricius (Lepidoptera: Crambidae), in Burkina Faso. International Journal of Tropical Insect Science. 29(3). 29:109-113.

Bello, J., M. Viswanathan, C. Dabiré, M. Ba, I. Baoua, M. Ishiyaku, M. Tamò, P. McClain and Barry Pittendrigh. Solar powered MP3 and hand held video players as training tools for oral learners in developing nations. Submitted to Journal of International Agricultural Education and Extension (accepted with minor revisions)

Margam, V.M. 2009. Molecular tools for characterization of the legume pod borer *Maruca vitrata* (Lepidoptera: Pyraloidea: Crambidae): mode of action of hermetic storage of cowpea grain. PhD Thesis, Purdue University. Co-major advisor: Barry Pittendrigh.

Gassmann, A.J., D. W. Onstad and B. R. Pittendrigh. 2009. Evolutionary Analysis of Herbivorous Insects in Natural and Agricultural Environments. Pest Management Science 65(11): 1174 – 1181.

Pittendrigh, B.R., L. Sun, P. Gaffney, and J. Huesing. 2008. "Negative Cross Resistance", in Insect Resistance Management. Ed. David Onstad. p. 108-124.

Sanon, A., Ba, N.M., Dabire-Binso C. L. and Pittendrigh, B. R. 2009. Effectiveness of Spinosad (Naturalytes) in controlling the cowpea storage pest, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). J. Econ. Entom. *In Press*.

Manuscripts In Progress

Baoua, I., Ba, M., Dabire, C., Tamò, M., Ishiyaku, M. Margam, V., and B.R. Pittendrigh. Infestations of insect pests on cultivated cowpeas in Niger, Burkina Faso, and Northern Nigeria. In preparation for the International Journal of Tropical Insect Science. [The manuscript will be completed pending our third field season of data in the summer of 2010].

Margam V. M., Coates, B., Ba, N.M., Dabire-Binso, Tamò, M., Pittendrigh B. R. and Murdock, L.L. 2009. Geographical variation revealed by molecular barcoding of the legume pod borer, *Maruca vitrata* (Lepidoptera: Pyraloidea: Crambidae). In preparation for Insect Molecular Biology. (from CRSP support). Expected to be submitted November 2009.

Margam V. M., Coates, B., Ba, N.M., Dabire-Binso, I. Baoua, Tamò, M. M. F. Ishiyaku, and Pittendrigh B. R. 2009. *Maruca vitrata* Fabricius (lepidoptera: pyraloidea: crambidae) mitochondrial genome. In preparation for Insect Molecular Biology. (from CRSP support). To be submitted December 2009.

Margam, V. M. I. Baoua, N. M. Ba, Ishiyaku, M. F., Huesing, J. E., Pittendrigh, B. R., and L. L. Murdock. Wild host plants of legume pod borer *Maruca vitrata* (lepidoptera: pyraloidea: crambidae) in southern Niger and northern Nigeria – implications for insect resistance management strategies. International Journal of Tropical Insect Science. To be submitted in November of 2009.

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

Principle Investigators

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Juan Carlos Rosas, Escuela Agricola Panamericana-Zamorano, Honduras

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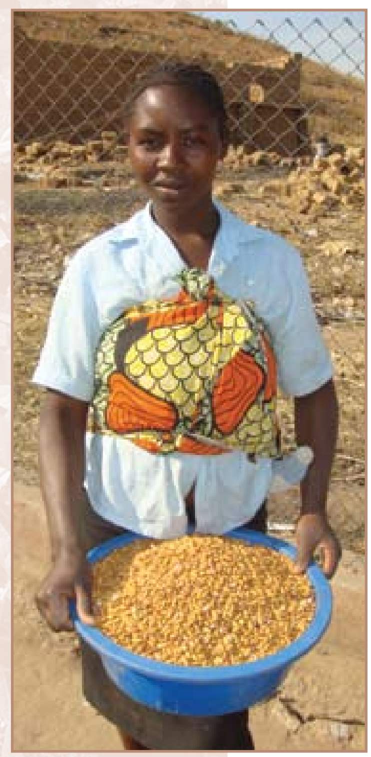
Antonio Chicapa Dovala, Instituto de Investigacao Agronomica (IIA), Angola

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



Abstract of Research and Outreach Achievements

Significant progress was made toward research and training objectives. Breeding lines were multiplied and tested in Angola, Haiti and Central America (CA). Small red and black bean regional performance trials were distributed to collaborators in CA and Haiti. Web blight and drought performance trials were distributed to collaborators. Andean bean breeding lines were sent to Rwanda for evaluation. The PASEBAF validation trial in Honduras included drought, low fertility tolerant lines developed with support from the Bean/Cowpea CRSP and Red SICTA. The Agrosalud trial included small red lines with greater mineral content (iron and zinc) that were developed in collaboration with CIAT and INTA/Nicaragua. At least one promising line currently under validation may be released during FY10 in Haiti and the CA countries that are currently participating in the project. The small red bean cultivars "CENTA Nahuat" and "CENTA CPC" were released in El Salvador. Both cultivars were developed with support from the Bean/Cowpea CRSP. Validation trials were conducted with support from the Dry Grain Pulse CRSP. Certified seed of small red cultivars developed by the project was produced and distributed by governmental bean seed and fertilizer dissemination programs in El Salvador, Honduras and Nicaragua. These seed programs have benefited more than 200,000 farmers in CA. A significant amount (12 MT) of seed of the black bean cultivars 'Aifi Wuriti' and 'Arroyo Loro Negro' were multiplied in Haiti during the past year. This seed was used to establish demonstration plots in the fields of 300 cooperating farmers, in the Vallée de Jacmel area in southeastern Haiti in cooperation with the NGO ACDIVOCA. The multiple disease resistant light red kidney bean cultivar 'Badillo' was developed and jointly released by the University of Puerto Rico and the USDA-ARS Tropical Agriculture Research Station. 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. In Puerto Rico, F3 lines derived from crosses between sources of tolerance to low N soils and sources of disease resistance were evaluated at two sites near Isabela, Puerto Rico. Recombinant inbred lines were selected for resistance and susceptibility to ashy stem blight in a replicated field trial that was inoculated with the pathogen. Phenotypic data will be used to identify molecular markers for resistance genes. Seed of landrace varieties of Lima beans were collected and evaluated in Puerto Rico and Honduras. A Haitian graduate completed requirements for a M.S. degree at the University of Puerto Rico. Two students from Angola initiated studies at the University of Puerto Rico for M.S. degrees in plant breeding. Workshops describing bean research techniques were conducted in Angola and Honduras.

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

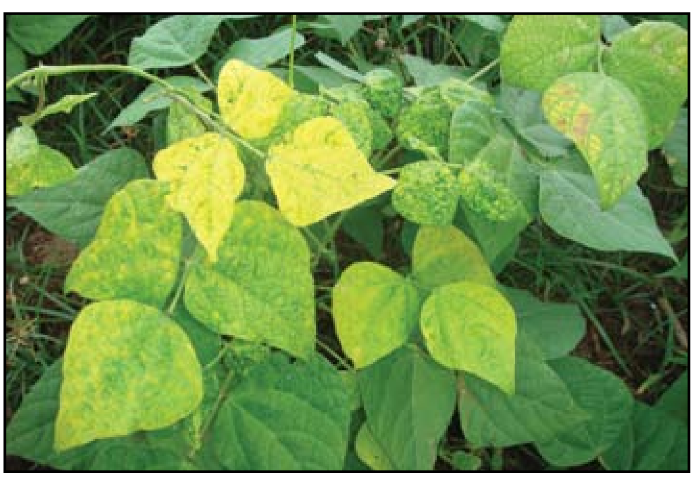
Objective 1. Develop, release and disseminate improved bean varieties

Development of breeding populations: Several different (> 50) 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 already available 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. Parents used in the crosses included promising breeding lines, improved cultivars and landraces, and sources of disease resistance and tolerance to abiotic factors from the bean breeding programs of the UPR, the USDA-ARS, Zamorano and CIAT. 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. Breeding lines from these populations will be tested in Honduras and Puerto Rico during the 2009 'postrera' growing season. Crosses were made in Honduras to improve small red landraces carrying the "Rojo de Seda" bean seed type for Central America and black bean cultivars for Guatemala and Haiti. A group of populations derived from crosses including local landrace cultivars were developed for testing and selection using participatory plant breeding (PPB) approaches in collaboration with farmers groups and researchers from El Salvador, Honduras and Nicaragua. 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 F2 and F3 generations based on agronomic characteristics and seed type (black, red mottled and yellow). Lines will be screened in later generations for disease and pest resistance and tolerance to low N soils. During the past year, seed of seven bean landraces were collected in Angola. These will be used as recurrent parents in backcrosses to incorporate genes for resistance to BCMV, BCMNV, anthracnose, rust and ALS.

Evaluation of breeding populations: More than 3,000 breeding lines developed with funding from the Bean/Cowpea and the Dry Grain Pulse CRSPs were tested and advanced in Honduras during the past year. Field evaluation included the following breeding materials: advanced lines with high nutritional value (high iron x elite small reds and black bean lines), lines from triple and double crosses of drought and angular leaf spot (ALS) resistant lines, lines from populations of the second cycle of recurrent selection for drought tolerance, lines from different populations (landrace x improved lines or cultivars) for PPB activities in Honduras, El Salvador, Nicaragua and Costa Rica, web blight resistant lines from the second cycle of recurrent selection, lines with resistance to ALS (Andean x Mesoamerican sources), lines resistant to rust (improved cultivar or line x multiple genes rust source), lines from several populations of improved cultivar x landrace, improved cultivar x ALS, improved cultivar x drought and high iron x ALS for El Salvador, Honduras and Nicaragua, inbred backcross lines (drought x improved cultivar), and several hundred lines developed by S. Beebe at CIAT (drought, BGYMV, high iron/zinc and seed quality).

Regional performance trials: During the past year, Zamorano distributed 12 small red and small black adaptation nurseries (VIDAC) and 24 yield and adaptation trials (ECAR) to five Central American countries and to Haiti. The majority of the advanced lines included in these regional nurseries were developed by Zamorano and UPR, and in collaborations with CIAT and national bean research (NBR) programs. Zamorano has been responsible since 1996 for the development and distribution of these nurseries and trials to members of the regional Bean Research Network.

Fourteen advanced lines trials including 76 web blight resistant lines and four checks (ERMUS), were distributed for regional testing to collaborators in Central America, Puerto Rico and Haiti. The entries in this trial included breeding lines from the cross 'Tio Canela 75 x VAX 6', lines from the second cycle of recurrent selection program, and breeding lines derived from an interspecific hybridization between a resistant accession of *P. coccineus* and *P. vulgaris*. Some of the lines also have resistance to common bacterial blight and BGYMV. The most promising lines will be considered for release as cultivars or breeding lines.



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. The 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 valuable parents in a breeding program for Angola. Preliminary results from trials planted in Huambo, Angola in October 2008 identified red mottled and small red bean breeding lines that were well adapted and expressed good yield potential and resistance to disease (Tables 1 and 2).

Table 1. Performance of red mottled lines planted in Huambo, Angola in October 2008.

Name	**Traits**	**Vigor**[1]	**Disease score at 45 days**[2]	**Disease score at 60 days**[2]	**Seed yield (kg/ha)**
PR0723-12	*bgm,bc3*	2.5	2.5	3.0	1777
PR9745-232	*bgm,I*	2.0	3.5	3.0	2237
PR0637-116	*bgm,I,bc3*	4.5	3.5	4.0	1546
PR0633-4	*bc3*	3.5	5.5	5.0	2237
PR0637-38	*bgm,bc3*	5.5	4.0	4.5	1777
PR0737-5	*bgm,bc3*	5.5	2.5	2.5	1579
PR0737-6	*bgm,bc3*	6.0	3.5	3.5	1711
Salagnac 90A	*Low soil fert.*	3.0	5.0	6.0	1777
PC-50		5.5	5.5	8.0	395
JB-178		2.5	3.0	3.5	1448
Mean		4.5	4.3	5.1	1284

[1] Based on a scale from 1-9 where 1 = excellent and 9 = very poor.
[2] Based on a scale from 1-9 where 1 = no symptoms and 9 = very severe symptoms.

On-farm validation of promising breeding lines: Two on-farm validation trials are being 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 includes drought, low fertility tolerant lines developed with support from the Bean/Cowpea CRSP and the Red SICTA. The Agrosalud (COVAMIN) trial includes small red lines with greater mineral content (iron and zinc) developed in collaboration with CIAT and INTA/Nicaragua. It is expected that during FY10, at least one line from each trial will be released as a cultivar in Honduras and Nicaragua. The PASEBAF trial was supported by IICA/COSUDE. The Agrosalud trial will continue to be supported by CIAT/CIDA for an additional year. The same trials have been distributed for on-farm validation in El Salvador and Costa Rica.

Ten of the most promising small red bean cultivars and lines for Central America, developed under the Bean/Cowpea CRSP, were sent to our HC collaborator in Guatemala (J.C. Villatoro), for testing in the most important lowland regions for bean production, such as Petén and Jutiapa. Small red bean production for export has increased in this region and cultivars with higher yield potential and greater disease resistance are needed in Guatemala.

Table 2. Performance of small red lines planted in Huambo, Angola in Oct. 2008.

Name	Traits	Vigor[1]	Disease score at 45 days[2]	Disease score at 60 days[2]	Seed yield (kg/ha)
Tio Canela 75	BGYMV, BCMV, adaptation	4.0	2.5	2.5	2764
DEORHO	BGYMV, BCMV, yield	4.0	2.5	3.5	2698
Cardenal	BGYMV, BCMV,	3.5	2.5	2.5	2698
IBC 301-204	BGYMV, BCMV, low fertility, drought	5.0	3.0	3.5	3619
IBC 302-29	BGYMV, BCMV	4.5	2.5	3.0	2500
Carrizalito	BGYMV, BCMV, highlands	4.0	4.0	2.5	1777
CENTA Pipil	BGYMV, BCMV, heat tol.	5.0	3.0	3.0	2106
Amadeus 77	BGYMV, BCMV, adaptation	4.0	3.5	2.5	1908
Mean		4.8	3.3	3.6	2020

The performance of small red lines were validated in Honduras, Nicaragua and El Salvador by farmer groups involved in PPB activities. In Honduras, the cultivars 'La Majada AF', 'Briyo AM' and 'Milagrito' were released by CIALs of the Yojoa Lake region. These locally released cultivars are mainly adopted by farmers groups from the participating communities. However, some of these PPB cultivars have been adopted in other regions, mainly when an adequate seed production and distribution mechanism is implemented by the farmer groups. A total of 11 PPB cultivars have been released in Honduras since 2003; these cultivars are being used as the main cultivar for at least 5,000 farmers resulting on increases in production, food security and income generation for these families and their communities.

During FY08, a set of 15 small red lines of the 'Rojo de Seda' market class was provided to the agricultural division of the Lafise Bank for field and consumer validation trials in Nicaragua. The bank has expressed interest on producing certified seed of at least one of the selected lines. The seed production company Agrovessa from Guatemala was involved in exporting seed of 'ICTA Ligero' to Haiti to address a FAO seed distribution request in that country after initial contact our project made with Abelardo Viana from the IICA office in Guatemala. Agrovessa is interested in producing seed of the bean variety 'Aifi Wuriti' for export to Haiti. The seed company Semillas del Trópico from Guatemala is testing advanced bean breeding lines and cultivars from the project, and is interested in producing and exporting seed of small red and black bean cultivars in the near future. The contacts in these two seed companies are Zamorano graduates. These companies would be good partners in producing seed for small farmers for government or private initiatives to be implemented in Guatemala, after the recent drought-related famine in some regions of this country. We plan to involve these companies in the Dry Grain Pulse CRSP seed production project recently approved for Guatemala and Haiti.

Release of cultivars and seed multiplication: The small red bean cultivars "CENTA Nahuat" and "CENTA CPC" were released in El Salvador on August 2008. Both cultivars were developed with support from the Bean/Cowpea CRSP Project, but a portion of the seed increase, validation trials and release process were conducted with support from the Dry Grain Pulse CRSP. Seed multiplication of these new varieties is being supported by the project in order to increase availability of the seed and enhance adoption by farmers. Foundation seed of these two cultivars has been provided to our collaborators from CENTA.

In Nicaragua, the small red line SRC2-18-1 is currently under on-farm validation and is expected to be released as the cultivar 'INTA Matagalpa' during FY10. There has been similar progress with the black seeded line MHN 322-9 which is being validated in Guatemala and considered for release as the cultivar 'ICTAZAM'. In Costa Rica, the white seeded line MEB 2232-29 is expected to be released this year. In El Salvador, the small red line MER 2226-41 is considering for release during FY10.

As in previous years, certified seed of small red cultivars developed by the project was produced and distributed by governmental bean seed and fertilizer distribution programs in El Salvador, Honduras and Nicaragua. During the past year, these programs have benefited more than 180,000 farmers in Central America.

The University of Puerto Rico has developed red mottled bean lines that combine resistance to Bean Golden Mosaic Yellow Virus, Bean Common Mosaic Virus, Bean Common Mosaic Necrotic Virus and common bacterial blight. Seed of these lines was increased in Puerto Rico during the past year. Another seed increase will be conducted in Puerto Rico during the upcoming year so that on-farm trials can be conducted in Haiti during 2010.

The small red bean cultivars "CENTA Nahuat" and "CENTA CPC" were released in El Salvador on August 2008.

The University of Puerto Rico, the University of Nebraska, the USDA-ARS Tropical Agriculture Research Station and IDIAF have developed tropically-adapted pinto bean lines that have resistance to Bean Golden Yellow Mosaic Virus, Bean Common Mosaic Virus, Bean Common Mosaic Necrotic Virus and rust. This breeding line may be of potential benefit to countries such as Haiti and Angola where pinto beans are consumed. In Haiti, the pinto bean breeding lines PT-38 and PT-47 were resistant to virus and rust and yield well in a low fertility soil. Susceptibility to powdery mildew is the most serious weakness of the pinto breeding lines.

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 reduce damage caused by common bacterial blight and increase the yield of marketable beans in Puerto Rico and other Caribbean countries that produce light red kidney beans.

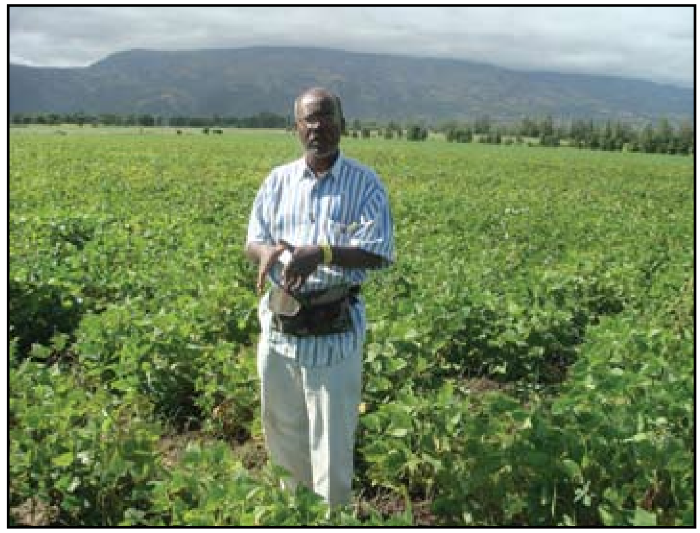
A significant amount (12 MT) of the black bean cultivars 'Aifi Wuriti' and 'Arroyo Loro Negro' were multiplied in Haiti during the past year. This seed was used to establish demonstration plots in the fields of 300 cooperating farmers, in the Vallée de Jacmel area in South Eastern Haiti in cooperation with the NGO ACDIVOCA. It was expected that 10 tons of seeds would be bought back from some selected farmers. At the end, only five tons of seeds were collected from the participating farmers, because neighboring farmers, in recognition of the superior performance of these cultivars, were buying the seeds directly.

The genotypes with higher nodulation have almost twice nodule DW and 50% greater plant DW, than those with lower nodulation.

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

Greenhouse trials were conducted in Honduras to identify lines with better performance under low N conditions, by expressing greater nodulation and BNF along with other mechanisms which allow beans to have greater accumulation of dry matter and seed yield under low N. The trials were conducted using soil: sand substrates that have low organic matter and N content, conditions which normally produces symptoms of N deficiency and low yield in bean genotypes with poor BNF ability. A preliminary trial including 180 bean accessions from the working collection of Zamorano breeding program inoculated with a mixture of two Rhizobium strains, CR 477 (R. etli) y CIAT 899 (R. tropici). The plants were grown in a soil: sand (1:1) substrate low in organic matter (1.24%) and N (0.06%). Significant variation for nodulation using a 1 to 9 scale (1= none or very few, small nodule; 9= maximum number of large nodules), root, shoot and total dry weight (DW), and root/shoot ratio were observed between genotypes. The cultivars and lines with higher nodulation scores also had greater root, shoot and total DW and the lowest shoot/root ratio.

The 35 accessions with the highest nodulation scores and total plant DW, and five accessions with poor performance from the previous trial, were included in a second trial, to test their performance under Rhizobium inoculation (strains CIAT 899 and CR 477) and treatments of added (70 ppm of N) or no



added nitrogen. The soil: sand (1:3) substrate was quite low in organic matter (0.86%) and N (0.04%). Significant differences were observed in nodulation, root, shoot and total DW among treatments and genotypes, but not for the T x G interaction. Greater nodulation were observed in the inoculation treatment than the treatments with or without added N. Larger root, shoot and total plant DW were found in the added N treatment. Although T X G interaction was not significant, there were some genotypes that had better nodulation using the Rhizobium strain CIAT 899 and other accessions that had better nodulation with the CR 477 strain. These results suggest that strain x genotype interaction should be taken into consideration when evaluating bean lines in a low N soil.

Twenty five accessions with the higher nodulation and total plant DW from the first trial were inoculated with a mixture of Rhizobium strains (CIAT 899 and CR 477) and grown in a soil: sand (1:2) substrate low in organic matter (1.41%) and N (0.07%). The best nodulation was observed in the Rhizobium inoculated treatment without N; and the greatest root, shoot and total plant DW were observed in the added N treatments, and both were superior to the without inoculation and no added N treatment. Significant differences were observed between genotypes for all variables; nodule DW ranged from 225 to 477 mg/pl and total plant DW from 3.2 to 5.4 g/pl. The genotypes with higher nodulation have almost twice nodule DW and 50% greater plant DW, than those with lower nodulation.

Field trials were conducted during FY09 with the selected genotypes from the previous greenhouse experiments. A trial including 16 genotypes and four checks ('Cardenal', BAT 477, 'Amadeus 77' and 'Rojo de Seda') was carried out during the dry season using sprinkler irrigation; drought stress was imposed at four weeks after planting (total irrigation of 100 mm). The same trial was conducted during the primera season under normal rainfall but using fertilized and non-fertilized plots. Genotypes with superior performance under drought and low soil fertility (mainly N and P) will be identified from these greenhouse and field trials conducted the past year.

Thirty-four elite bean breeding lines were evaluated in a low N soil at Isabela Puerto Rico over a two-year period (Tables 1 and 2). PR0443-151, a black bean, had the best overall performance. The seed yield of this line was ranked no lower than 3rd in both + N and – N treatments. VAX 3, a common bacterial blight resistant small red bean germplasm, produced seed yields similar to PR0443-151 in the – N treatment. These lines also had the greatest efficiency of N use (kg of seed yield in the – N plots / kg of N in the soil). PR0443-151 also had the greatest agronomic efficiency (kg of seed yield / kg of N applied) and the greatest amount of N accumulated in the seed. These trials were part of the M.S. thesis research of Ronald Dorcinvil.

PR0443-151, VAX 3 and other promising breeding lines were crossed with elite breeding lines having disease resistance (BGYMV, BCMV, BCMNV and web blight). During the past year, individual plants were selected from an F2 nursery based on agronomic characteristics and commercial seed type. In June 2008, approximately 500 F3 lines from 12 different populations were evaluated at two sites. One site was a low N soil at the Isabela Substation that received at planting only 20 kg/ha of N that in the form of a granular fertilizer. The other field at the USDA-ARS research farm at Isabela was not fertilized and is often used to screen beans for root rot resistance. A few of the populations had much better overall performance. The F4 lines will be screened in the greenhouse for reaction to BCMNV and in the laboratory for the molecular marker associated with a gene for resistance to BGYMV. During the upcoming year, the most promising F3:4 lines will be evaluated in replicated field trials in Puerto Rico.

Superior bean breeding lines selected from the field studies conducted in low N soils at Isabela, Puerto Rico, and from the greenhouse and field studies at Zamorano, will be used to initiate the first hybridization cycle of a recurrent selection program to develop cultivars with greater yield potential in low N soils.

More progress has been made in developing small-seeded Middle American bean lines that are adapted to low N soils. During the upcoming year, we plan to evaluate Andean bean landraces from Haiti, Dominican and Puerto Rico for adaptation to low N soils. Traditionally, these landraces have been planted with few or no external inputs. Most of these landraces have an indeterminate (type III) growth habit that may confer some advantages when produced in low fertility soils.

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, 'ICA Pijao', 'Sanilac', 'Pinto Villa', 'Rio Tibagi', DOR 364, 'Morales', 'Tapatio', and eight resistant genotypes, A 300, Tacana, SEA 5, TLP 19, BAT 477, Tio Canela 75, G 5059, and XAN 176, were tested. RAPD B386900 (coupling) was not amplified in BAT 477 nor in other resistant genotypes, while B4591600 (repulsion) was not amplified in any susceptible genotypes. Bands of other sizes were amplified with each RAPD marker but were not associated with resistance. The PCR cocktail and PCR amplification conditions were then modified in order to optimize amplification and to reproduce the reported bands, but they were not reproducible. Consultation with another group working with Macrophomina phaseolina in common bean confirmed that B386900 and B4591600 do not have utility for charcoal rot (Mayek, pers. comm.).

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, which are expected to segregate for resistance and susceptibility to ashy stem blight, were obtained from CIAT by Dr. Tim Porch. In September 2008 and 2009, 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 using bulk segregant analysis (BSA).

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

Field experiments were planted at the Isabela Substation in September 2008 to compare the performance of 16 lima bean landrace varieties from Puerto Rico and one landrace from Haiti. Phenological and agronomic traits and pest and disease problems were noted for each line by graduate student Luis Ruiz as part of a special topic course. A few of the landraces produced seed throughout most of the dry season. This would represent an important source of protein during a period when there are often shortages of beans.

Dr. Rosas planted the Lima bean landraces in Honduras in June, 2009. A few of the landraces were insensitive to photoperiod suggesting that Lima beans could be produced throughout the year in Central America and the Caribbean. The project is collaborating with Ms. Emmalea Ernst, at the University of Delaware in the evaluation of the HCN levels in the seed and leaves of the Lima bean plants. Seed of many of the landraces HCN levels > 100 ppm which are unsafe levels if the Lima beans are cooked improperly. The results from the Lima bean research will be presented at the 2009 meeting of the Bean Improvement Cooperative.

The most promising Lima bean line will be considered for release in Puerto Rico. Dr. Molly Welsh, curator of the USDA bean germplasm collection in Prosser, Washington, visited the Lima bean plots in February, 2009. Once sufficient seed has been produced, the varieties will be sent to the USDA and CIAT bean germplasm collections.

Photoperiod sensitive cowpea lines from the University of California, Riverside (PI-UCR-1 project) were evaluated at Isabela, Puerto Rico (18º N latitude). A trial was planted at the Isabela Substation in January 2008 to increase seed and to conduct a preliminary evaluation for adaptation. All of the cowpea lines from the University of California, Riverside flowered within 45 days and produced seed. Another trial was planted at the Isabela Substation in June 2008 to observe the performance of the cowpea lines during longer days. The cowpea lines tended to flower later and produce more biomass during the summer months. In fact, there was so much vegetative growth that the plants tended to grow together when planted at a 0.76 m row width. Another trial was planted at the Isabela Substation in February 2009. The plants were harvested at approximately 60 days after planting to measure biomass production. The line UCR 2532 produced 8 T/ha of biomass whereas the UCR 739 had the best combination of dry matter yield (7.9 T/ha) and % protein (18.7%). These results suggest that these cowpea lines have potential either as a forage or as a cover crop.

Zamorano recently received a collection of 19 cowpea lines from Jeff Ehlers, UC-Riverside that will be tested during FY10. With the permission of Dr. Ehlers, a portion of seed of each of these cowpea lines was provided to Gasner Demosthene from Haiti during the Bean Breeding Workshop held at Zamorano last August.

Networking With Stakeholders

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

Fifty small red and black bean cultivars and promising lines were sent from Zamorano to Julie G. Lauren, Cornell University (PI-CU-1), for testing in Kenya. In addition, 33 bean lines and germplasm accessions with resistance to ALS were sent to Dr. Paul Gets, UC-Davis, for testing in East Africa. Twenty small red and black lines and cultivars were sent to Dr. Robert Shank, Ministry of Agriculture, for testing in Belize. The bean rust differentials nurseries and the ERMUS trial were provided to Angel Murillo, INIAP, Ecuador, and the anthracnose and rust differentials nurseries to Julio Cesar Villatoro, ICTA, Guatemala, during the Bean Breeding Workshop held at Zamorano, August 10-14, 2009,

Interspecific (*P. vulgaris* x *P. coccineus*) lines, originally developed in Puerto Rico for web blight resistance, were screened at the University of Idaho for white mold resistance. Three lines were identified that had high levels of resistance to white mold. (Singh et al. 2009). Scarlet runner bean germplasm accessions G 35006 and G 35172 possess resistance to multiple diseases of common bean. Ann. Rep. of the Bean Improv. Coop. 52:22-23).

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 in the Dominican Republic the most promising lines from our breeding program. This collaboration should result in the release of disease resistant black and red mottled bean cultivars.

BGYMV has become an important production constraint for snap bean producers in Costa Rica. The UPR bean breeding program provided Ing. Juan Carlos Hernández, Ministry of Agriculture bean researcher in Costa Rica with seed of snap bean breeding lines that should combine resistance to BGYMV and BCMV. The performance of these lines is currently being tested in the field in Costa Rica.

The UPR bean breeding program provided Ing. Emigdio Rodríguez, IDIAP bean researcher, with seed of white bean breeding lines. The most promising white bean lines produced seed yields (> 2,000 kg/ha) that were significantly greater and web blight scores that were significantly lower that the local white bean check variety.

The UPR and Zamorano bean breeding programs provided Dr. Doug Maxwell with seed of black bean breeding lines that combine resistance to BGYMV, BCMNV and BCMV. These lines were tested on small-scale farms in Guatemala and Aifi Wuriti was the principal cultivar selected by farmers of the southeastern region, recently affected by the severe drought observed on their farms. A seed increase will be conducted to permit distribution of this well-adapted cultivar to farmers stricken by the drought.

Leveraged Funds

Scientists involved in this project have effectively used Dry Grain Pulses CRSP support and institutional linkages to leverage >$250,000 in external funding in 2009 to achieve objectives related to those of this project.

Accomplishments

The President of El Salvador, Elías Antonio Saca, participated in an official ceremony where seed (10 kg sacks) of small red bean varieties CENTA Pipil, CENTA San Andrés and INTA Rojo were distributed to farmers. The program has distributed approximately 30,000 hwt of seed to 120,000 farmers in El Salvador. The contribution of the Bean/Cowpea CRSP was recognized at the ceremony.

Publications

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Singh, S.P., H. Terán and J.S. Beaver. 2009. Scarlet runner bean germplasm accessions G 35006 and G 35172 possess resistance to multiple diseases of common bean. Ann. Rep. of the Bean Improv. Coop. 52:22-23.

Dorcinvil, R., A. Ramírez, D. Sotomayor and J.S. Beaver. 2009. Performance of dry bean lines in a low N soil in Puerto Rico. Ann Rep. of the Bean Improv. Coop. 52:124-125.

Rosas J.C., M.S. Guachambala and R. Ramos. 2009. Guía ilustrada para la caracterización de variedades de frijol común (*Phaseolus vulgaris* L.). Zamorano, Honduras, 22 p.

Acevedo M., J.R. Steadman and J.C. Rosas. 2009. Virulence diversity of *Uromyces appendiculatus* and screening for resistance to common bean rust in wild and domesticated *Phaseolus* species in Honduras. Phytopathology (submitted).

Rosas J.C., R. Araya and I. Ortega. 2009. Variedades de frijol rojo obtenidas por fitomejoramiento participativo en Honduras y Nicaragua. Est. Exp. Fabio Baudrit Moreno, Costa Rica, 40 p.

Institutional Capacity Building and Human Resource Development FY 2009 Summary Report

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 equipments. The status of activities planned and undertaken under these three categories of capacity building activities is included under the progress report of each project. Here we provide a summary of these activities for the whole 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 the Pulse CRSP work because of their understanding and insights 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 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 and support average of two to three degree training activities.

Annex 1 provides data on all the degree trainees financially supported by the Dry Grain Pulses CRSP as of September 30, 2009. A total of 22 students were either fully or partially supported in graduate degree programs in FY2009. Unfortunately seven degree training activities were either delayed or discontinued. (Annex 1). 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 9 graduate students at U.S. universities in 2009 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, and the purchase of text books and computers.

Table 1: Summary of Degree Training as of September 30, 2009.

	No. of trainees
Training Status	
Active:	22
Delayed/Pending:	3
Discontinued/cancelled:	4
Profile of "Active" trainees (22)	
Gender	
Male	11
Female	11
Region of Origin	
East Africa	14
Southern Africa	4
West Africa	1
Latin America/Caribbean	1
United States	2
Degree program	
M.S.	18
Ph.D.	4
Training Location	
U.S.	6
Host countries	14
Third countries	2

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, and short-term individualized training at CRSP participating institutions. Training activities last only a few days training programs (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 2009, an estimated 1,069 individuals benefitted from short term training through the Dry Grain Pulses CRSP. Of these short term trainees, over 48% were female. The list below presents a listing of some of the short-term training activities completed in FY 09. 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 nort 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.

List of Examples of Short-term Training Activities Supported by the Pulse CRSP, FY 2009.

Type of Training: Technical
Description of Training: Visit to INIAP breeding program to learn the management of such a program in a resource limiting environment.
Location: Quito, Ecuador
Beneficiaries: Luis Butare from ISAR, Rwanda
Number of Participants: 1

Type of Training: In-service training
Description of training: Provision of skills to the trainees on using value chain concepts to evaluate bean and cowpea supply and demand systems nationally and regionally
Location: Universidade de Antonio Neto, Huambo, Angola
Beneficiaries: A total of 40 participants attended the Value Chain training, from both the University (UAN) and from the Agricultural Research Institute (IIMA).
Number of Participants: 40 (Male- 32; Female-8)

Type of Training: In-service Training
Description of training: Provision of skills to the trainees on data entry and processing and econometric analysis of bean and cowpea production and marketing data
Location: UAN, Huambo, Angola
Beneficiaries: Research staff at university
Number of Participants: 10
Type of Training: In-service Training
Description of training: Provision of skills to the trainees on using value chain concepts to evaluate bean and cowpea supply and demand systems nationally and regionally
Location: IIAM, Maputo, Mozambique
Beneficiaries: Staff of IIAM.
Number of Participants: 55 (35 males and 20 females)

Type of Training: Organic Farming Workshop
Description of training activity: The workshop reviewed principles of organic agriculture, including soil fertility and plant nutrition, and management of pests and diseases.
Location: Zamorano, Honduras
Beneficiaries: Staff at the Escuela Agricola Panamericana-Zamorano
Number of Participants: 16

Type of Training: Dr. Ba (INERA) spent several months working in Dr. Pittendrigh's laboratory (UIUC)
Description of training activity: Training of a host country scientist (Burkina Faso) in (i) molecular biology tools (for IPM-omics strategies), (ii) computational modeling for IRM modeling, and (iii) extension materials development for deployment strategies.
Location: University of Illinois at Urbana Champaign
Beneficiaries: INERA and the overall network of African researchers. It is expected that the skills Dr. Ba will develop will be useful for the development of extension materials that will benefit a large number of cowpea producers (>10,000) over the long term.
Number of Participants: 1

Type of Training: Bio-control agent rearing and release
Description of training: Drs. Tamò, Ba, Dabire, and Baoua provided training on advancements in the rearing and release of biological control agents for the control of pests of cowpeas
Location: Benin, Burkina Faso, and Niger
Beneficiaries: Research staff of IITA, INERA, and INRAN. This training will allow all three institutions the capacity to better develop and deploy biological control programs for pests of cowpeas.
Number of Participants: 16
Type of Training: Training of Technicians at INRAN, Niger
Description of training: Technicians were trained in various aspects of the biology and biological control of pests of cowpea.
Location: Maradi, Niger
Beneficiaries: Technical staff of INRAN.
Number of Participants: 6 (3 male and 3 female)

Type of training: Bean breeding workshop for Central American and Caribbean bean researchers.
Description of training activity: The five day workshop discussed recent advances in bean and cowpea breeding and reviewed standard techniques used to screen beans for resistance to biotic and abiotic stresses. The network for the testing and validation of bean lines were discussed. The presentations were in Spanish, recorded on CDs and distributed to participants of the workshop.
Location: Zamorano, Honduras
Beneficiaries: Plant breeders from the public bean breeding programs in Central America
Number of Participants: 20

Type of training: Informal training of bean research personnel in Angola
Description of training activity: A one week short course on methods used to screen bean lines for resistance to biotic and abiotic constraints. Taught in Portugues by Drs. Beaver, Porch and Estevez from the University of Puerto Rico.'
Location: Huambo, Angola
Beneficiaries: IIA pulse crop researchers and staff
Number of Participants: 15 people

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 budget and competitively awarded 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 (e.g., IEHA, etc.) which are projected as potential future collaborators.

In FY 2009, the Management Office in consultation with the Technical Management Advisory Committee approved the award of 13 supplemental activities totaling $176,465.50 that were considered to contribute to build capacity of host country institutions. See Annex 2.

Annex 1: Status of degree training planned and executed in FY 2009

#	Project	Given name	Last name	Country of citizenship	Gender	Training institute	Degree	Discipline	Training status as of 10/1/08	Start date	Anticipated completion date	Type of CRSP support
1	PI-CU-1	Crispus Mugambi	Njeru	Kenya	M	Moi University	M.S.	Soil Science	Active	02/08	02/10	Full
2	PI-CU-1	Belinda Akinyi	Weya	Kenya	F	Egerton University	M.S.	Soil Science	Active	08/08	08/10	Full
3	PI-CU-1	Jane Francisca	Lusweti	Kenya	F	University of Nairobi	M.S.	Plant Protection	Active	10/07	10/09	Partial
4	PI-ISU-1	Cyrille	Syanobe	Rwanda	M	Makerere University	M.S.	Technology	Active	08/08	08/10	Partial
5	PI-ISU-1	Gerald	Sebuwufu	Uganda	M	Iowa State University	Ph.D.	Agronomy	Active	08/08	05/12	Partial
6	PI-ISU-1	Geoffrey Arijole	Nyakuni	Uganda	M	Iowa State University	Ph.D.	Food Science & Human Nutrition	Canceled			
7	PI-ISU-1	Aisha Nakitto	Musaazi	Uganda	F	Makerere University	M.S.	Food Science & Technology	Active	08/08	06/09	Partial
8	PI-ISU-1	Simon	Okiror	Uganda	M	Makerere University	M.S.	Agricultural Economics/ Agribusiness	Active	08/08	06/09	Partial
9	PI-MSU-1	Gerardine	Mukeshimana	Rwanda	F	Michigan State University	Ph.D.	Plant Breeding and Genetics	Active	08/08	08/11	Full
10	PI-MSU-1	TBD	TBD	Rwanda		Michigan State University	Ph.D.	Participatory plant breeding and agroecology	Delayed			
11	PI-MSU-2	Maria da Luz	Quinhentos	Mozambique	F	Michigan State University	M.S.	Agricultural Economics	Canceled			
12	PI-MSU-2	Ana Lidia	Gungulo	Mozambique	F	University of Pretoria, South Africa	M.S.	Agricultural Economics	Delayed			
13	PI-MSU-2	Estaveo	Chaves	Angola	M	University Federal Vicosa, Brazil	M.S.	Agricultural Economics	Delayed			
14	PI-PSU-1	IIAM Scientist 1	TBD	Mozambique		Penn State	M.S.	Agronomy	Delayed			
15	PI-PSU-1	IIAM Scientist 2	TBD	Mozambique		Penn State	M.S.	Plant Nutrition	Delayed			
16	PI-UPR-1	Ronald	Dorcinvil	Haiti	M	University of Puerto Rico	M.S.	Soil Sciences	Active	08/06	05/09	Partial
17	PI-UPR-1	Monica	Mbui	Angola	F	University of Puerto Rico	M.S.	Plant breeding	Delayed			
18	PI-UCR-1	Manuel	Costa	Angola	M	University of Puerto Rico	M.S.	Plant Breeding/Genetics/ Plant Pathology	Canceled			
19	PI-UCR-1	TBD	TBD	African		University of Ghana, Legon and UCR	Ph.D.	Plant Breeding/Genetics/ Plant Pathology	Delayed			
20	PI-UCR-1	Antonio	David	Angola	M	UPR	M.S.	Plant Breeding	Delayed			
21	PI-UIUC-1	Traore	Fousseni	Burkina Faso	M	University of Ouagadougou	M.S.	Entomology	Active	09/08	08/10	Full
22	PI-ISU-1	Martin	Mutambuka	Uganda	M	Iowa State University	Ph.D.	Food Science & Human Nutrition	Delayed			

Annex 2: Supplemental Funding Awarded by the Dry Grain Pulses CRSP for Institutional Capacity Building in FY 2009.

Awards to Enhance HC Institutional Capacity Building (Approved in 2009 for Expenditure in FY 2010)
Dry Grain Pulses CRSP

		Overview		
osal #	Project	Beneficiary Host Country Institution	Institutional Capacity Building Activity	Budget Approved
1	PI-UCR-1	ISRA, Senegal	Short term training of technical staff in identification, isolation, culture and conservation of bean pathogens.	$3,500.00
2	PI-MSU-1	Institute des Sciences Agronomiques du Rwanda (ISAR)	Purchase of equipment and supplies to establish a molecular genetics lab to be able to conduct marker assisted breeding.	$20,000.00
3	PI-UPR-1	Escuela Agrícola Panamericano (Zamorano), Honduras	Improvement of Basic Seed Production and Storage Facilities in CenCentral America, Haiti and Angola.	$11,000.00
4	PI-UPR-1	Escuela Agrícola Panamericano (Zamorano), Honduras	Organize workshop at the upcoming PCCMCA Meetings to review the current situation of bean production, consumption and commercialization in CAC; to identify opportunities to adopt new technologies and to determine if new traits need to be evaluated; to identify how NBR programs can have a greater level of participation in the generation, development and testing of bean breeding lines.	$10,000.00
5	PI-CU-1	Kenya Agriculture Research Institute(KARI)	Build capacity building of KARI through the training of 2 MSc. students in Kenya.	$12,678.00
6	PI-ISU-1	Kigali Institute of Science & Technology (KIST), Rwanda	Purchse of a single bore extruder to strengthen the research capacity of KIST in the area of Food Science and to create opportunities to develop value added bean-based processed foods.	$6,050.00
7	PI-UPR-1	Instituto de Investigacão Agronómica (IIA), Angola	Improvement of Basic Seed Production and Storage Facilities in Central America, Haiti and Angola.	$12,820.00
8	PI-UPR-1	Ministry of Agricultrue, Haiti	Improvement of Basic Seed Production and Storage Facilities in CenCentral America, Haiti and Angola.	$11,800.00
9	PI-UCR-1	Institut de l'environnment et de recherches Agricoles (INERA), Burkina Faso	Purchase of a new vehicle for the Cowpea breeding program of INERA in Burkina Faso.	$39,000.00
10	PI-UIUC-1	l'Institut National de la Recherche Agronomique du Niger, Institut de l'Environment et des Recherches Agricole, Institute for Ag. Research, Institut d'Economie Rurale, International Institute of Tropical Ag. (West Africa)	To host a workshop on biocontrol of cowpea pests in conjunction with the Fourth World Cowpea Conference in Dakar, Senegal.	$11,197.00
11	PI-PSU-1	Agricultural Research Institute of Mozambique -IIAM	Purchase of several equipments in support of root biology research at Sussundenga and bean breeding research at Chokwe.	$21,100.00
12	PI-UCR-1	Instituto de Investigacão Agronómica (IIA), Angola	To purchas equipment to establish a functional pathology laboratory at IIA- Angola (environment controlled incubator shaker cabinet, a dissecting microscope and supplied)	$10,000.00
13	PI-ISU-1	Makerere University, Uganda	Short term traing of MSc graduate student (Catherine Ndagire) from Makerere University at Iowa State University.	$7,320.50
			Total	**$176,465.50**